Food and Agriculture Organization of the United Nations

PROCEEDINGS OF THE GLOBAL SYMPOSIUM ON SALT-AFFECTED SOILS

Halt soil salinization, boost soil productivity

20–22 October, 2021

Government of the Republic of Uzbekistan

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Theme 1. Assessment, mapping, and monitoring of salt-affected soils

Salinization and sodification in irrigated agricultural areas in arid regions, Northern Patagonia Argentina

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Keywords: Aridisols, water table, electrical conductivity (EC), pH

Introduction, scope and main objectives

The north of Patagonia, (38º 35' to 39º 14' S; 66º 33' to 68º 35'W) is one of the great agricultural areas under irrigation of arid regions of Argentina. It includes the Lower valley of Neuquén River (LVNR, 9.500 ha) and the Upper Valley of Río Negro (UVRN, 81.000 ha), with mainly fruit trees and vineyards. Aridisols and Entisols (Apcarian *et al.*, 2006, 2014; Echenique *et al.*, 2007, 2013), are developed on different levels of fluvial terraces and alluvials fans. The climate is arid mesothermal (Thornthwaite) with annual rainfall less than 200 mm, concentrated mainly in winter; average temperatures 15.3 ºC, with hot summers and cold winters, high evotranspiration and wide daily temperature range. These conditions make irrigation essential to cultivate during seven months per year. The quality of the irrigation water is C1S1 (USDA). Irrigation practices produce rising of the water table. It is common to observe discontinuous saline efflorescences on the soil surface. The aim of this work is to inform the presence and current increases of salinization and sodification processes promoted by used and management in irrigated soils of arid regions.

Methodology

The information came from two areas: a) UVRN: Planialtimetry was carried out in two catenary transects across the different levels of fluvial terraces (T1, T2, T3); 136 soil profiles were described, sampled, analyzed and classified according to conventional standards (Soil Taxonomy). The fluctuation of the water table during spring, summer and winter was recorded. The chemical composition of the groundwater was analyzed in eight soil modal profiles (Apcarian *et al.*, 2014). b) LVNR: 3 landscape units (LUs): high fluvial terrace, alluvial fan and low fluvial terrace (LFT), with viticultural use, and with drip irrigation only; experimental units (EU) were established on each LU, with three repetitions. In each EU 46 soil samples were extracted at two depths, in summer and in autumn during two years. The pH and EC were analyzed. The spatial and temporal variability in geostadistics maps of each LU shows inter-row pH and EC (Salaberry, 2017).

Results

UVRN: Sodification and salinization processes affected to Sodic Aquicambids (T1) and Durinodic Natrargids (T2). Salinization is present with different intensity in soils of T1 and T2, with EC from 4 to 20 dS/m without meeting the characteristics of salic horizons. During the irrigation season (spring and summer) the elevation of the water table was observed, mainly in depressed areas. The pH of the water table fluctuates from 7 to 8. The EC of the water table is 2 to 13.06 dS/m (T1), 2 to 2.24 dS/m (T2) and < 0.8 dS/ m near the river (T3). LVNR: EC and pH values increased in the inter-row in all LUs, being > in the LFT.

Discussion

UVRN: Salinization is produced by raising the water table and capillary elevation of salts by evapotranspiration, depositing the salts up to the surface. The high EC of groundwater affects the process (Imbellone *et al.*, 2010). LVNR: Salt washing occurs only under the drippers, moving the salts toward the edge of the wet bulb and concentrating on the inter-row. This is a threat to crops and a chemical barrier to root extension (Nijensohn, 1977).

Conclusions
UVRN: areas with > salinization are recognized in slightly depressed sectors (T1, T2) with > elevation of the water table, and > EC in the water table. LVNR: drip irrigation produced an increase of salinity in the inter-row, not observing salt washing. Depressed positions in the landscape and anthropic action through irrigation accelerate the salinization processes.

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Salinization processes in irrigated soils of Mirzachul

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Keywords: meadow-Serozem soil, Serozem-meadow soil, meadow soil, soil profile, salinity level, saline

Introduction, scope and main objectives

It is important to determine the properties of soils formed and developed in Mirzachul, to analyze the changes that occur in them, to prevent degradation processes under the influence of factors limiting soil fertility, to determine the level of soil fertility (Kuziev and Abdurakhmonov, 2015; Sobitov and Abdurahmonov, 2011).

Methodology

The research was carried out in field and laboratory conditions according to the generally accepted standard methods of soil science, using geographical, genetic, historical-comparative, lithological-geomorphological, chemical-analytical and profile methods.

Results

The Mirzachul region is a "salt-collecting" basin with no groundwater runoff, and the Paleogene and lower Quaternary salt deposits, which retain large amounts of salt, are widespread among the soil-forming parent rocks. Therefore, in a number of independent hydrogeological regions that determine the geological and structural structure of the region, the depth of groundwater does not have a constant value (indicator) It fluctuates seasonally and throughout the year, depending on how different parts of the water balance are formed (Kuziev, Sektimenko and Ismonov, 2010).
Therefore, the current modern development of soil processes can be divided into three groups; that of saline, salting and desalination.

The key areas studied in the Mirzachul area are non-saline (salt content <0.3 percent), saline in various degrees (0.3–3 percent) and occasionally, Solonchaks, where differences in salinity (> 3 percent) are observed. Depending on the depth, thickness and salinity of the topsoil in the soil section, Solonchak (maximum salt content in the 0–30 cm layer), high Solonchak (30–50 cm), Solonchak-like (50–100 cm), deep Solonchak (100–150 cm) and deep saline (150–200 cm) groups are noted.

The total amount of salts in the topsoil of non-saline soils (0–30–40 cm) is 0.130–0.260 percent, in weakly saline soils, 0.490–0.540 percent, chloride ion 0.014–0.035 percent, in medium and strongly saline soils 1.190–1.785 percent, chloride ion 0.030–0.126 percent. The salinity of some highly saline soils in the region (424 soil samples) was 0.116–0.332 percent by the chloride ion in the whole profile, while in the lower part of the horizons of another sample (38 soil samples) chloride ion was observed in the amount of 0.126–0.140 percent, which made a highly saline (150–200 cm) group of soils.

It should be noted that the characteristic feature of the soils of the studied key areas is the "profile salinity", in which the salts are distributed in almost the same high quantities (1,190–1,785 percent) in the entire profile of the soil section to groundwater.

Discussion

The main salt sources of the existing transformed soils in Mirzachul are parent or deposited rocks, as well as surface streams and groundwater (Sobitov, 2018). Depending on the condition of hydro-meliorative systems, the amount and reserves of salts in the soils of key areas are expressed in different indicators, including salinity levels and types, as well as their different appearances depending on where the location of the upper salt horizons in the soil profile are observed.

Conclusions

It was found that the amount of salts in the soil profile decreases or increases towards the subsurface, and in some cases occurs at the same rates. The data obtained will serve to develop recommendations for improving the reclamation of areas and maintaining and increasing soil fertility.

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Use of aboveground electromagnetic induction meter for detecting salinity gradients and indurated soil layers in a volcanic landscape

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Keywords: Saline-alkaline soils, Electromagnetic induction, volcanic landscapes,

Introduction, scope and main objectives
In some volcanic landscapes salts accumulation can appear in the bottom parts of the relief as a consequence of the downward transport of the solutes released from rock weathering (Ma *et al.*, 2010). Such geochemical process can originate the appearance of mineral-zonation belts according to the relative solubility of the minerals that precipitates from transported solutions when their solubility product is reached (Arriola-Morales *et al.*, 2009). Electromagnetic induction (EM) is a non-invasive technique that allows quick surveying of landscapes, producing a primary magnetic field that induces a secondary magnetic field, if electrical conductors are present into the soil. The measurement integrates the induced secondary magnetic field from a volume of soil that depends of the sensor geometry. Using the Geonics EM38 sensor, the effective depth of measurement extends up to 2 meters what is appropriate for soil survey and agricultural applications, integrating soil and geologic materials response from different depths (Triantafilis and Lesch, 2005; Ondrasek and Rengel, 2021).

Methodology
An andesitic hill in Central Mexico is surrounded by rings of Entisols, Calcisols and Aridisols arranged in the downhill sense. A radial top-bottom longitudinal survey has been performed measuring with a Geonics EM38 meter, as well as surface temperature measurement with an infrared thermometer, in 95 points along a distance of 762 meters, positioning each measurement with GPS-GLONASS enabled (HDOP<1 meter). Several soil samples were taken to calibrate the EM38 for relating the bulk EM ECa with ECe of the soil saturated paste (Lesch, 2005), where pH, EC, SAR and ionic composition was analized. Soil minerals were studied by XRD and SEM.

Results and Discussion
The measurements provided data for the bulk soil conductivity at every point, showed salinity gradients, area heterogeneity, detected the appearance of petrocalcic horizon and computed if salinity is in top–or in bottom soil. Three distinct soil zones were clearly discriminated: a first belt of shallow soils with moderated slope (Entisols), a second belt with non-saline soils with petrocalcic horizon (tepetate) where halophytes are absent, and a third belt of saline-alkaline soils with halophytes and cactacea. The pH change gradually from neutral to extreme alkaline, and minerals recognized follow the series predicted by Eugster and Jones (1979), starting with clays 1/1, sulphates, chlorides, borates, nesquehonite, clays 2/1, trona-soda, to zeolites.

Conclusions
Electromagnetic induction was found very useful for detecting salinity gradients and for assisting soil sampling in order to investigate the geochemical process of sequential mineral formation. A good correspondence was found between EM signals and soil properties and mineralogy. The calibration of the EM device makes possible making a wide area map with prediction of the soil properties and mineralogy.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Evaluation of soil salinity levels through using Landsat-8 OLI in Central Fergana Valley, Uzbekistan

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Keywords: Soil salinity, Soil erosion, Land degradation

Introduction, scope and main objectives

Soil salinity is a major concern in Uzbekistan. It negatively affects plant growth and crop yields in Fergana Valley's agricultural lands (Akramkhanov and Vlek, 2012). The central part of the valley is semi-desert and desert which affects agricultural areas due to subsidence, erosion and lessening ground water quality, leading to further soil erosion and land degradation (Isaev *et al.*, 2021b). Traditional soil salinity assessments have been done by laboratory analysis of collected samples, through determining totally dissolved soils (TDS) and electro conductivity. However, Geoinformatic systems (GIS) and Remote Sensing (RS) technologies provide more efficient, economic and rapid tools and techniques for soil salinity assessment and mapping (Allbed and Kumar, 2013; Platonov, Noble and Kuziev 2013). The main goals of this research have been to map the soil salinity of Fergana Valley, relate the result with traditional analysis, together with GIS technology using satellite images provided by Landsat-8 OLI (Isaev *et al.*, 2021a; Peng *et al.*, 2021). The results obtained using remote sensing data were compares with those ground truth data provided by Soil Composition and Repository, Quality Analysis Centre of Uzbekistan (Kulmatanov, Adilov and Khasanov, 2020).

Methodology

First of all, a remotely sensed Landsat 8 OLI image was projected to the WGS 1984 UTM Zone 42N coordinate system and clipped to the extent of the study area. After that, we used an NDSI mask to isolate the saline areas. Normalized Difference Soil Index (NDSI) using the equation formula can be used only for the Landsat OLI 8 satellite. Sensor raster layers were calculated using the following formula (Jumanov *et al.*, 2020):

NDSI = (Green - SWIR)/ (Green + SWIR) (Equation 1)

Results

In this research area, soil salinity caused by natural or human-induced processes is a major environmental hazard. We have analyzed and implemented a Normalized Difference Soil Index to achieve our goal and as a consequence, it can be detected that arable land without salt content is partially missing in the soil salinity map (Fig. 2). The results of the NDSI analysis show that the analysis of the soils of the area study with the help of remote sensing technology is reflected in the statistics and can be applied (Table 3). In soil mapping from remotely sensed data, the term 'accuracy' is typically used to express the degree of 'correctness' of a classification. A map that is derived from a remote sensing classification process should provide a high measure of accuracy. Classification accuracy refers to the degree to which a map derived from a remote sensing classification process matches real field information.

Discussion

Ghabour and Daels (1993) gave recommendations to decrease the cost of soil salinization mapping. Firstly, to use the multi-temporal satellite images for creation of soil salinity map and to collect the soil samples from a limited amount of points inside the fields with different gradation of soil salinity from the soil salinity map were indicated and it was mentioned that use of this approach will increase the accuracy of soil salinity map with minimum expenditures on soil sampling.

Conclusions

Soil sampling is a costly, time and labor-consuming activity with one soil specialist and two workers able to sample an average of 15–20 points per day. Owing to our study using satellite sensors, the level of land degradation through soil salinization, for example, can be measured at an 80 percent accuracy. The remotely sensed satellite images are also freely available on the internet. Consequently, soil salinity mapping using GIS and RS is extremely cost-effective with a higher degree of spatial accuracy. Our results displayed almost all of the arable land territories threatened by different types of salinity levels. As long as proper and prompt measures are not taken in this field, it will continue to negatively reflect on our economy and agriculture.

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Characterization and modelling of salt-affected soils properties using VNIR hyperspectral data

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Keywords: salt-affected soils, spectral characterization, PLSR modelling, hyperspectral data

Introduction, scope and main objectives

Soil salinization and alkalinisation are soil degradation processes in arid and semi-arid regions of India impacting crop production. Conventional methods of detecting salt-affected soils (SAS) based on saturation extract SAS parameters entails additional time, labour and capital. The study aims to characterize SAS based on hyperspectral data and to estimate the SAS properties using a multivariate modelling approach for the rapid and cost effective assessment of SAS.

Methodology

The study was carried out on the SAS of five villages, situated in the Ghaghar basin of Kaithal district of Haryana, India, where the use of poor quality sodic (with high RSC) groundwater is common practice for irrigated agriculture. Soil sampling was done based on a 250×250m grid basis after rice harvesting during October, 2019. Samples were then processed for spectroradiometer data recording and chemical analysis. The whole data set was divided into calibration and validation sets for a PLSR model using Unscrumbler-V.10.1 software. Prediction accuracy was tested based on R^2, RMSEP and RPD values.

Results

The spectral reflectance value from the soil reduced with an increase of soil pH_s value from 6.2 to 9.6 and EC_e value from 0.1 to 5.5 dS/m. High ESP and SAR values decrease the spectral reflectance, whereas, high organic carbon content reduces the reflectance value. The PLSR model performed well for K in soil solution (RPD=2.7) and ESP (RPD=2.1), whereas, the performance of OC, $CaCO_3$, Cl, CO_3^{2-}+HCO_3^- and SO_4^{2-} in saturation extract were acceptable (2>RPD>1.4). The wavelengths 410, 490, 910, 1020, 1410, 1910, 2210 and 2350 nm showed peculiar absorption characteristics for different level soil pH.

Discussion

The significant absorption drops at different wavebands within VNIR range were due to the presence of different types and levels of salts and the vibration of different chemical bonds (Wang *et al*., 2019). The significant band can be used for identification of salt ions in soil. The identified bands (410, 490 and 910 nm) in the visible range are related to iron oxide contents, the bands 1410 and 1910 nm are related to water content and 2210 nm is linked to the SOM content. The presence of highly hygroscopic salts in SAS reduces the soil spectral reflectance (Nawar *et al*., 2014). The prediction accuracy using the PLSR model in the study area for pH_s, EC_e and SOC were less accurate than literature (Mahajan *et al*., 2021; Farifteh *et al*., 2007) reported the advantageous site of the PLSR model over others due to its similar prediction accuracy and requiring minimum time for development and reproducibility of the model.

Conclusions

The increased use and application of VNIR will aid in building a spectral library for SAS and in conjunction with the developed index and model will provide real time monitoring, as well as rapid information enabling farmers to deal with salt degradation more effectively and efficiently.

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Characterization of Spatial and Temporal Variability in Soil Salinity in Relationship to Alfalfa (*Medicago sativa* L.) Productivity

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Keywords: saline irrigation, alfalfa, salinity, EM38 surveys, spatial analysis

Introduction, scope and main objectives

Drought and competing water demand from municipal and environmental sectors necessitate the use of saline water sources for irrigation in California, especially for forages and row crops. Alfalfa (*Medicago sativa*) is a valued forage for dairy production in California because of its high yields, digestibility and protein content. The objective of this study was to examine the spatial variability of soil salinity imposed by saline irrigation in a field trial comparing alfalfa varieties for salinity tolerance and to develop the relationship between soil characteristics and alfalfa yield, and the ability to detect cultivar by salinity effects in the field

Methodology

Thirty-five alfalfa cultivars, including new salt-tolerant materials, were tested in a three-year field trial in a clay loam soil, under saline, sub-surface drip irrigation. Two irrigation water treatments (high saline (HS) = 8–10 dS/m and low saline (LS) = 0.3–1.0 dS/m EC_w) were applied to field plots in a split-plot design with salinity as the main plot and variety as the sub-plot factor with four replications. Soil sampling (0–180 cm in 30 cm increments) was conducted in late spring and fall each year. Assessment of the spatial variability in soil salinity imposed by the saline-sodic irrigation was critical for a fair comparison of variety salt tolerance. Soil surveys were conducted using an EM38-MK2 electromagnetic induction sensor after each of four harvests (April, July, August & September) in the last growing season (2020). Ordinary least squares (OLS) regression was utilized to build the model for the correlation of the sensor-based (ECa) data to actual soil salinity (ECe) of soil samples collected after each survey. Bootstrapping statistics were performed to obtain the model coefficients for the ECa to ECe conversion with an R^2 value of 0.90, root mean squared error (RMSE) of 1.64 and mean absolute error (MAE) of 1.27.

Results

Soil salinity for the LS basins was relatively uniform whereas the HS basins had greater spatial variability in ECe, due in part to differences in clay content detected in the experimental basins. Direct EC probe readings taken from different distances away from the drip line system did not show any significant differences in salinity on a micro scale. The accumulation of soil salinity over three and half years of saline irrigation resulted in salinity levels ranging from 7.5–12.5 dS/m ECe for the 0–180 cm soil depth, while the cumulative alfalfa yields were reduced 24 percent when averaged over all varieties and the three complete years.

Discussion

Our data from three field trials support Cornacchione and Suarez (2015) who concluded from sand tank experiments that irrigation waters resulting in soil salinities less than 6 dS/m ECe could be used throughout the alfalfa production cycle (multiple harvests) without substantial yield loss. Although the exact soil salinity threshold beyond which alfalfa yields begin to decline can be debated, it appears that for varieties improved for salt tolerance, 6 dS/m ECe may be a closer estimate than the established threshold of 2 dS/m ECe and potentially, the slope value for yield loss may be less than the established value of 7.3 (Maas and Grattan, 1999).

Conclusions

Modeling and statistical approaches similar to that developed in this study utilizing ECe and clay content can potentially be used in covariate analysis of the dry matter yields and ranking of the cultivars for salt tolerance, as well as for field trials ranking salt tolerance in other crops.

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Application of GIS in mapping salt washing norm maps

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Key words: soil quality, soil salinity, salt washing norms, geo information systems.

Introduction, scope and main objectives

It is known that, soil salinity is considered one of the main factors, which has negative influence on soil fertility. Soil salinity has negative impacts on the development of agricultural crops, and decreases harvest from them significantly. Soil salinity is one of the most urgent problems, in particular, in our research areas, and most parts of the irrigated lands of Sirdarya region is considered as less and medium saline soils.

The development of computer technology has led to the emergence of a new trend in soil cartography–digital soil mapping (DSM) (McBratney, Mendonça, Minasny, 2003). Digital soil mapping is the creation and computer production of soil spatial information systems using numerical modeling of spatial and temporal variability of soils and their properties based on field survey data and on soil formation factors (Mendonça-Santos, *et al.*, 2010). In our study, we used DSM methods to create salt washing norm maps according to soil salinity and soil mechanical contents.

Methodology

Coordinates–geographical location of the chosen observation sites were marked with the instrument "GPS Garmin ETrex". Soil samples were taken from serozem-meadow soils in the area. Field surveys were carried out on the basis of "Instruction on soil survey and soil mapping for the State Land Cadastre". Laboratory-analytical and cameral studies were developed and conducted on the basis of commonly used techniques developed by Research Institute of Soil Science and Agrochemistry. Geographic information system analyzes were carried out using ArcGIS 10 software and its Geostatistical Analyst modules.

Results

According to the data of the aqueous extract analysis of the irrigated soils of the chosen key fields, the total solid residues of salts in the ploughed and under ploughed layers of the light serozem soils, distributed in this area, is 0.175–0.199 percent, and in lower layers it is 1.66–2.43 percent. Salinity in these soils is mostly with sulphate and sulphate-cloride, according to the salinity level they are mostly included to the group of soils of less saline, medium saline and sometimes high saline.

The soils of the studies soils according to mechanical composition of the soils and the amount of chlorine ions are compared then differentiated to the relevant salt washing recommendation groups. Soil with medium and light loamy according to the mechanical composition, and chlorine ion concentrations are in the range of 0.01–0.04, salt washing norms as follows:

Common salt washing norms: 3000–3500 m^2
Number of salt washes: one
Period of salt washing: October–December.

After the above salinity parameters have been identified according to soil salinity and at the next stage spatial analyzes were performed using a several indicators. At the same time, a map of soil salinity washing norms for the territory has been created, based on the soil mechanical composition and the amount of Cl salts.

Conclusions

It should be noted that the use of modern geoinformation technologies in the effective management of land resources can provide accurate and timely information, increase their operational processing and storage capacity, and creating relevant database will ultimately provide an excellent analysis of the state of the land resources.

Acknowledgements

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Current condition, fertility and characteristics of irrigated soils of Peshku district of Bukhara region

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Keywords: irrigated soils, nutrients humus, phosphorus, potassium, mechanical content, salinity.

Introduction, scope and main objectives

The urgent tasks today are to systematically increase the rational use and efficiency of land resources of the Republic and to maintain, restore and increase the current state of soil fertility used in agriculture, especially to prevent the use of irrigated lands for other purposes, to establish systematic control.

In particular, by analyzing the current state of irrigated agricultural land, it will be possible to develop proposals, recommendations and obtain new information to prevent further negative processes.

Methodology

The basis of the methodology is the analysis of soil maps of the studied areas, comparative geographical, soil-cartographic, laboratory, cameral-analytical work. (Kuziev *et al.*, 2013) and (Kuziev, Sektimenko and Ismonov, 2010), (Kuziev and Sektimenko, 2009).

The object of research includes irrigated soils distributed in the territory of Peshku district of Bukhara region. The area under irrigated crops is 20122 hectares.

Results

As a result of the interaction of geomorphological, lithological, hydrogeological and climatic conditions of the region, irrigated meadows, barren meadows, desert meadows, meadow-swamp, meadow alluvial soils formed partially swampy soils, 51.5 percent of meadows, 27.4 percent of desert meadows, 15.0 percent are bald-meadow and 6.1 percent are brown soils. The studied soils consist of 21.1 hectares of clayey, 1440.6 hectares of heavy sandy, 9398 hectares of medium sandy, 6326 hectares of light sandy, 2718.5 hectares of sandy and 217.8 hectares of sandy mechanical composition. Irrigated soils are mostly supplied with humus, very little (19404.5 ha), low (717.5 ha) and partly moderate (9.4 ha), very little, sometimes moderately, with active phosphorus and exchangeable potassium.

Nineteen percent of the studied area was not saline, 68.9 percent of areas with varying degrees of salinity were low, 10.4 percent were moderate, 1.3 percent were strongly saline, and 0.42 percent were very saline.

According to the quality of irrigated lands used in agriculture, they are divided into cadastral groups, including low-average lands 5397.2 hectares, average lands 9470.1 hectares, good lands 5254.7 hectares.

Conclusions

In conclusion, it should be noted that irrigated meadows and meadows-desert soils are distributed in the main area, medium and light sandy loam soils are more abundant than other mechanical soils, humus and nutrients are very low, low salinity is the main area reaches

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Wheat salinity stress detection using VNIR spectrometry

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Keywords: salinity stress, VNIR spectrometry, wheat

Introduction, scope and main objectives

Soil salinity is one of the main environmental factors that adversely affect plant growth and productivity in arid and semiarid regions (El-Hendawy *et al.*, 2019). This problem is most prevalent in arid and semiarid regions of the world such as Iran. Many studies confirm the potential of hyperspectral data in plant salinity stress detection (Hamzeh *et al.*, 2012; El-Hendawy *et al.*, 2021; Zhu *et al.*, 2021). This research aimed to investigate the capability of spectrometry in discriminating wheat salinity stress.

Methodology

Wheat (*Triticum aestivum* L.) species were grown in pots under controlled conditions. Here, 20 seeds were cultivated in each pot. Five treatments were defined for irrigation based on Richards (1954): < 2 dS/m (non-saline), 4 dS/m (slight), 8 dS/m (moderate), 12 dS/m (high), and 16 dS/m (extreme). Each treatment was replicated seven times (70 pots in total). The treated samples were irrigated using saline water. The chlorophyll content for each pot was measured by the SPAD-502 instrument. The samples' spectra were measured through the FieldSpec-3 spectrometer (Analytical Spectral Devices Inc, USA) at the canopy level. Eight spectra were collected for each sample. Splice correction and smoothing were done for all gathered spectra before processing. The geometric parameters (area, depth, width, and position) of absorption features (AFs) in the continuum removed spectra were used to measure different levels of salinity stress. The support vector machine (SVM) method was used for classifying the treatments. Cross validation method has been used for validation.

Results

The average of chlorophyll content of samples were 3.66, 3.11, 2.88, 2.45 and 2.33 mg/g for control, slight, moderate, high, and extreme saline treatments, respectively. Results shows that the increase of salinity levels will increase the red and 1350–2150 nm region reflectance alongside the height and slope of red edge (680–750 nm), whereas the reflectance of 800–1250 nm will decrease. As salinity levels increase, the area, depth, and width of AF located in 400–750 nm were reduced. Position of AFs located at 1350–1550 nm and 1850–2150 nm tends towards higher wavelengths. SVM classification showed an accuracy of 92 percent in separating stressed from not-stressed samples and an accuracy of 81 percent in separating stress levels.

Discussion

Increasing the salinity levels leads to some changes in the wheat spectra, including: a decrease in the red edge height and slope, a decrease in the depth and area of the (400–750 nm) AF, and an increase in the 1350–2400 nm reflectance. These results are in agreement with Hamzeh *et al.* (2013), El-Hendawy *et al.* (2019), and El-Hendawy *et al.* (2021). The salt-affected wheat could be separated from not-stressed samples with good accuracy using the SVM method.

Conclusions

Salinity stress creates an obvious change in wheat's VNIR spectral. The SVM classifier offers a rapid and non-destructive alternative approach for the early detection of salinity-induced stress.

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Soil Salinity Mapping and Biosaline Agriculture in Kazakhstan

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Keywords: Salt-affected soils, soil salinity map, biosaline agriculture, Kazakhstan

Introduction, scope and main objectives

Increasing of aridity and salinization are expected to have profound consequences on functioning and stability of desert ecosystems (Toderich *et al.*, 2018; Metrak *et al.*, 2020). Kazakhstan with its typical arid climate and intensive irrigation agriculture is severely exposed to soil salinization. According to FAO (2017), the salt-affected area by irrigation in Kazakhstan is 404, 300 hectares as of 2017, which is about 19.6 percent of the total irrigated area, and has been expanded by about 44 percent in 20 years (1997–2017). The FAO-GEF project "Integrated Natural Resources Management (INRM) in Drought-prone and Salt-affected Agriculture Production Landscapes in Central Asia and Turkey (CACLIM-2)" aims to scale up best practices and INRM approaches in five Central Asian countries. Particularly in salinity management, CACILM-2 Kazakhstan focuses on soil salinity mapping and dissemination of best biosaline practices and technologies.

Methodology

The soil salinity mapping is being done jointly with the government of the Republic of Kazakhstan. The government collects ground measurements, and CACILM-2 calibrates remote sensing data using the ground data for a more precise result. Meanwhile, CACILM-2 organized related training sessions to improve experts' mapping capacity. An integrated modular approach on soil, water, crop diversity and salt-affected agrolandscapes was applied for the guidelines.

Results

Soil salinity maps of the Zhambyl and Kyzylorda oblasts were made as of now, and a preliminary salinity map of the whole territory of Kazakhstan is planned to be made this year using the ground measurement. Three training sessions about the soil salinity mapping were held in 2020, where 135 experts participated and learned how to make a map using GIS tools. The guidelines include how to assess the soil salinity and rehabilitate the land with halophytes, and discussions about cross-cutting themes such as value chain and gender.

Discussion

The government had difficulties making effective interventions because the soil salinity map had not been updated since the 1980s, but now, decisions can be made based on the scientific evidence. As the government officially includes the ground measurements in its action plan, the soil salinity mapping can be sustained with the experts' mapping capacity developed through the training sessions. The best biosaline practices and technologies in the guidelines are to be applied with a focus on salinity vulnerable areas identified by the soil salinity mapping. The subsequent change in salinity will be monitored by a regular update of the map.

Conclusions

CACILM-2 makes the soil salinity maps in collaboration with the government and disseminates the best practices via publications as well as extension services. As more oblasts are included in the map, the salinity management is expected to be more efficient because it helps to identify which areas need urgent interventions. In addition, a possibility of more advanced research on salinity will open such as economic assessment of salinity. The guidelines are to be published by FAO, which is expected to improve farmers' access to the knowledge of the best biosaline practices and technologies. These outputs by CACILM-2 will be widely scaled up in the neighboring countries with similar climatic and socio-economic backgrounds.

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Salinity risk mapping using an integrated approach and land cover in semi-arid area, Morocco

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Keywords: Salinity Risk, Land cover, Tadla Plain, Morocco

Introduction

Salt-affected soils are increasingly gaining global attention due to population pressure and the resulting ever-increasing food demands in parts of the world where such soils exist. Globally, over one fifth of the total irrigated land is salt-affected (Singh, 2021). In Morocco, according to Badraoui (2003), about 16% of irrigated land is affected by secondary salinization. Soil salinization is a multifactorial and complex phenomenon that can occur through primary (natural) or secondary (anthropogenic) means, or the combination of both (Chaaou *et al.*, 2020; Shahid *et al.*, 2018). Furthermore, natural salt accumulation processes are associated with and accelerated by certain physical factors, such as soil properties and permeability, geological aspects, depth of water table, topographic, climate conditions, water use, and groundwater salinity (Abdou, Al-Ali and Mohammed, 2021; Sadiki *et al.*, 2016). Additionally, practices management can strongly influence the process of salt accumulation. Land cover practices have a crucial impact on local hydrology, which exacerbates soil salinization processes (Vargas *et al.*, 2018; Wiebe *et al.*, 2007). Against this background, in this research we propose a modified version of the soil salinity risk index (mSSRI). The first goal of this work is mapping soil salinity risk in Tadla plain, through the use of the mSSRI. The second goal is the integration of land cover as a dynamic component, in order to assess the potential influence of agricultural practices on soil salinity risk.

Methodology

The soil salinization risk index (SSRI) is an additive method (Chaaou *et al.*, 2020; Masoudi *et al.*, 2006), which includes nine factors. The classical version of the SSRI is based on a 5 x 9 matrix with two weighting levels (1 and 2):

Five risk classes of salinization, ranging from zero risk to very severe risk and nine factors including electrical conductivity of groundwater, electrical conductivity of irrigation water, electrical conductivity of soil, depth of water, aridity index, climate type, topography, soil texture and substratum. Each factor is assigned a weight (Wi) to represent its relative influence on the accumulation of salt in a given soil.

In order to calculate the mSSRI, land cover factor was elaborated. Land cover mapping has been based on a time series of satellite images from Sentinel-2A sensor. Land cover classes have been classified according to their contribution to the risk of salinization. The weighted values for each factor are added together to estimate mSSRI, which ranges from 10 "very low" to 50 "very high" depending on the risk class.

mSSRI = (Status of soil salinity X 2) + 1 X (Quality of irrigation water + Depth of water table + Ground water quality + Soil texture + Climate + Dry index + Slope + Efficacy of surface geology + Land cover)

Results and discussions

The spatial distribution of the soil salinity risk, delineates four classes: moderate potential risk, low potential risk, moderate current risk and severe current risk. The results show the predominance of the moderate potential risk class. It is also noteworthy that the areas of severe potential risk correspond to soils that are very sensitive to salinity which are located meanly in the sub-perimeter of Beni Amir. The severe risk class appears lies in areas where the salinity of groundwater and soil is high. In addition, the variability of salinity risk shows a strong relationship with the topography in the Tadla plain. The downstream regions are characterized by a severe risk class. According to the results, sub-perimeter of Beni Amir has a higher level of salinity risk than sub-perimeter of Beni Moussa. This dissimilarity is the result of several factors, notably the use of saline water for irrigation and the intensification of agricultural practices, which is associated with high use of fertilizers. It should also be pointed out that the increase of irrigated areas and the persistent demand for water constrain farmers to overexploit groundwater despite its poor quality. Accordingly, the integration of land cover allowed us to improve the salinity risk mapping scale from a large homogeneous risk unit to the plot. In the light of the results achieved, it can be concluded that land cover can be a key dynamic variable in the prediction of soil salinity risk in line with its effect on soil water status. The more water- and fertilizer-demanding crops are, the more they promote the accumulation of salts in the soil.

Conclusions

Morocco faces huge challenges related to extent of salt-induced land. The results provide a spatial distribution of different current and potential risk classes of soil salinity and demonstrate the benefit of using mSSRI approach and the integration of multi-source data for the characterization of soil degradation risk by salinization in Tadla plain. The use of this approach is also justified by its simplicity and its ease of implementation in a GIS environment. The improvement of the index by the integration of land cover in the original model allowed us to evaluate properly the soil salinization risks in the irrigated perimeter of Tadla, and to enhance soil salinization prediction. To maintain soil quality and control the risk of soil salinity, it is recommended that consideration be given to crop selection, tillage practices, irrigation and nutrient management applied to a particular field over a period of time. Additionally, the installation of a proper drainage system is recommended. The results presented in this study will certainly instigate new studies in other semi-arid areas in order to validate the proposed method, which might be, in the future, a fundamental tool for evaluating and planning land cover and use.

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Saline soils in the Baixada Maranhense: a case study in Maranhão state, Brazil

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Keywords: Solonetz, Vertissols, Katogypsic, Pantogleic, pastures, livestock.

Introduction, scope and main objectives

The Baixada Maranhense region is located in northeastern Brazil in the Maranhão state. Is an interior plain with around 6266 km^2. It comprises hydrophilic floodplain fields, halophilic mangroves, muddy tidal plains. Gleysols (Solonetz) and Vertisols are the dominant salt-affected soils. The natural vegetation is a hygrophilous tropical (Dantas *et al.*, 2013). The main land use systems are extensive livestock and shrimp farming.

The main goal of this study is to show the characteristics of two saline soils and the contents of PAW to crop sustainable production.

Methodology

The study area is located in the Maranhão state, Brazil in a region called Baixada Maranhense. The climate is hot and humid, type Aw, with an average annual rainfall of 1580 mm and air temperature of 26.5°C. We selected two soil profiles to discuss the saline soil in this region, the profiles are described in Oliveira et al. 2020 and classified using the Brazilian Soil System of Classification (EMBRAPA, 2018) and to World Reference Base Soil (FAO and IUSS, 2015).

The Vertissolo Hidromórfico Sálico which corresponds in WRB to a Katogypsic Vertisol (saline soil)–03° 00' 24.7" S e 44° 21' 30.8" W and Gleissolo Sálico Sódico which corresponds to a Katovertic Pantogleyic Epigeoabruptic Solonetz (saline sodic soil)–03° 22' 37.0" S e 44° 51' 16.4" W.

We selected chemical, physical, mineralogical data to discuss these saline soil characteristics. The characterization of these profiles are in Oliveira *et al.* (2020). Plant available water (PAW) was estimated by subtraction of the volumetric soil moisture in 6, 10, and 33 kPa (field capacity) from the moisture at the permanent wilting point - 1500 kPa (Teixeira et al. 2020).

Results

The Solonetz profile studied has a predominance of the fine sand and silt fractions with smectite in both profiles.

The exchangeable sodium percent are around 30 percent in some horizons and the electrical conductivity is >4 dS/m^1 that characterize a "Sálico Sódico Gleissolo" in the Brazilian Classification.

The values of PAW ranged from the lowest value of AW33 of 1.18 mm/cm (in the Apw horizon in the Vertisol) to the highest AW10.45 mm/cm in the Ag horizon in the Solonetz.

Discussion

The dominant salt-affected soil in this region is the saline-sodic Solonetz in an estimative more than 70000 hectares (BDIA, 2020). The prismatic soil structure of these profiles reflect it pedogenesis and the presence of smectite and are a good visual indicator of them (Calderano *et al.*, 2020).

Mostly Solonetz in this region is saline and sodic soils, typical soils in saline mangroves. Apart from high salinity, the productivity of those eutrophic soils is restricted due to such soil factors as iron toxicities and deficiency of oxygen to the roots caused by the large periods of saturation. According to Teixeira *et al.* (2020) the plant available water (PAW) in saline soils may be restricted to high osmotic potential, normally are neglected.

Conclusions

The large areas of Solonetz show many agricultural reactions that reduce their agricultural aptness. Irrigated rice plantations with tolerant varieties and adapted pastures to saline soil are among the feasible options.

The PAW for salt-affected soils should be more investigated as the standard criterion to estimate PAW may super estimate the real available water.

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The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Land capability and suitability maps of a salt affected costal area (Ravenna, northern Italy)

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Keywords: soil salinity, geographic information system, arable lands, land capability map, land suitability map, land degradation

Introduction, scope and main objectives

Salinization is one of the major threats of land degradation for coastal areas. Soil salinity of these areas threaten the sustainability of agriculture by affecting agricultural production. To preserve soil resource and promote the sustainable land management practices, measurements and mapping of soil salinity are required. Land capability (LC) and land suitability (LS) can be helpful tools to ensure delineation of management zones aimed to suitable land use. The present work aimed to assess the suitability for cultivation purposes of a coastal reclaimed area in Italy through the building of LC and LS maps.

Methodology

The studied coastal area is 3488 ha wide and is located in North-Eastern Italy. The soil sampling was carried out through a grid with cells of about 1 km on the side. The soil samples were analysed for the main physicochemical properties (pH, carbonate, total organic C, particle size distribution, electrical conductivity-EC, bulk density and available water capacity-AWC). Due to the change in soil salinity according to the irrigation season, monitoring of soil EC has been carried out in two different seasons (winter and summer). Topographic, morphological, geological, soil delineations and land cover maps, remote sensing image and climate data were acquired and elaborated with physicochemical soil data through QGIS software to obtain the LC and LS maps.

Results

About 42 percent of the area was clustered in I and II classes of the LC which showed a loam texture and low EC values. About 44 percent of the area belonged to class III and IV which was characterized by soils with lower AWC and higher EC than the soils of class I and II. Four-and-half percent was classified as class V and VI which was characterized by flooding happening, on average, every 15 years or by high sand content. Finally, 9.5 percent of the area clustered in class VII and VIII because of the excessive drainage or they were protected areas. According to the LS classification, the area was mainly characterized to be moderately (S2) and marginally (S3) suitable (33.9 and 35.7 percent, respectively) for cultivation. About 20 percent of the area was non-suitable because corresponding to environments of naturalistic importance or subject to risk of flooding.

Discussion

The I and II classes of the LC indicate that their soils are suited for a wide range of plants with none or few limitations. Soils clustering in III and IV classes indicates that they have severe limitations linked to AWC and EC that reduce the choice of plants and limit plant growth and yields. Soils of class V and VI are not cultivable and can be addressed only to pasture, woodland, or wildlife food and cover. Because of the lower AWC and the higher EC values in S2 and S3 areas than S1 one, the cultivation is suitable if some agricultural management techniques are used. For example, the S2 areas can be cultivated also with intensive crops such as processing tomato, sunflower and melon, but irrigation is needed. For S3, instead, tree orchards should be excluded and should be addressed to open field salt tolerant or moderately tolerant crops.

Conclusions

Our findings highlighted that LC and LS classification could help to define the best agricultural practices in order to preserve soil functions. The application of LC and LS models should be considered as a mandatory action for the optimization of land use planning. Further, such tools could easily assist the authorities in decision-making regarding to accept or reject the alternative kinds of land managements.

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Use of geoinformation system technologies to increase the fertility of saline soils

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Introduction, scope and main objectives

The use of automated geographic information systems (GIS) in land management, in conservation and restoration of soil fertility, is one of the most pressing problems. The basics of using geoinformation technologies in determining soil fertility and plotting agrochemical maps were developed to solve the problem of soil salinization (Djalilova, 2017; Smirnova *et al.*, 2011).

Methodology

The methods for assessing soil fertility and modern experience worldwide in this area were used in the study. These methods are based on the results of agrochemical analysis, statistical analysis of comparative geographic laboratory data and geophysical analysis data based on geographic information systems. To analyze the results obtained, the most widely used modern programs ArcGIS, Microsoft Excel, Erdas Imagine were used.

Results

Field studies were conducted on slightly saline alluvial-pasture soils based on the GIS technologies. Soil samples taken at the base points were subjected to chemical analysis. Based on the data obtained, an assessment of soil fertility was conducted using the analysis of geographic information systems. When determining the geographical location of the main and base points from which the soil samples were taken, the coordinates of the site were determined using GPS devices (Djalilova *et al.*, 2021).

To characterize the level of soil fertility and salinity on the basis of the cartogram, the main indices were determined that indicate the fertility and agromeliorative properties of soil–humus, mobile nitrogen N-NO_3, phosphorus P_2O_5, potassium K_2O, water-soluble salts. With the results obtained, cartograms were compiled based on the analysis of geoinformation systems through the Geostatisrical Analysis module of the ArcGIS program.

The soils under study are poor in humus and mobile nutrients. The ameliorative state of these soils is satisfactory. They are slightly saline, chloride-sulfate and sulfate soils, according to the types of salinity. The chloride content is very low–0.01 percent and has little effect on plants. It should be noted that chlorides are mobile and easily dissolve in water. Therefore, the washing of salts can be performed in the lower horizons.

Discussion

Analysis of data on irrigated meadow soils formed on alluvial deposits using GAT technologies allows obtaining accurate and timely information about the agromeliorative state of soil, its degree of fertility.

Conclusions

Thus, the use of technologies of geographic information systems in agriculture creates great opportunities for the efficient use of land resources, proper farming, the placement of crops based on agrochemical and reclamation indices of soils, obtaining high-quality yields; for correct application of fertilizers, increasing their efficiency and reducing consumption; and for protecting the environment.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Impact of salinity on soil organic carbon in a semi-arid environment from 2000 to 2020 (Northwestern Algeria)

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Keywords: salinity, irrigation water, soil, degradation, organic carbon, semi-arid

Introduction, scope and main objectives

The largest area of saline soils in the world is in arid and semi-arid regions where evapotranspiration exceeds precipitation and where continuous irrigation with poor quality groundwater has taken place (Rabah and Ruellan, 2007).

Today, in all Mediterranean countries, the severity and risks of soil salinisation are not assessed (Alexakis *et al*., 2015).

In 2015, the FAO and ITPS indicated that Algeria loses 300,000 ha of its useful agricultural area (in its northern part) each year due to human or natural factors, including desertification, drought or irregular rainfall.

The plain of Sidi Bel Abbes is an agricultural area mainly dedicated to cereals and is quite representative of all the interior plains of Algeria in terms of soil classes. The plain belongs to the semi-arid stage, its climate is defined by a hot and dry season, quite long, averaging more than five months, and a cool season where the characteristics of the Mediterranean climate prevail, notably by its highly contrasted rainfall pattern. Faraoun (2014) classifies the irrigation waters of the study region in majority as bad, saline, very hard, with a high sodium absorption ratio (SAR), and a high risk of alkalinity.

This study aims to compare and analyze in a geospatial context the relationship between the salinity of irrigation water and the soil organic carbon content for two periods which are 2000 and 2020.

Methodology

Our approach is based on the chronic study of soil and land cover using Landsat sensor data, after collecting real field data. A supervised classification was applied to the selected images, namely the normalized vegetation index (NDVI) and the soil redness index (RI) to identify soil and vegetation types.

From the sampled irrigation water points, we were able to interpolate to characterise in a geospatial context the distribution of different salinity levels in the study area.
Several overlays of soil, vegetation, and water salinity maps were made and analysed.

Results

By exploiting the data collected between 2000 and 2001 on the cereal-growing agricultural soils of the Sidi Bel Abbes plain and comparing them with the data collected between 2019 and 2020, we were able to observe a remarkable decrease in soil organic carbon rates over two decades.

Discussion

The current situation shows a decrease in organic carbon capital and in soil fertility and productivity.

One of the main causes may be related to the salinity of irrigation water. Mancer *et al.* (2020), in a recent study, demonstrated that in a semi-arid context, a high salinity rate of irrigation water would cause rapid mineralization, thus favoring the destocking of soil organic carbon and consequently the decrease of organic capital.

Conclusions

The overlaying maps revealed that the soils most marked by a decrease in organic carbon content coincide with the highest SAR values. It was also found that calcareous soils were the most affected with a decrease of about 50 percent in their organic carbon capital.

It would be interesting to identify the salts responsible for this degradation in order to better understand the impact of irrigation water salinity on the storage and release of organic carbon in the soil.

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Current challenges in application of Electromagnetic Induction method in monitoring soil salinity and sodicity in irrigated agricultural lands: Case studies from Portugal

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Keywords: Soil salinity and sodicity, Electromagnetic Induction, soil electrical conductivity, inversion, efficient field assessment

Introduction, scope and main objectives

Efficient field assessment methods are needed to monitor the dynamics of soil salinity and sodicity in salt-affected irrigated lands and evaluate the performance of management strategies. Our study aims to examine the ability of the electromagnetic induction (EMI) sensors and recently developed inversion techniques for field-scale monitoring of soil salinity and sodicity over several irrigated agriculture lands in Portugal and to address the challenges associated with the proposed methodology.

Methodology

The proposed methodology consists of four main steps: 1) use of time-lapse EMI surveys to measure the soil apparent electrical conductivity (EC_a) and its changes during the experiment period; 2) inversion of time-lapse EC_a data to assess the spatiotemporal distribution of the soil electrical conductivity (σ); 3) calibration process consisting of a regression between σ and the electrical conductivity of the saturated soil paste extract (EC_e), sodium adsorption ratio (SAR), and exchangeable sodium percentage (ESP), used as proxies for soil salinity and sodicity; 4) conversion of spatiotemporal distribution of σ into salinity and sodicity cross sections using the obtained calibration equations.

Results

Our results indicate that the ability of the proposed methodology depends on soil salinity level in the study area and spatial variability of other soil properties (e.g. clay fraction, moisture content–θ) which influences the EMI signal. It was possible to predict soil salinity and sodicity with good accuracy from EMI data in Lezíria de Vila Franca, located in Lisbon region (Farzamian ***et al.*** 2019, Paz *et al.* 2020a) due to high level of soil salinity in the south of the study area (ECe > 4 dS/m) and relatively small variability of soil texture in this region. In contrast, in the Roxo irrigation district in Alentejo region, we found a stronger correlation between σ and clay fraction due to large variability of soil texture and reduced level of salinity (ECe < 4 dS/m) which make it difficult to establish a regression model to predict soil salinity from σ.

Discussion

Predicting soil salinity changes from time-lapse EMI data over large areas is more challenging (Paz *et al.* 2020b). This is due to the large variability of other dynamic parameters including θ, soil temperature, level and salinity of groundwater which impact the EMI signal and make it more difficult to infer soil salinity changes. We found it particularly challenging to assess soil salinity changes in the root zone from EMI measurements, as θ and temperature vary more significantly in this zone due to different irrigation practices, root uptake of different crops, and evapotranspiration processes.

Conclusions

The EMI method provides enormous advantages over traditional methods of soil sampling because it allows in-depth and non-invasive analysis, covering large areas in less time and at a lower cost. However, a proper interpretation of the EMI inversion models in terms of soil salinity dynamics is usually difficult owing to the fact that σ is a complex function of several soil properties, which may vary significantly over space and time. Thus, retrieving soil salinity from EMI data requires an appropriate understanding of site-specific soil processes, EMI data, and inversion process (Farzamian *et al.* 2021). This fact highlights the necessity of collaboration of geophysicists, soil scientists and hydrologists to construct a conceptual model which can explain the salinity and water processes in the soil.

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Methods for the Analysis of Salt-Affected Soils

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Keywords: Laboratory, Salinity, Sodic, Saline, Sodicity, MIR, EMI, mid-infrared, electromagnetic induction

Introduction, scope, and main objectives

According to Burt (ed., 2014), the USDA NRCS routinely analyzes salt and sodium affected soil samples to place them in salinity, pH, and sodicity classes, to classify them for making determinations of best use and management.

Methodology

NRCS Soil and Plant Science Division uses various methods to characterize salt affected soils. Electrical conductivity (EC) describes the amount of electrical current conducted by a saturated paste extract. Sodium adsorption ratio (SAR) reports sodium relative to calcium and magnesium in a saturated paste extract, or in irrigation water. Gypsum is determined on soil with suspected gypsum content. Exchangeable sodium percentage (ESP) expresses sodium as a percentage of the cation exchange capacity. As stated in a recent report (Seybold *et al.*, 2019), mid infrared (MIR) spectrometry is used as a rapid tool for estimating selected soil properties. As various studies demonstrate (Corwin and Lesch, 2005; Doolittle and Brevik, 2014; Smith and Doran, 1997), electromagnetic induction (EMI) is used as a proximal sensing method for identifying and mapping salt affected soils.

Results

Measured, predicted, and proximal soil data are used to help identify, classify, interpret and manage salt affected soil resources.

Discussion

According to Burt (ed., 2011), laboratory data help drive the understanding of salt affected soils. For example, the more salts a soil has, the greater the EC reading. The SAR of a saturated paste extract allows assessment of the state of dispersion of clay aggregates; sodium promotes dispersion of clay particles while calcium and magnesium promote flocculation, influencing soil structure and permeability to water. Sodic soils have poor structure and erode more easily during rain events. Such information drives agronomic and engineering interpretations and, for example, is useful for managing irrigation and drainage.

Conclusions

A variety of methods are used by the USDA NRCS Soil and Plant Science Division to characterize salt affected soils to help interpret and / or manage soil resources.

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The views expressed in this information product are those of the author and do not necessarily reflect the views or policies of FAO.

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Salting of ski slope snow and its ecological impact

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Keywords: ski slopes, snow, salting, ecology

Introduction, scope and main objectives

In the preparation of ski slopes for competitions at above freezing daytime temperatures, salting is still often used. Up to 30 kg of salt can be used to prepare one course, which may be enough to keep the course fit for competition for five to eight hours. Salt is scattered over the snow's surface, sinking into the depths of the snow mass with melt water. In spring, all the added salt accumulates in the soil and groundwater which then flows into nearby water bodies, creating salinity. The need for salting ski slopes and the subsequent problems of soil and water salinization is becoming more frequent and urgent in light of climate change and needs to be monitored.

Methodology and Results

The soil salinity was investigated on the Moscow ski resort's slopes during the spring. This showed an increase in soil salinity.

Discussion and Conclusions

The method of preparing ski slopes by applying salt is rather cheap and efficient but not very ecologically friendly and possibly should be avoided. Perhaps some other reagents like those used for de-icing streets and roads in winter could be used instead.

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Saline gypsum soils and their biological activity

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Keywords: gypsum-bearing soils, saline soils, water-physical properties, biological properties, soil respiration

Introduction, scope and main objectives

The problem of combating salinization is relevant for many countries of the arid zone worldwide, including Uzbekistan. Over the past fifty years, the amount of saline lands has gradually increased. Recent studies on the current state of soils in the Republic showed that out of the 2 418 800 hectares of irrigated soils studied, the areas with varying degrees of salt-affected soils had reached 1 743 600 ha by 2018, being 72.1 percent of the total area of irrigated land (Gafurova *et al.*, 2019; Makhkamova, 2017; Makhkamova and Gafurova, 2017).

Methodology

In the course of the study, soil sections were selected, and samples were taken from genetic horizons to study the structure, as well as the agrochemical, general physical and microbiological properties and enzymatic activity of soils.

Results

Among the studied groups of microorganisms, the predominance of ammonifiers was observed. Actinomycetes occupied second place in terms of quantity, then the nitrogen-containing and denitrifying bacteria, cellulose-destroying microorganisms and fungi. A low content of butyric acid and nitrifying bacteria was noted. The change in the number of microorganisms by season, soil subtypes, and the depth of the soil horizon can be explained by a lack of moisture and a weak accumulation of organic matter along the soil profile. In soil types, a decrease in biological activity was observed with an increase in gypsum content. In weakly gypsum, non-saline typical Sierozem soils, in comparison with medium and strongly gypsum, and varying degrees of saline, meadow, Sierozem-meadow and meadow-saline soils, a high activity of microorganisms was noted. The biological and enzymatic activity of the studied soils decreased in terms of the gypsum content, with the highest activity being observed in soils with a gypsum content of less than two percent. An increase in gypsum content, namely from low to medium, high and very high, with a decrease in the microbiological and enzymatic activity of soils was observed. All studied soils are characterized by individual interconnection systems. As a result, it becomes possible to determine some general patterns of soils in the region. The different effects of the gypsum content of soils, as well as the degree of salinity on the number of physiological groups of microorganisms, enzyme activity and the release of carbon dioxide (CO_2) were determined in the studied soils. There was a decrease in the biological activity (BA) of soils in terms of the gypsum content, from non-gypsum soils, all the way to very strongly gypsum soils.

Discussion

As a result of the complex studies conducted, the connection of the general biological activity of soils was noted, not only with the specific properties of soils, but also with the surrounding system and processes.

Conclusions

Thus, microbiological analyses have shown that the studied soils are to some extent susceptible to salinization, affecting the microbiological activity of soils. For example, in non-saline typical Sierozem, the activity of microorganisms is higher than in moderately and highly saline meadow and Sierozem-meadow soils. These soils are poor in humus and nutrients, and therefore have low biological activity. The largest number of microorganisms was observed in the sod horizon in all studied soils; in the lower part of the profile, their number sharply decreased.

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Haplic Kastanozems Chromic of the North-West Caspian region under climate change conditions

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Keywords: climate change, Kastanozems, salinization, mobile salts

Introduction, scope and main objectives

Global climate warming affects all regions and can lead to unexpected environmental consequences. The peculiarity of some arid regions is presence of mobile easily soluble salts in the soils, subject to seasonal and long-term dynamics. Based on the position on pedogenesis as an integration of SPP–specific pedogenic processes (Targulian, Krasilnikov, 2007)–the dynamics of soil salts can be considered as a reversible SPP in accordance with groundwater dynamics, depending on Caspian Sea level changes and determined by mutually reversible multidirectional climate trends.

The aim is to show the impact of climate change on Haplic Kastanozems Chromic in the North-West Caspian region.

Methodology

The soil identification and the degree of salinity coincide to WRB: ST–strongly salty, MO–moderately salty, Sl– slightly salty, N–not salty. Textural classes are based on Soil classification of Russia: the percentage of physical clay (ph.cl.)–amounts of soil particles from 10 μm and less in fine earth fraction: light loam–30 percent and less ph.cl.

Results

Over the past 30 years, two climate trends can be distinguished in the North-West Caspian region: from the late 1980s to 2010 with an increasing in precipitation (P) and in average temperatures (T); from 2010 to the present - a relative decreasing in P and T. Like climate trends are typical also for other regions with similar climate conditions (Ergina and Zhuk, 2019).

Soil pits were laid on dominant and subordinate relief positions on Haplic Kastanozems Chromic endosalic underlying with fluvial deposits covering marine ones, Dagestan, Russia (44.26.07N; 46.25.53E). Groundwater level (hG) is 4–6 meters.

Pit 1 is laid on dominant relief slopes with a relative height (H) = 3.8 m. Texture is light loam–27.1 percent ph.cl., hG is more than 4 m.

Since 1990 up to 2018 the degree of salinity in the upper 0–30 cm soil thickness was decreased by two orders of saline value: 1990→2011→2018 yy.: MO→Sl→N. In the lower 30–70 cm thickness: ST→MO→Sl.

Pit 2 is laid on subordinate slopes. H = 1.5 m. Texture is light loam–29.3 percent ph.cl., hG is less than 4 m.

Since 1990 up to 2018 the degree of salinity in the whole profile was decreased by one order of value: 1990→2011→2018 yy.: MO→MO→Sl (0–30 cm); ST→ ST→MO (30–70 cm).

Discussion
The relationship between dynamics of mobile salts in Haplic Kastanozems Chromic profiles and climate trends has been shown.

Conclusions
In the North-West Caspian region since late 1980s up to 2018 yy., positive changes have been occurred: soil profiles have been desalinated. Of course, the dynamics of soil salts is reversible, but taking into account the direction of soil salts migration can be useful for planning of irrigation norms.

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Salt Affected Soils in the Awash River Basin irrigation projects in Ethiopia

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Keywords: land degradation, ground water table, soil salinization, irrigation

Introduction, scope and main objectives

In Ethiopia, most of the irrigated State Farms where export crops such as cotton, sugar cane, citrus fruits, banana and vegetable crops are found in the Awash, Wabi-Shebele, and Rift Valley Lakes River Basins. Yet sizeable areas of these river basins were affected by salinity (Kidane ***et al.***, 2006). They attributed the problem largely with improper irrigation practices. Thus, this review paper attempts to collate available studies and show a comprehensive picture of the extent and sources of soil salinization in the Awash River Basin.

Methodology

We selected Wonji, Metehara, Amibara and Tendaho large-scale irrigation projects in Aswash Basin, Ethiopia. We used a systematic literature review to understand the history of soil salinization in four major irrigation schemes in Aswash basin, Ethiopia.

Results

Wonji Irrigation Scheme: Dengia and Lantinga (2016) studied the salinity status of soils, which were under sugarcane cultivation for the last forty years and compared with that of soils in the adjacent uncultivated lands. The result showed that the mean EC value of the soil in the sugarcane cultivated land was 59 percent and 66 percent lower than the soil of the virgin land at 0–30 cm and 30–60 cm soil depths, respectively.

Metehara Irrigation Scheme: About 726 ha (6 percent of the farm) of Metehara Irrigation scheme was highly saline. The spatial distribution of salinity in the area was highly influenced by the water table (Mekeberiaw, 2009) and saltwater intrusion from lake Beseka (Ayenew, 2007).

Amibara Irrigation Scheme: Moltot (2004) reported that the ECe of the soils in the area increased to 49 dS/m and seldom to 154 dS/m in some areas (Table 1). Lack of appropriate irrigation water management and poor drainage are causing secondary salinization (Abebe, Alamirew and Abegaz, 2015).

Table 1. Salinity status of different farms in Amibara plain of middle Awash River Basin *(Adapted from Heluf, 1985)*

Sampling site	pH	EC (dSm^{-1})	SAR	ESP	Classification
Abandoned cotton field	7.20	18.57	37.06	6.21	Strongly Saline
Poor cotton field	7.20	16.68	7.43	4.03	Saline
Good banana field	7.63	2.22	5.70	0.42	Slightly Saline
AIP pilot drainage study site	7.20	16.24	34.15	5.92	Strongly Saline

Tendaho Irrigation Scheme: Sileshi (2015) analyzed extent and severity of salt affected soils using satellite data of 1974 and 2014. Accordingly, the 2014 satellite image analysis showed that about 80 percent of the Dubti farm was affected by various degrees of salinization and sodication (Sileshi, 2015).

Discussion

Further, the Awash River salinity in this part of the basin is higher as it increases from upland to the lower basin. Solomon (2005) also reported his observation that frequent over-flooding and an increase of salinization of the soil due to poor irrigation practice with furrow irrigation system has decreased the suitability of the land for farming. Similar studies elsewhere showed that the longer the water table remains close to the surface, the greater the possibility of saline or sodic soils development due to geochemical reactions taking place between the rocks and water (Molatakgosi, 2006; Ezlit, 2009).

Conclusions

The Awash River basin where over one-third of the largescale irrigation schemes of the nation are concentrated is a typical example of the problem of secondary salinization. Discharge to the groundwater by surplus irrigation has caused significant rise in the water table in many irrigated fields, and problems with secondary salinization in the surface and sub-surface soil horizons are common.

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Study of soil salinization process in the semi-arid agricultural areas of Masis region, Armenia

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Keywords: groundwater quality, soil salinization, electrical conductivity, irrigation, Masis region

Introduction, scope and main objectives

Soil salinization is an environmental worldwide problem that impairs soil quality and limits the sustainable development of regional economies and agriculture (Ghazaryan and Chen, 2016; Jiang *et al.*, 2019). Such an ecological issue also exists in Armenia, particularly in Masis region which is characterized by natural and climatic conditions that can cause soil salinization (Ghazaryan *et al.*, 2020). These conditions are also combined with anthropogenic activities, namely agriculture, which intensifies the process of soil salinization. Considering this fact, the monitoring of soil salinity in the mentioned area is an important activity that is necessary to understand the distribution of saline soils and explore the mechanism of soil salinization.

Methodology

Soil salinization processes in the agricultural lands of Masis region were investigated. Soil samples were collected from 26 agricultural lands at the beginning (April) and the end (October) of the irrigation season in 2019. Electrical conductivity (EC) of water extracts of the soil is a standard parameter for describing soil salinity (He *et al.*, 2012). Extracts (1:5 soil to water) were prepared from field soil samples using standard procedures. Soil salinity was assessed by EC of the saturated paste extract (EC_e) obtained by recalculation of $EC_{1:5}$ according to the following formulas (Sonmez *et al.*, 2008): $EC_e = 7.36\ EC_{1:5} - 0.24$ for clay soil, $EC_e = 7.58\ EC_{1:5} + 0.06$ for loamy soil, and $EC_e = 8.22\ EC_{1:5} - 0.33$ for sandy soil.

Results

The results of the study demonstrated that the mean values of EC in April increased in parallel with the depth of soil layer: the lowest mean value of EC (0.3772 dS/m) was observed for the depth range of 0–10 cm, and the highest value (0.4416 dS/m)–for the depth range of 60–100 cm. The opposite pattern was observed in October, namely, EC values decreased in parallel with depth, and the highest average value (0.6696 dS/m) was recorded for the depth range of 0–10 cm, while the lowest (0.4073 dS/m)–for the depth range of 60–100 cm.

Discussion

Changes in EC values observed at the beginning and end of irrigation season may have been conditioned by certain factors: chemical composition of groundwater used for irrigation purpose, groundwater level, and precipitation. The results of the study show that the continuous use of irrigation systems and irrigation water of the quality that are actually used (Ghazaryan *et al.*, 2020a) can lead to an intensive accumulation of readily soluble salts in the upper horizons (0–10 cm and 10–30 cm) of the soil and a slight accumulation in the middle horizon (30–60 cm), while the accumulation was practically absent in the deep horizon (60–100 cm) and there was even desalination, and so the improvement in salinity degree in some observation sites.

Conclusions

The process of salinization of agricultural soils revealed in Masis region may result in decline in productivity and, ultimately, in soil degradation. Depending on the specific area, the identification of sources of better quality irrigation water, transition to a drip irrigation system and groundwater level lowering, in order to prevent the salinization of soils by groundwater with a high salinity degree and to make the process of natural washing of soils more efficient, have to be considered as urgent measures to avert soil salinization process and improve soil condition.

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Monitoring tridimensional soil salinity patterns at the field scale using electromagnetic induction sensing and inversion

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Keywords: electromagnetic induction, exchangeable sodium percentage, inversion, saturated paste extract conductivity, soil salinity, soil sodicity

Introduction, scope and main objectives

Efficient monitoring of field-scale soil salinity/sodicity is essential in environments such as the B-XII irrigation district (SW Spain) where a shallow saline water table and intensive irrigated agriculture has created a fragile equilibrium between salt accumulation and leaching in the topsoil. This is also affected by climate fluctuations and the implemented soil and crop management strategies. We evaluated the extent to which electromagnetic induction (EMI) soil sensing and inversion with calibration based on limited soil information can be used to accomplish such monitoring purposes in this specific environment. The objectives of this work were (1) to provide robust calibration equations to estimate the saturated paste extract conductivity (ECe) and the exchangeable sodium percentage (ESP) from the estimated electrical conductivity (EC) using minimal soil analysis data, and (2) to map the change in soil salinity/sodicity status across the soil profile after three years.

Methodology

EMI surveys were performed in 2017 and 2020 using a DUALEM-21 sensor in a 4-ha tile-drained field in the B-XII irrigation district in Lebrija, SW Spain, which is characterized by heavy clay soils (60–70 percent clay) underlain by a shallow saline water table (Dominguez *et al.*, 2001). Soil samples were taken during both surveys at five locations along a transect, with depth increments of 0.2 m down to 1 m and analyzed for salinity/sodicity-indicative soil parameters. Linear calibration relationships between EC and the soil parameters were estimated and used to produce depth-specific salinity/sodicity maps (Triantafilis and Monteiro Santos, 2013; Koganti *et al.*, 2018) and evaluate spatially explicit changes in the salinity status of the field.

Results

Spatial apparent electrical conductivity (ECa) was larger overall in 2017 and spatial ECa patterns were consistent between both years, with ECa increasing with depth of exploration. Inversion of the ECa data along the transect yielded consistent conductivity images for both years and showed strong relationships with the soil parameters (R^2=0.80). Overall, soil salinity/sodicity increased from 2017 to 2020, resulting in a shift in the topsoil (0–0.3 m) classification from "non-saline/non-sodic" to "sodic" and "saline/sodic".

Discussion

The wetter soil profile in 2017 provided better salt leaching conditions than in 2020, resulting in a less saline/sodic soil in 2017 despite the larger ECa. The larger soil water content appears to be decisive for leaching salts towards the subsurface drainage system and for the sustainability of these agricultural soils. Overall, the observed changes between both surveys show how dynamic the salt balance of these soils is and underlines the fragility and dependence of this agricultural system on proper water management.

Conclusions

This study demonstrates the potential of EMI sensors and inversion for detailed field-scale monitoring of soil salinity and sodicity under the specific conditions of the B-XII irrigation district. Monitoring of soils at risk of resalinization using EMI is essential, since laboratory analysis of soil samples has become prohibitive for economic reasons. Future work will address the reliability and robustness of the used calibrations by evaluating their performance in other fields of the B-XII irrigation district.

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Salt-affected soils in Colombia: modelling study case in CAR zone

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Keywords: Salinity, CAR, Soil Degradation, GIS, Models

Introduction, scope and main objectives

In Colombia the soil degradation study is in the incubation stage. So, this implies many challenges to aboard. La Salle University and the environmental Authority CAR (Regional Autonomous Corporation of Cundinamarca) decided to make a project to generate a model to determine the damage generated in soils by salts in the CAR territory. To make that, the team work looked for salinity historical information of the area founding some problems. The first one was that only some places of the area where monitored previously. The second one was that different institutions with different methods have been made measures. To take advantage of the information, a diagnosis of the soils of CAR territory was made, to identify which variables and information were available, and the relationships between the variables were determined.

Methodology

According to Colombian Congress, 1993 the CAR territory has some cities of the Cundinamarca and Boyaca states grouping in 14 regional directions. It was determined to the territory that the agricultural activity is the main one, follows by livestock and mining activities. This information gave some variables to affect the soil by places of each regional direction. The data was crosschecked with some CAR physical-chemical analysis of soils of the regional directions (CAR, 2019) and with the IGAC (Agustin Codazzi Geographical Institute) information obtained, this institute is the National Reference Laboratory of Soils. The results were interpreted by the IDEAM (National Environmental Reference Laboratory) the IGAC scales. IDEAM uses the exchangeable percent of sodium (PSI), sodium adsorption ratio (RAS), PMgI, CaCO3 eq, pH and electrical conductivity (IDEAM, CAR and UDCA, 2017). IGAC uses electrical conductivity, salt percent. The ranges and scales are different of each them. All the information was run by the Narváez, Bustamante and Combatt, 2014 model. This model was run using forward, backward and stepwise regression with the CAR and IGAC data and interpreted by IDEAM and IGAC scales.

Results and Discussion

Results indicate that CAR and IGAC data are different, they do not measure the same variables at the same places. There are more than 10 years of difference in data, so using all the information in the model did not generate an adequate correlation output. As CAR did not have information for all regional directions, is impossible to predict what happened in them. Only 9 of 14 regional directions have acceptable correlation coefficients ($R^2$0.7) (using only CAR data) and is necessary to get new and complete information to validate the model. In addition to that, there are two different interpretations according IDEAM and IGAC, so is important to make an agreement between them.

Conclusions

There is some spread information about salinity in Colombia. During the years, many institutions have participated in the salinity measures, but using different methods in different places; so, is necessary a complete monitoring campaign for the CAR territory. To model salinity using the proposed model and to improve the correlation between variables in CAR territory is needed more data. This is not only a problem in the CAR territory, is in the whole country and political decisions about soil degradation is needed.

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Salt-affected soils in Bulgaria

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Keywords: soil salinization, soil monitoring, Solonchak, Solonetz

Introduction, scope and main objectives

Salt-affected soils cover about 55 000 ha of the Bulgarian territory, 35 500 ha of which having been salinized by natural processes and 25 000 ha by industrial and drainage activi ties before 1990. This was the period with high industrialisation, irrigation and intensive agriculture (Teoharov and Hristov, 2017). Salt-affected soils in Bulgaria can be found in places such as the Danube river plain; the lowlands along the Danube river (Karaboazka, Svishtov-Belenska, Brashlenska, Tsibarska, etc.) and near some tributaries - Skat, Osam, Vit, Yantra, Studena, etc. They are also present in the Upper Thracian Plain - around Plovdiv region, the Tundzha plain; in the regions of Yambol, Nova Zagora, Kermen, Radnevo, Karnobat, Straldzha (former Straldzha marsh) and the Southern Black Sea coast, near the Burgas lakes; Lake Vaya, Lake Mandra and Lake Atanasovsko. There are also some small areas in western Bulgaria, close to the rivers. (Teoharov ed., 2019).

The areas of salt-affected soils are slowly decreasing, due to using different chemical amendments, a lack of irrigation and better industrial technologies or closed industrial pollutants.

Methodology

The monitoring of the soil salinization process is carried out in selected areas defined by the Bulgarian Executive Environment Agency (ExEA). Eight soil indicators are measured; water-soluble Na^{+}, Cl, SO_4^{2}, HCO^{3-} and CO_3^{2-}, exchanged Na^{+}, and CEC as well as groundwater properties. The areas are representative of saline soils. The research on salt-affected soils in Bulgaria is carried out by soil scientists from agricultural institutes and universities.

Results

The process of natural soil salinization is associated primarily with a high groundwater table with conditions for natural drainage, periodic summer droughts present in most of the plains in Bulgaria, with the characteristics of local relief and some other natural factors.
Soil salinization is a process in which the content of water-soluble salts and/or exchanged sodium in soils increases in quantities that negatively affect their properties, and therefore their productive potential.

Usually in Bulgaria the salinization is low, but the soil dries out significantly in the summer period and salts are observed. In other places, spring rains bring a shallow layer of water, but in summer the high groundwater carries up a lot of dissolved salts, which "bloom" on the surface.
According to ExEA, in Bulgaria, about 35 500 ha of arable land are affected by the salinization processes, this is under 0.5 percent of the state territory. About 252 ha of the area has sodic salinization. The processes mainly affect the districts of Burgas, Varna, Veliko Tarnovo, Pleven, Plovdiv, Sliven, Stara Zagora and Yambol (ExEA, 2018).

The type and degree of soil salinization is due to differences in the nature of salinization. The accepted classification divides into the two classes of Solonchaks and Solonetz.

In some salt-affected areas with a high content of water-soluble salts, the Solonetz evolved as Solonchaks-Solonets. These are the most common cases in Bulgaria. During the wet periods the salts are washed and soils have the properties of Solonetz. During the dry seasons, capillary action causes the salt water to rise and soils have the property of Solonchaks (Teoharov, ed., 2019).

Discussion

In the last decade, the trends have continued, with some of the areas having a decrease in the content of exchanged sodium and a decrease in the soil reaction (pH). The salinization processes is determined by climate change, irrigation and intensive agriculture. Most of the salt-affected soils are in abandoned agricultural areas or wet areas with low fertility. Their inclusion in the arable fund of the country is possible after correction of the existing drainage systems and implementation of chemical amendments, in accordance with the specific conditions of each site.

By 1990, Bulgaria had irrigated about 1.2 million ha of agricultural land. In 2012, the area was only 541 800 ha and sometimes much lower (Patamanska, 2012). A limited area with irrigation decreases the process of salinization.

According to ExEA (2018) the salinization is high in the Plovdiv and Varna regions. The latter is influenced by the process of industrial secondary salinization. The soils are located mainly around the salt mine along the Provadia-Devnya salt pipeline and in the lower part of the Provadiyska River to its delta.

Conclusions

The degree of salinization processes in Bulgaria is determined by different natural and anthropological factors such as precipitation, vegetation, land use, irrigation, drainage system, industrial pollution, etc. Soil research and soil monitoring conducted in our state shows an improvement of soil quality. In some observed places there are decreases in the content of exchangeable sodium, as well as a decrease in the soil reaction. Limited irrigation in the last few decades also decreased the salinity levels. In some areas, the implementation of chemical amendments was also used to decrease high concentrations of exchangeable sodium. Nevertheless, in low relief forms, salinization can arise from a rise of the water table in soils with a high presence of sodium substances. Some salt-affected areas are in reserves, because of protected halophyte species and wet zones.

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Changes in some hydromorphic soils of the Aral Sea region under the influence of desertification

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Keywords: salinity formation, semi-hydromorphic soil, saline, residual-boggy, takyr, salinization

Introduction, scope and main objectives

Salinization in the lower part of the modern delta of the Amu Darya is the result of desertification under conditions of high saturation of the soil layer with water-soluble salts, low relative air humidity, and good capillary properties of soils.

In connection with the desertification of the lower reaches of the Amu Darya, floodplain alluvial soils usually together with mineralized groundwater evolve into bog salt marshes. Swamp salt marshes are a subtype of salt marshes in which the processes of salt accumulation and waterlogging are considered.

In the virgin and pasture areas of the Aral Sea region, residual-boggy, residual-meadow Solonchaks, moderately hydromorphic saline soils, coastal semi-hydromorphic saline soils and Takyr (desert-sandy and sandy) soils are widespread. In particular, the residual boggy soils of the Muynak massif are formed on the modern deposits of the lower reaches of the Amu Darya. On the Kazakdarya massif, residual-meadow salt marshes are widespread, which are formed on the modern deposits of the Amu Darya as a result of the development of bog soils and subsequently due to salinization. (Rizaev, 2003).

Methodology

In the Muynak region, during the period under study, there was more than a two-fold increase in Takyr Solonchak soils (42–116.5 thousand hectares), as well as fixed and non-fixed sands with spots of desert soils and saline soils (52–155.6 thousand ha). Meadow and bog soils decreased from 478 to 264 thousand hectares and meadow alluvial Solonchak soils appeared (36.5 thousand hectares) (Akramkhanov *et al.*, 2012).

Results and discussion

Saline and Solonchak meadow alluvial soils occupy 45 percent of irrigated land. It should be noted that all the soils under consideration are highly saline. The salt content in the dry residue from the upper horizon of the residual bog soils is 3.915–5.05 percent, 1.894–4.916 percent in the residual meadow Solonchak soils and between 5.06–5.79 percent in the semi-hydromorphic and coastal Solonchaks. The maximum content of chloride ions in semi-hydromorphic and coastal salt marshes were 2.586 percent and 2.359 percent, respectively. The salt profile was characterized by one regularity- the mass accumulation of salts in the upper layers. The ionic composition of salts is predominated by ions of SO_4, Cl^-, Ca^{2+}, and occasionally Na^+.

The complexity of the mechanical composition is striking. The mechanical composition of salt marshes and meadow-Takyr soils are medium and light loamy and the content of mechanical fractions has the following regularities: coarse sand (1–0.25 mm)–from 0.1–10.0 percent, medium and fine sand (0.25–0.05 mm) from 10–85 percent.

Conclusion

Natural soil diversity along with the increasing modern process of anthropogenic desertification will undoubtedly be reflected in the agrophysical properties of salt marshes and other basic types of soils in the Aral Sea region, primarily on their mechanical and aggregate composition.

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Relations between the electrical conductivity and salt content for 1:5 soil-to-water extract: contribution of the salinity chemistry

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Keywords: salinity chemistry, total dissolved salts, irrigation, salinity stress, sustainable management.

Introduction, scope and main objectives

Soil salinity severely affects ecosystem quality and crop production. Large amount of data on soil salinity has been collected in the Commonwealth of Independent States (CIS, formerly USSR) and many other countries during more than 70 years, but its current use is complicated because in these countries salinity was expressed by (i) total soluble salts (total soluble salts, TSS, %) and (ii) eight salinity types (chemistry) determined by the ratios of the anions and cations (Cl^-, SO_4^{2+}, HCO_3^{2-}, and Na^+, Ca^{2+}, Mg^{2+}) in diluted 1:5 soil/water extract without assessing electrical conductivity (EC) (Basilevich and Pankova, 1968; Hazelton and Murphy, 2016). Measuring the EC (1:5) is more convenient and can be easily linked to saturated paste extract, ECe (Sonmez *et al.*, 2008; He *et al.*, 2013; Kargas *et al.*, 2020). Yet, EC is not only affected by salt concentration but also by salinity chemistry (Corwin and Scudiero, 2019, Ismayilov *et al.*, 2021). The latter also influences soil physical characteristics, soil-water-plant relations and abiotic stresses (Levy *et al.*, 2005; Rengasamy, 2010). The objective of this study was to examine the relationship between EC and TSS of soils in a diluted extract (1:5) for the eight classic salinity types used in CIS.

Methodology

Extracts (1:5) of 1100 samples of a clayey soil (0–30 cm) collected from cultivated semi-arid and arid regions of the Kur-Araz basin, Azerbaijan, were analysed for EC, TSS, soluble cations (Na^+, Ca^{2+}, Mg^{2+}), and anions (HCO_3^{2-}, Cl^-, SO_4^{2+}). Eight types of salinity chemistry were formed in light of the geomorphological conditions, irrigation, and drainage history in the basin.

Results

Results revealed that (i) the variation in the proportional relations (R^2=0.91–0.98) between TSS (0.05%–2.5%) and EC (0.12–5.6 dS/m) could be related to salinity type, and (ii) the proportionality coefficient of the relations (TSS = a EC; a= 0.313–0.447) decreased in the following salinity chemistry order: SO_4 > $Cl(SO_4)–HCO_3$ > $Cl(HCO_3)–SO_4$ > SO_4 $(HCO_3)–Cl$ > Cl. Formerly reported mean value of the coefficient (a = 0.336) was significantly lower than our mean value (a = 0.408), but still within the range of coefficients obtained in our study (a = 0.313– 0.447)

Discussion

The traditional reported coefficient (TSS = 0.336 EC) is based on soil salinity dominated by NaCl. This coefficient was (i) comparable for chloride dominant salinity type (0.313, 0.323, and 0.336 for Cl, SO_4–Cl, and HCO_3–Cl, respectively); (ii) similar but somewhat lower for the sulfate dominant type of salinity (0.369 and 0.371 for Cl–SO_4 and HCO_3–SO_4, respectively); and (iii) lower for sulfate itself and the carbonate and bicarbonate dominant type of salinity (0.447, 0.402, and 0.396 for SO_4, Cl–HCO_3, and SO_4–HCO_3, respectively). Thus, new TSS= a EC relation were (and should be) determined by ion characteristics or salinity type (Ismayilov *et al.*, 2021).

Conclusions

The findings suggest that once soil salinity type is established, EC (1:5) values can be used for evaluation of salinity degree in irrigated land in the context of sustainable soil and crop management. Results can assist in application of advanced precision agriculture and management strategies associated with mapping, leaching fraction, salinity stress, and selection of cultivars tolerance to salinity level and deterioration of soil physical quality.

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Saline soils of the Aral Sea region and their rational use

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Keywords: soil salinization, desertification, soil degradation, irrigated soils

Introduction

The article presents modern data on the soil cover of the Republic of Karakalpakstan. Particularly unfavorable salinity status of soils is observed in up to 86 percent of total land area. The purpose of this work to develop a system of measures for the conservation and improvement of soil cover in Uzbekistan, and especially in the Aral Sea region, the protection of soils from secondary salinization, land degradation, desiccation and prevention of other negative phenomena due to drying out of the Aral Sea.

Materials and methods of research

Changes in hydrogeological conditions in a significant part of the republic in the direction of aridization of the water area of the Aral Sea. Methods of generalization and comparative geographic analysis were used in the survey of the soil cover of the Aral Sea area. We used generally accepted methodological guidelines and instructions (Kuziev *et al.*, 2013), the Agro soil and land assessment maps of the Republic of Karakalpakstan (MAWR, 2002), as well as previously compiled soil maps.

Research results and their discussion

Under the current irrigation-alluvial water regime, meadow soils predominate among the genetic groups of soils in the region, occupying 95.2 percent of its area (Kuziev and Sektimenko, 2009; Rozanov, 2004). The territory of the Amu Darya Delta is characterized by an unsatisfactory natural outflow of ground water. Their artificial drainage is also insufficient, creating conditions for raising the level of mineralized ground water and developing a salt marsh process in the soils.

Currently, the amount of highly saline soils in the republic is 15 percent of the total area of the irrigation zone, with medium-saline soils at 30.3 percent, slightly saline and washed soils at 39.6 percent and much less highly saline soils and salt marshes (15.1 percent) (Arinushkina, 1975; Dobers, Ahl and Stuczynski, 2010). Especially unfavorable land reclamation conditions are observed in Muinak, Karauzyak, Kegeyli, Bozatau, Kungradsky, and Tashkuprik districts, where the proportion of highly saline soils reaches 43–86 percent, and slightly saline and washed soils at 12–23 percent (MAWR, 2020).

Conclusions

Analyzing the data on the state of irrigated soils, it can be concluded that most of the soils covered by forest are subject to aridization. This is due to the increasing processes of soil salinization, wind erosion and desertification, which together lead to soil degradation. At high ground water levels, when their consumption is largely spent on evaporation, salt marsh processes are activated in the soils.

Recommendations

To prevent secondary salinization of soils, it is advisable to maintain ground water below the critical level of a two meters depth. The most promising solution is combined drainage, consisting of open horizontal drains with vertical wells. In this regard, on irrigated soils In the Aral Sea region, depending on their mechanical composition and the degree of salinity, it is recommended to carry out flushing irrigation.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Statement of soil salinity in Burkina Faso

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Keywords: Soil salinity, salinity parameters, soil types, BUNASOLS, Burkina Faso

Introduction

Burkina Faso, a Sahelian country, is located in the heart of West Africa in the Niger loop between 9° 20' and 15° 05' North latitude, 5° 30' West longitude and 2° 20' East longitude. It is located in a tropical Sudano Sahelian climate, with rainfall unevenly distributed in space and time. This present work aims to take stock of the salinity of the first thirty centimeters and thirty to 100 centimeters in depth of the soils of Burkina Faso.

Methodology

The methodology of this work is dependent on that of the national map of soil salinity commissioned by the FAO for the development of the world map of soil salinity.
A number of data and materials were used: Lenovo core i7 branded laptop with 8Gigas of ram memory and 1 Terra of internal hard drive and free software. The salinity parameters: these are mainly the water pH, electrical conductivity and sodium.

Results

Electrical conductivity has a low level in the first hundred centimeters. More than 97 percent of the land is affected by electrical conductivity, including between 0.75 and 2 dS / m for the first thirty centimeters of soil depth and more than 99 percent for the depth of thirty to one hundred centimeters. Soils acidity is ranges from strongly acidic to moderately acidic. Indeed, the results show that more than 28 percent of the territory is concerned by a strong acidity with a water pH which varies between 4.5 and 5 in the thirty first centimeters against 30 percent of the territory for the same.

Discussion

The results of this work revealed that most of the soils in country have very low electrical conductivity. The low electrical conductivity of soils indicates low salinity and does not affect crop development. The results of this work are also possible that the majority of soils have a very low exchangeable sodium rate which does not impact on the development of crops in country

Conclusion

This study provided us with information on the salinity state of soils in Burkina Faso. It emerges from this study that the soils of Burkina Faso generally have a low electrical conductivity, a low rate of exchangeable sodium and a medium to high acidity.

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Salinized irrigated hydromorphic soils of Central Fergana

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Keywords: soil salinization, solonchaks, soil degradation, irrigated soils, Central Fergana

Introduction

Scientific research is carried out in the world in such priority areas as determining the current state of soils and their changes under the influence of anthropogenic factors, improving the reclamation state, and preserving and increasing fertility. In particular, special attention is paid to research on improving the reclamation state of soils. The aim of the study is to prevent negative processes and preserve and increase the fertility of the hydromorphic soils of Central Fergana.

Materials and methods

The research was carried out in the field and laboratory conditions on the basis of the standard methods generally accepted in soil science, in particular, geographical, genetic, historical-comparative and chemical-analytical methods (Arinushkina, 1975; Kuziev *et al.*, 2013).

Results and discussion

The soils of the studied territories are mainly weakly and moderately saline, with strongly and very strongly saline lands being found in insignificant territories. The weak and average salinity of the irrigated soils of the territory is reflected in the peculiar structure of the soil cover of the soil-lithological profile, as well as in the results of chemical analyses of water-soluble salts (Ismonov *et al.*, 2018; MAWR, 2020).

According to the average quantitative indicators of salts in the upper 0–100 cm layer of the soil profile, the salt reserves in them vary widely, from 60.8–192.7 t/ha, of which the chloride reserves are 2.0–8.7 t/ha, and sulfates, 42.2–125 t/ha. The highest content of salt reserves (0–100 cm) was observed in newly irrigated meadow-alluvial soils (192.7 t/ha) and newly irrigated meadow soils (169.8 t/ha). The smallest reserves (60.8 t/ha) were observed in newly irrigated meadow-alluvial soils, while the remaining soils occupy intermediate (84.2–115 t/ha) places.

One of the characteristic features of the percentage content and t/h reserves of water-soluble salts in the soils of Central Fergana is that the main part of the chloride and sulphate reserves have accumulated in the sub-arable soil horizon (Ismonov, Kalandarov and Mamajanova, 2017).

Conclusion

Irrigated meadow-alluvial and meadow soils have developed on the site of the complex of salt marshes that existed in 1971 at the study area, and today there is a nearly threefold increase in the area of irrigated hydromorphic soils. The leaching of chloride ions during the agricultural use of salt marshes and the influence of irrigation caused the development of a sulphate type of salinization on the studied soil. Today there is an almost nine-fold increase in weak and medium saline lands at the studied territory against previous strong, very strong saline soils and Solonchaks.

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Spatial Predictability of Salinity Hazard with Machine Learning Algorithms and Digital Data in the Irrigation Plain

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Keywords: Soil salinization, Digital soil mapping, CORINE land cover class, Human-induced salinization, Irrigation associated salinity, Agricultural regions, Sentinel 2 MSI

Introduction, scope and main objectives

In the irrigation area in semi-arid regions, spatially detection studies are important marker for accurate monitoring of soil salinization. As a result of irrigation, capillarity, which is the soil dynamic system, tends to increase soil salinity on the surface (Scanlon ***et al***, 2016; Hopmans ***et al.***, 2021). The association of socioecological differences with irrigation and the use of land cover classes as a variable that can reflect its differences (Mponela ***et al.***, 2020) are investigated. Machine learning-based modeling approaches in agricultural systems are used to suggest decision/support systems (Yamaç, 2021).

Methodology

The study was carried out in an agricultural plain where irrigation activities have been carried out for a quarter of a century. EC (μS/cm) was determined in the saturation paste (Rhoades, Chanduvi and Lesch, 1999) for 91 samples taken from the field. Environmental variables were generated from Sentinel 2A-MSI satellite, Digital Elevation Model, and CORINE Land Cover Classes. The data set was divided into 70 percent training and 30 percent test set. Relevant packages were used in R Core Environment in data set preparation processes and modeling (R Core Team, 2021; Omuto ***et al.***, 2020). Ordinary kriging was applied by controlling the normal distribution of the dependent variable. Also, random forest algorithm spatial modeling was used. In the hybrid (RF-Regression Kriging) approach, explanatory variation is estimated by RF algorithms and the process is carried out by summing the regression value of EC and the kriging values of model residuals in non-sampled locations. Root mean square error (RMSE) values were used as model accuracy criteria.

Results

The mean of EC values, standard deviation, coefficient of variation, minimum and maximum were 612.1, 288.5, 47.1 (%), 110.0, and 2068.0, respectively. Permanently Irrigated Land Class has the highest average EC value (828.9 μS cm^{-1}). Modeling and cross-validation resulted from ordinary kriging, the RMSE value was determined 270.8 μS cm^{-1}. For the RF model, the RMSE value was determined at 102.4 μS cm^{-1} in the training set and 314.0 μS/cm in the test set. The most important environmental variables in the random forest model were CLCC 212 Permanently Irrigated Land, Aspect, and Normalized difference vegetation index. For the RF-RK approach, the RMSE value approached zero in the training (RMSE: 5.9e-14 μS/cm) and test sets (RMSE: 9.6e-14 μS/cm).

Discussion

The approach of machine learning-based modeling was given relatively accurate results compared to the geostatistical-based modeling, furthermore, the hybrid modeling technique obtained more accurate modeling results than both approaches. In machine learning-based modeling approaches, the location of sample points can also be neglected (Hengl ***et al.***, 2018). Land cover class and NDVI value were found to be important factors in the random forest model, indicating that agricultural activities carried out on the land are also important for salinity risk (Maleki ***et al.*** 2020).

Conclusions

Machine learning-based modeling approaches using land cover classes as environmental variables may be preferred to mapping soil salinity using a purely geostatistical method. In hybrid modeling approaches, the spatial relationship present in model residuals significantly improves model accuracy. It can provide more accurate insights into salinity management and monitoring from digital maps produced.

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Soil salinity and the associated effects in Mingbulak district, Fergana Valley in Uzbekistan

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Keywords: humus, management, soil salinity, texture

Introduction, scope and main objectives

Uzbekistan has a harsh continental climate with large daily and seasonal changes in temperature. The total agricultural land occupies 25.2 million hectares, with 4.3 million hectares being irrigated land. Most irrigated lands in the Republic of Uzbekistan are subject to various levels of salinity (more than 50 percent of the irrigated land), due to the country's arid climate, as well as the geological and hydrogeological conditions of its irrigated areas (Ruzmetov *et al.*, 2018). Soil salinity is one of the major soil constraints which can affect plant growth and the survival of soil organisms (Richards, 1954). This study aims to identify the soil salinity in the Fergana Valley and its relationship with the measured soil properties like humus, soil texture and silt content. Again, certain management options are put forward for these salt-affected soils.

Methodology

Soil samples were collected at a 40 cm depth from nine sampling points from the Mingbulak district, Namangan region, Uzbekistan. The samples were air dried and the soil properties were analyzed in the laboratory. Soil humus was determined using the Tyurin Method, soil salinity/total soluble salts by the evaporation of a soil water extract (TSS), and the soil texture using an aerometric method.

Results

The soil salinity of the collected soil samples varied from 0.1 percent to 1.69 percent. Based on salinity, the soils were categorized as non-saline, low saline and medium saline. The humus content of the soils varied from 0.36 percent to 1.45 percent. These were categorized as very low, medium and high. The soil texture included silt clay (11.11 percent of total samples), sandy clay (33.33 percent of the samples), sandy clay loam (33.33 percent of the samples) and sandy loam (22.22 percent of the samples). The silt content of the soils varied from 10.3 percent to 53.3 percent. A significant positive correlation was observed between the humus content and soil silt ($r=0.57$). Salinity and humus showed a negative relationship but it was not statistically significant ($r=-0.38$).

Discussion

The results showed that an increase in soil humus content can reduce soil salinity due to the increased cation capacity of soil. The soil texture can influence various properties of the soil (Kholdorov *et al.*, 2021). The soils also had a high amount of silt content and it is proved that the silty nature of soils can increase the soil salinity. Most of the soils had a clayey or silty texture and thus this property of the soil needs to be studied in detail. Both of these are very important results as they can be adopted for the management of salt-affected soils. A good method for the improvement of these soils will be continuous soil monitoring, and the reduction of salinity through the planting of salt tolerant plants with an added advantage of contributing towards soil humus content.

Conclusions

Soil salinity in the region is a major problem and proper management measures need to be adopted. The monitoring of the salinity of the affected soils at regular intervals and on a seasonal basis is a very important and primary step. Scientific crop management can also be put forward as an efficient method for the management of saline soils.

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Status of salt-affected soils in Cameroon

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Keywords: Digital soil mapping, machine learning, Saline soils, salinization, sudano-sahelian climate, land management

Introduction, scope and main objectives

In Cameroon, salt-affected soils (SAS) are dominant in the northern semi-arid region, where the Sudano-Sahelian climate prevails. To a lesser extent, they are also found in the coastal southwestern parts of the Country, where the equatorial climate prevails. According to estimates based on the FAO-UNESCO (1977) soil map of Cameroon, soils with excess Na (ESP > 15 percent) occupy about 3 percent (1,418,670 ha) of the total land area while saline soils (EC > 4 dS/m) occupy about 1 percent (472,890 ha) (Ngachie, 1992). Estimates by Massoud (1977) indicate that Cameroon has a total of 671,000 ha of salt-affected soils. Although it well known that the major drivers of these SAS in Cameroon are climate, parent material and hydrography, there is no adequate information on their spatial distribution and the precise linkage with the drivers. The main objective of this study was to make the best use of modern techniques of digital soil mapping to generate baseline information on the spatial extent and intensity of SAS in Cameroon.

Methodology

Digital mapping of SAS was carried out following procedures described by Omuto (2020), using a machine learning approach. Input data were mainly georeferenced soil data (EC, pH and ESP) and soil forming factors as covariates. The dataset consisted of 291 sampling points (profiles) for EC (0–30 cm), 285 points for EC (30–100 cm), 938 points for pH (0–30 cm), 1458 points for pH (30–100 cm), 1083 points for ESP (0–30 cm) and 924 points for ESP (30–100 cm), and were used for calibration and validation. Soil profile data were obtained from the national harmonized soil legacy database of Cameroon (Camsodat 0.1) (Silatsa *et al.*, 2017).

Results

Results indicate that 16 percent of the country is covered by salt-affected soils (0–30 cm), dominating in the northern part of the country where the Soudano-Sahelian climate prevails. The group of saline soils is the most dominant but with varying intensity as follows: Extreme salinity (9.02 percent), Very strong salinity (4.08 percent), Strong salinity (2.08 percent), moderate salinity (0.01 percent), slight salinity (0.03 percent) and slight sodicity (0.61 percent).

Discussion

The salt-affected soils originate from various sources/drivers acting either alone or in combination. With regards to climate, in areas where evapotranspiration exceeds precipitation, the downward flow of water through the soil profile is only sufficient to remove the most soluble weathering products such as Na^+ salts, and accumulation of less soluble compounds is prominent due to limited water flow (Ranst, 2007). As concerns parent material (e.g. gypsum, lime), weathering products accumulate *in situ* and result in the development of salinity and/or sodicity. Additionally, irrigation with low quality water enriched with chlorides and sulfates adds to salts already present within the soil profile and are transported to the soil surface where they accumulate after evaporation. Soils near coastal areas usually have high salt concentrations as sea water contributes significant quantities of salts, with localized action along Cameroon coastal soils.

Conclusions

In Cameroon, saline soils are more dominant than sodic soils. This information is helpful in decision-making vis-à-vis land use and management in Cameroon. Although this preliminary study did not identify salt-affected soils along the Cameroonian coast, their presence should not be ignored and future assessment approaches should include mechanisms to identify and map them.

Acknowledgements

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Salinity of irrigated soils at the Sarpinskaya hollow in the Caspian lowland

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Keywords: sodium ions activity, sulfate-chloride salinization, calcium chlorides, irrigated lands

Introduction, scope and main objectives

A variety of natural and economic conditions affect the manifestation of soil salinity and its spatial distribution. In the Volgograd region (Russia), many irrigation systems are built on lands with saline soils with solonetz complexes formed in various lithological and geomorphological conditions. The aim was to study the salinity distribution of irrigated soils in the territory, where a distinctive feature is the shallow occurrence of saline Khvalynsk chocolate clays (within 1–2.5 m).

The Dubovrazhny irrigated massive is located in the Caspian Lowland in the Sarpinskaya Hollow, an ancient valley of the Volga. The territory is drainless, represented by the alternation of low ridges and elongated depressions between them, composed of layered deposits of alluvial-marine origin, being a cloak of loams and/or sands with a thickness of 1–2.5 m, underlain by saline marine heavy clays of Khvalynian age. The soil cover pattern includes Haplic and Luvic Kastanozems (Aric, Loamic)) and Haplic Solonetz (Aric, Loamic, Cutanic and Differentic)). In the 1980s and 1990s, the site was irrigated with sprinkler irrigation (Gorokhova and Chursin, 2021). Currently, irrigated plot Duboovrazhny is a vegetable-growing farm. Drip irrigation type is applied.

Methodology

The salt distribution was estimated by three longitudinal catenas along weakly convex ridges and elongated depressions between them and a transverse catena intersecting the mesorelief wave (39 wells to a depth of 200 cm). The content of water-soluble salts was determined by water extract with a soil: water ratio of 1: 5, measuring the activities of Na^{+}, Ca^{2+}, and Cl^{-} ions in soil pastes with a moisture content of 30–70 percent by a potentiometric method using ion-selective electrodes. Two-dimensional distribution profiles of soil salinity were created in Surfer-13.

Results

Two-dimensional distribution (depth, distance) profiles of the ion activity (Ca^{2+}, Cl^{-}, Na^{+}) along four catenas were constructed. The salinity of the sulfate-chloride-sodium type prevailed, which is characteristic of the natural soils of the Sarpinskaya Hollow. There were signs of residual secondary soil salinization, which were expressed in the presence of calcium chloride in the soil solution.

Discussion

We discussed the reasons for the difference in the distribution of salts in the studied plot from the other irrigated plots characterized by different lithological and geomorphological natural conditions.

Conclusions

The salt distribution in the Dubovrazhny irrigated area is determined by the Khvalynsk clays' internal relief, which forms the areas of transit and accumulation of water and salts. Salinization of soils occurs in the conditions of the emergence of a temporary ground water table at a depth of 1 m on the concave areas of the clay surface.

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The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Physical and chemical properties of irrigated meadow soils of Jandar Region

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Keywords: irrigated meadow soils, lowest moisture capacity, granulometric composition, water properties, reserves of humus and nutrient elements

Introduction, scope and main objectives

A number of scientific studies are being carried out in the Republic, aimed at further developing agriculture, preserving, reproducing and increasing soil fertility, efficiently using land resources, optimizing the ecological state, assessing the water-physical, technological, agrochemical properties and the reclamation state of soils.

The morphogenetic structure, geographical distribution, reclamation state, agrophysical and agrochemical properties of the soils of the Bukhara oasis and other regions have been studied by many scientists, such as X.T. Artikova (Artikova, 2005; Artikova, 2019), R. Kurvantaev (Kurvantaev, 2000; Kurvantaev and Nazarova, 2019), S.M. Nazarova (Nazarova, Kungirov, Kurvantaev, 2016; Nazarova and Kurvantaev, 2018), N. Hakimova (Hakimova and Kurvantaev, 2020) and others. However, scientific research on the study of the current ameliorative state, and the physical and mechanical properties of irrigated meadow soils in the Jandar region have not yet been carried out sufficiently.

Methodology

The studies were carried out in soil-field and analytical-laboratory conditions. The reliability of the data obtained was carried out using the Microsoft Excel program based on *Methodology of field experiments*.

Results and discussion

The irrigated meadow soils of the Jandar region are heavy and medium loamy. In terms of the content of water-soluble salts, not saline (dense residue 0.150–0.375 percent), or in some places can be slightly (mainly chloride) saline (0.014–0.031 percent). In the studied soils, the humus content in the arable and subsoil layers is between 0.94–0.63 percent. At the same time, in the lower layers, no sharp differences are observed in the humus content, and along the sections, the humus content is between 0.41–0.30 percent. The influence of the irrigation's age on the content of nutrient reserves (nitrogen, phosphorus and potassium) is clearly seen. In the irrigated meadow soils of the Jandar region, nitrogen is 1.9–3.2 t/ha, phosphorus is 6.5–14.5 t/ha, and potassium is 51.4–106.5 t/ha.

Physical, mechanical properties of irrigated soils in the Jandar District are distinguished mechanical composition by their originality in the administrative and geomorphologic regions formed on alluvial deposits of the lower part of the Zarafshan river. Basically, the mechanical composition consists of the following particles: coarse sand (1–0.25 mm), medium sand (0.25–0 mm) and fine sand (0.1–0.05 mm). In irrigated meadow soils in the district of the lower reaches of the Zarafshan River, the specific weight is 2.58–2.66 g/sm^3.

Volumetric mass is a variable and different unit depending on various processes occurring in the soil. In the top, arable soil layer, the bulk density varies between 1.27–1.63 g/sm^3 depending on humus content, texture, salinity and other properties. Among the upper layers, the highest density (1.53–1.63 g/sm^3) is observed in the soils of the Jandar region. In irrigated soils, the movement of water, the content of soluble salts, the preservation of moisture, and the provision of air to the root system is directly related to the porosity of the soil. In the studied meadow soils, the total porosity, depending on the duration of irrigation, varies widely across the genetic layers of the profile (42–51 percent).

Conclusion
According to the content of water-soluble salts in different periods, irrigated meadow heavy loamy and medium loamy soils are classified as non-saline and in some places slightly saline. In 2010, the content of solid residue and chloride amounted to 0.320–0.585 and 0.021–0.028 percent, and in 2017 respectively 0.215–0.280 percent and chloride ion decreased to 0.014–0.031 percent, due to agrotechnical measures. The humus content in the arable layer of the Jandar region is insignificant (0.94–0.63%), in the lower horizons their content (0.41–0.31%) sharply decreases.

Soils of geomorphologic regions are characterized by their peculiarity in the mechanical composition of soils and consist of sandy loam, of light, medium and heavy-loamy varieties, mainly consisting of coarse, medium and fine sand. The specific gravity in the genetic layers varies in the range of 2.56–2.67 g/sm3. Soils on the genetic horizons have different density (1.27–1.63 g/sm3). The total porosity in the upper layer is satisfactory (47–51 percent), while the porosity in the lower layers is less so (38–42 percent).

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Assessment of the State of Soil Salinity for Analysis of Geochemical Stability of Landscapes in Dry Areas

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Keywords: geochemical stability, landscape, soil salinity, drylands

Introduction, scope and main objectives

In soil science, the process of salinization or desalinization is usually diagnosed by "salt profile". However, the diagnostic possibilities of analysing the distribution of salts in the soils have not yet been fully exhausted. In this work, based on the generalization of the literature data, as well as on the basis of our own studies of soils and landscapes in the arid territories of Central Asia and Kazakhstan, Transnistria, the North Caucasus, the SouthWestern Siberia, it is shown that the integrated analysis of the distribution of salts along the soil profile and by the elements of meso-, micro- and the nano-relief makes it possible to estimate the geochemical stability of landscapes in arid territories with respect to soluble salts.

Methodology

Different combinations of soils with various soil profiles, rate of salinity and compound of salts, and located on different elements of micro- and meso-relief in arid, semi-arid, and arid sub-humid regions were studied.

Results and Discussion

It has been shown that the water regime of soils and the redistribution of moisture over elements of relief determine the entire range of different types of salinity in soils occurring in arid areas. So, in the case of high level of saline groundwater and a small amount of atmospheric or surface waters, the evaporation of groundwater is the main factor in salt accumulation. In this case, depending on the level of the groundwater capillary border, soluble salts are concentrated in the soil profile or on the surface, and the salt profile develops according to the type of salinity. At the same time, in the dry period, a "wick" effect is observed on the elevated elements of micro- and nano-relief.

If the microrelief is strongly marked, then the elevated elements are less saline than the lower ones. In this case, a profile of salinization develops in the soils of the depressions: if the capillary border reaches the level of the surface of the soils of the depressions and does not reach the soils of the elevations. The desalinization profile develops when the capillary border from the groundwater does not reach the soil body. In this case, desalinization is due to the surface and subsurface waters located in lowered elements of the mesorelief, which cause desalination of the soil mass.

Soils forming in conditions of periodic additional watering or irrigation and a weak outflow of high level of groundwater, during the period of exposure to this additional precipitation are washed to a certain depth, and filtered waters containing dissolved salts tend to nano-, micro- and meso-depressions of the relief, causing a relative excess of salts there. In this case, such micro-depressions serve as a local centers of salt accumulation, and saline soils are formed in them, up to the formation of solonchaks.

The landscapes of geochemically stable territories are distinguished by a great uniformity of the distribution of salts in soils and by relief elements. The soils of arid regions become geochemically stable when the soil layer is separated from the groundwater and the redistribution of salts occurs only within the landscape or even in their smaller elements. It should be noted that geochemical stability is not achieved immediately after the level of saline groundwater drops below the critical level, but gradually, as equilibrium is achieved between the redistribution of salts in the soil mass and the regime of atmospheric precipitation.

Thus, the salt regime of any territory, which corresponds to the above scheme, makes it possible to diagnose it as geochemically stable. This feature can serve as an important characteristic of landscapes in conditions of rapid desertification of irrigated or deltaic areas caused by the cessation of watering and a sharp decrease in the groundwater level.

Conclusions

The combined analysis of the distribution of salts along the soil profile and by elements of nano-, micro- and mesorelief can serve as a method for diagnosing the geochemical stability of landscapes with respect to readily soluble salts. In general, this method is presented in the form of a tabular algorithm

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Distribution of sodium-affected soils in the Amazon: genesis, characterization and agricultural aptitude

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Keywords: Surumu depression, Planosols, sodium saturation, agricultural use

Introduction

Although Amazonian tropical conditions do not influence the formation of sodium-affected soils, the occurrence of these types of soils is well evidenced in the drier savanna environment and forest/savanna transition of northern Amazonia. In this sense, the objective of this work was to evaluate the occurrence and distribution of sodium-affected soils in the northern Amazon, its genesis, morphological, chemical, physical attributes, use and agricultural aptitude.

Methodology

The work was carried out based on a survey of soil profiles and the soil map of Roraima state (Schaefer *et al.*, 1993; Schaefer and Dalrymple, 1996; Vale Júnior, 2000; IBGE, 2005; Oliveira *et al.*, 2018; Melo and Vale Júnior, 2018).

Results

The Amazonian sodium-affected soils are found northeast of Roraima in an intermediate depression zone to the mountainous reliefs, (Serra de Pacaraima), and low plateau, (Boa Vista Formation), with an altitude below 120 m and composed of acidic volcanic rocks of the Surumu Group – rhyolites, dacites and rhyodacites. This geology, associated with a dry climate and poor drainage, result in the formation of sodium-affected soils, which support a savanna-dominated vegetation with some occurrences of xerophytic species, occupying an area of 3739 km^2. These soils have a base saturation above 70 percent throughout the entire profile, which rises considerably in the textural B horizon, with a low potential acidity. The pH ranges from acid on the surface, (4.5–6), to neutral on the subsurface, (6–8). These soils have a sodium saturation of around 26 percent, a value that can vary with the depth of textural B.

Discussion

Due to variations in the depth of the textural B horizon, the Planosols of the region have a silt/clay ratio range between 1.0 and 15.0, being higher on the surface than the subsurface. Agricultural use of these soils is limited by the presence of higher levels of sodium and is an impediment to mechanization during the rainy season. Furthermore, the permeable layer of the soil is restricted to the depth of the textural B horizon due to the dispersed clay, which may be below 20 cm in some cases. However, this class can be suitable for pastures that have a tolerance to water deficit cycles followed by a poorly drained environment in the rainy season.

Some Solonetz, where the textural B horizon is deeper than 15 cm, and the textural gradient is above 3.0 can be cultivated with flood-irrigated rice, reaching a productivity above 6.5 t/ha. Other sodium-affected soils, not classified as Solonetz or Lixic Ferralsol (Planosolo Háplico in SiBCS) have a restricted aptitude for agriculture, due to a low water retention capacity and low fertility, and are destined to be natural pasture. After the demarcation of the Raposa Serra do Solo and São Marcos indigenous lands, the use of these soils was restricted to the grazing of cattle on native pasture by the indigenous communities. The constant occurrence of fires during the dry season in the environments with sodium-affected soils, has led to the degradation of natural pastures and soils exposed to erosion, which has worried scientific authorities and public administrators. Aware of this problem, the IBAMA has created guidance and fire control brigades in order to fight large fires.

Conclusions
Sodium-affected soils in northern Amazonia have an expressive area in a depression environment, inheriting the influence of a past dry climate that defines its genesis. Agricultural aptitude is conditioned by the textural gradient. When high, the soil is suitable for growing irrigated rice. Otherwise, its use is recommended for natural pastures.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Freshwater tidal swamp and peat collapse after storm-driven saltwater surge

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Keywords: Climate change, Drought, Freshwater swamp, Global warming, Regime shift, Relict forest, Soil salinification, Taxodium distichum

Introduction, scope and main objectives

Elevation maintenance via peat building is essential to the resilience of coastal wetlands after salinification related to sea-level rise, storm surge (Chambers, Steinmuller and Breithaupt, 2019) and freshwater over-usage (Middleton and Souter, 2016). Peat building is facilitated by root production (Chambers, Steinmuller and Breithaupt, 2019), wood production, and slow rates of decomposition (Middleton, 2020). Coastal freshwater wetlands are increasing in salinity as levels in surface and groundwater rise (Wilson *et al.*, 2011).

Mangroves and other salt-tolerant species may influence salinification in coastal wetlands by pulling salt from saline groundwater into the vadose zone via evapotranspiration (Jiang *et al.*, 2015). Freshwater species are at a disadvantage because these species must stop evapotranspiration to cope with increased salinity in the vadose zone. Even though salinity exceeding 2 ppt shifts tidal swamp to marsh over decades, *Taxodium distichum* trees have several ways of coping with salinity (Krauss and Duberstein, 2010).

The objectives of this project were to document the effects of salinity intrusion into ground and surface water on subsequent peat collapse, tree mortality, and vegetation dominance in a tidal *T. distichum* swamp observed along the Pocomoke River in Maryland (USA).

Methodology

Tidal freshwater swamps in Hickory Point State Forest experienced salinity surge during the wrap-around event that pushed saltwater upstream in the lower Pocomoke River during Hurricane Sandy (October 29, 2012; Middleton 2016a). Forests of these freshwater tidal swamps were dominated by *T. distichum*, *Acer rubrum*, *Liquidambar styraciflua*, and *Pinus taeda* (Middleton 2016a, 2016b). Hickory Point State Forest is part of a larger network of study areas in the North American Baldcypress Swamp Network, with a sampling design consisting of five permanent plots marked with a stake and placed at stratified random positions along a 125 m transect. Measurements were taken in plots, which varied in size for each survey component (i.e., ground vegetation, saplings/shrubs, roots, tree growth/mortality, elevation change, and soil/pore water salinity) (Middleton, 2016a).

Results

An earlier Hickory Point study connected standing freshwater tree mortality to high soil salinity levels after salinity intrusion during Hurricane Sandy (e.g. maximum soil salinity one year after storm = 3.5 ppt; Middleton 2016a). Salinity surge from Hurricane Sandy was apparent at channel gages near the study site (13.1 and 18.6 ppt; Middleton 2016a).

Following salinity intrusion along the Pocomoke River during Hurricane Sandy in 2012, peat collapse occurred in portions of a tidal swamp at Hickory Point State Forest. Between 2015–2020, the rate of elevation change at one site fell, while the rate of elevation change at a second site increased (rate = -1.1 cm per year vs. 4.1 cm per year, respectively; $p < 0.0001$). Tree growth was slow, and by 2016, 60 percent of the *T. distichum* trees had died. Root biomass decreased after *T.*

distichum trees declined (root biomass: 2014–2016 and 2019–2020: 1280.1 ± 169.1 vs. 285.9 ± 52.7 g/m^3y; $p < 0.0001$). Saplings but no seedlings of *T. distichum* were observed indicating that the forest has reached relict status. *Typha* x *glauca* cover, and pore water and soil salinity increased from 2013 to 2020. Vadose zone salinity exceeded 5 ppt for more than 65.5 percent of the time in 2019, with a maximum salinity level of 13.4 ppt.

Discussion

Coastal freshwater vegetation is dying where sea-level rise has pushed too much salt into inland ground and surface water (Wilson *et al.*, 2011), where freshwater is depleted by extreme drought, and over-usage (Middleton and Souter, 2016). While observed previously, regime shift in freshwater ecosystems following salinity intrusion has been not been wholly documented. This study captured salinity changes in surface and groundwater with subsequent peat collapse, tree mortality, and vegetation change in a tidal freshwater *T. distichum* swamp in Maryland.

Typha x *glauca* expanded after Hurricane Sandy, but it is not known if it had a role in pulling salt to the soil surface. Salt-tolerant species such as mangrove pull salinity from groundwater into the root zone via evapotranspiration (DeAngelis, 2012). Reduced root production following salinity intrusion could impact the ability of *T. distichum* to accumulate peat and lead to vegetation transition.

Conclusions

Salinification of freshwater swamps during storm surge can cause the ecosystem and peat collapse along with the loss of carbon storage and vegetation.

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Minimizing the effect of soil salinity on prediction accuracy of soil organic carbon

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Keywords: soil salinity, soil organic carbon, VNIR spectrometry, EPO, PLSR

Introduction, scope and main objectives

About 34 million ha (20 percent) of Iran's total land area is affected by salinity (Qadir *et al.*, 2008). In the past decades, numerous visible and near-infrared (VNIR) spectrometry techniques and technologies were developed to quantitatively measure soil characteristics. The development of VNIR spectrometry is related to a variety of experiments and efforts, including efforts to develop portable spectrometer equipment for *in situ* field soil spectrometry (Mouazen *et al.*, 2005, 2007). Farifteh (2011) argues that salt causes anomalies in soil spectra and can disturb the soil moisture prediction using VNIR. The external parameter orthogonalization (EPO) method has been recognized as the most effective method to minimize external effects to date (Nawar *et al.*, 2020). This study aims to minimize the interference effect of salinity on the accuracy of VNIR estimation of soil organic carbon (OC) by adopting EPO.

Methodology

Here, 230 soil samples were taken at 0–30 cm depths. Soil samples were dried, ground, and, sieved using a 2-mm sieve. Natural salt (dominant salt type is sodic), collected from Hoze Soltan Salt Lake (35º00′00″ N, 50º56′25″ E), was used for comprising the salinity treatment into five classes of salinity based on Richards (1954): < 2 dS/m (non-saline soil), 4 dS/m (slightly saline), 8 dS/m (moderately saline), 12 dS/m (very saline), and 16 dS/m (extremely saline). The soil samples with initial salinity (electrical conductivity (EC) < 1), and classified as non-saline soil, were saturated with double distillate water. The samples' spectra were measured by the FieldSpec-3 spectrometer (Analytical Spectral Devices Inc, USA) using a contact probe and an internal light source. For each soil sample, five spectra were collected from different parts of the petri dish and a total of 1125 spectra were collected for all samples. Splice correction and smoothing were done for all of the collected spectra before processing. An EPO algorithm was developed for soil salinity. The EPO projected spectra were used for predicte OC through partial least squares (PLSR). Overall, 95, 45, and 90 samples were used for OC model calibration, EPO development, and evaluation, respectively.

Results

Results show that the overall reflectance was changed proportionally as salt concentrations were increased in soil. The width and depth of the absorption features (AFs) around ~1400 and 1900 nm were increase while the depth of AF around ~2200 nm decrease as samples became more saline. OC prediction through salt-affected spectra showed moderate accuracy (RPD = 1.81). The Cosine similarity method was used to describe the similarity between the transformed spectra. The similarity between EPO transformed spectra was 98 percent. After EPO implementation, the accuracy of OC prediction experienced an improvement (RPD from 1.81 to 2.34).

Discussion
Change of the soil reflectance caused by the presence of salinity was seen in all spectra, whereas, it was more obvious in AFs located around ~1400, 1900, and 2200 nm. These results are in agreement with Wang *et al.* (2018). Farifteh *et al.* (2008) argued that the degradation of the absorption band ~2200 nm due to the presence of salt, is related to loss of crystallinity in the clay minerals. EPO was able to successfully remove the effect of salinity in soil spectra and improve the OC prediction accuracy as well.

Conclusions
The presence of sodic salt up to 16 dS/m in soil can disturb the soil reflectance and reduce the accuracy of OC prediction by VNIR spectrometry. EPO implementation leads to moderate improvement in the accuracy of OC prediction.

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Investigation of short-scale soil spatial variability of a salt-affected land allotment in Maha-Illuppallama, Sri Lanka in support of applying site-specific soil management practices

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Keywords: Short-Scale Soil Spatial variability, Potential Management Zones (PMZs), Sodic soil, Site-Specific Soil Management (SSSM)

Introduction, scope and main objectives

Development of salt-affected soils is one of major challenging constraints for sustainable agricultural crop production in many parts of the world including Sri Lanka (FAO, 2009; Young, 1994). Delineation of Potential Management Zones (PMZs) in salt-affected soils provides a strong basis to apply Site-Specific Soil Management (SSSM) practices. This study was conducted to investigate short-scale spatial variability of a salt-affected land allotment in dry zone, Sri Lanka and explore the applicability to delineate PMZs in support of SSSM.

Methodology

The study site (2.94 ha) was located at Maha-Illupallama in Anuradhapura district of Sri Lanka. Seventy soil samples from a depth of 0–30 cm were randomly collected within the study site. Each sample was analyzed for Electrical Conductivity (EC), pH, Cation Exchange Capacity (CEC), Exchangeable Potassium (Ex.K), Ex.Na. Ex.Mg and Ex.Ca. Sodium Adsorption Ratio (SAR) and Exchangeable Na (ESP), K (EPP), Mg (ECP) and Ca (ECP) percentages were calculated. Exploratory data and variogram analyses were performed for each investigated soil parameter. Digital soil maps of the investigated soil parameters were prepared using ordinary kriging procedure. Spatial addition of the raster layers of ESP, EPP, ECP and EMP was performed to produce the map of Base Saturation (BS). Delineation of PMZs based on the spatial variability of soil pH, EC, SAR, and ESP was performed using Fuzzy *k*-mean classification. Significant differences in the investigated chemical parameters among PMZs were identified using Tukey's post hoc test.

Results

The mean and standard deviation values for pH. EC, CEC, ESP, EPP, EMP, ECP, BS and SAR were 9.11±1.1, 3.18±2.42 dS/m, 8.88±4.15 cmol/kg, 28.3±25.40 percent, 1.7±1.63 percent, 29.69±12.24 percent, 39.75±16.84 percent, 99.41±1.93 percent and 7.06±8.04, respectively. The Coefficient of Variation (CV) of the investigated soil properties ranged from 1.8 percent and 113.8 percent. The spherical shape variograms were best fitted with all the investigated soil parameters. The Relative Nugget Effect (RNE) of each variogram was less than 16.2 percent. Four PMZs i.e., PMZ1 (1.31 ha), PMZ2 (1 ha), PMZ3 (0.4 ha) and PMZ4 (0.23 ha) were delineated using Fuzzy *k*-means classification. Highest EC and SAR mean values were observed in PMZ2 ($p<0.05$). Higher EMP mean values were observed in PMZ 1 and 3 in comparison to PMZ 2 and 4 ($p<0.05$). Other investigated soil parameters varied among the delineated PMZs.

Discussion

According to CV classification of (Warrick and Nielsen, 1980), EC, ESP, SAR and EPP showed higher spatial variability (60%<CV) while CEC, EMP & ECP showed moderate spatial variability (12%<CV<60%). Moreover, pH and BS revealed lower spatial variability (12%>CV) within the study field. According to RNE classification of (Cambardella *et al.*, 1994), variogram analyses revealed presence of the strong structured (RNE<25%) spatial variability for each investigated soil parameter within the study site. Soils of some locations showed pH>8.5, EC< 4.5 dS/m, ESP<15% and SAR>13 values indicating an occurrence of sodic soil according to salt-affected soil classification of Richards (1954). The ordinary kriged maps of each investigated soil parameter showed continuous spatial variability within the study site. The investigated soil parameters were almost uniform within each PMZ and different among the PMZs revealing a high applicability of Fuzzy *k*-mean classification to delineate PMZs in the study site.

Conclusions

The implementation of SSSM practices based on the PMZs in the studied salt affected soil is highly applicable to enhance the productivity.

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National study of soil degradation by salinization in Colombia

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Keywords: salinization, salinity, soil degradation

Introduction
An approach to assess soil salinization for Colombia is presented, which includes a conceptual framework involving a salinization classification system, based on the environmental impacts on soil functions and services. The first step was to identify areas prone to salinization, using a model with available data at national level. Subsequently, a national baseline map was created from primary data between 2015 and 2017. The type, class and degree of salinization were identified in critically affected regions.

Methodology
A model integrating information about the factors influencing salinization such as soil, climate, relief, land cover and use was carried out at a 1:100 000 scale (Ideam, 2017). For each factor, available data from variables was analysed and weighted according to its relationship with the salinization process. Data was integrated into a geographical information system, obtaining a map with five proposed qualitative degrees of susceptibility to salinization, in terms of intensity and probability of occurrence.

Once soils susceptible to salinization were identified, soil samples were taken in 1037 sites. Soil pH, EC, SAR, and Mg, Na, $CaCO_2$, $CaCO_4$ content were measured using a statistical design. Laboratory analysis allows us to identify the different chemical salinization classes such as saline, alkaline, sodium, calcic, magnesium, gypsum and sulphated acid soils. Results were interpolated to homogeneous land units in terms of soil, climate and use, leading to a map showing the current salinization state. Applying the conceptual FPEIR approach by LADA (FAO, 2007), the driving forces, pressures, status, impacts and responses were correlated with economic, social and environmental indicators.

Results
After applying the model to determine areas prone to salinization, it was estimated that 12.7 percent of Colombian soils are susceptible to this process (144 1845 km^2). Soils which are most susceptible to salinization are situated mainly in lowland and dry areas in the Caribbean and inter-Andean valleys, some Andean highlands and scattered areas in the Orinoco basin and the southwestern Pacific. Approximately 100 946 75 km^2 present some degree of salinization (8.9 percent of the country), from which 116 731 75 km^2 are in a critical to irreversible state of degradation, causing desertification at extreme degree.

Salinization in Colombia occurs mainly due to human activities such as drainage, irrigation, fertilization, amendments and deforestation. Chemically, Colombia has alkaline, sodic, calcic, magnesium, sulphate acid (both coastal and continental) and saline soils, according to the national study of soil degradation by salinization (Ideam, 2019).

Discussion
Determining areas prone to salinization becomes the first strategy in addressing the problem, so as to identify and prioritize areas, establish early alerts and to propose management guidelines.

A protocol to assess and monitor degradation by salinization using a standardized system of type, class and degree of salinization is proposed at a national, regional and local level, setting a baseline in order to develop guidelines and strategies to combat salinization.

Conclusions

This study provides valuable information about soil degradation due to salinization in Colombia. Results are important for decision-makers who deal with Sustainable Soil Management at diverse temporal and spatial scales and to contribute with the Colombian national and international compromises and goals.

Acknowledgements

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The influence of the soil formation factors on the mapping of salt-affected soils on a national scale in South Africa

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Keywords: Geology, climate, topography, salinity, sodicity, alkalinity

Introduction, scope and main objectives

A wide variety of mapping and measurement techniques are available to map salt-affected soils. These technologies are derived from the disciplines of soil science, hydrology, geology, geomorphology, geophysics and remote sensing. The optimum strategy for mapping salt-affected soil depends on the scale and resources available. The purpose of this study was to determine the baseline salinity, sodicity, and alkalinity conditions for South African soils. The research objectives were as follow: (i) To describe and quantify the primary salinity, primary sodicity and primary alkalinity status on a national scale in terms of the major geological formations, rainfall, evaporation, aridity zones, elevation and slope (ii) To prepare a saline sodic soil map at a scale of 1:1 000 000 for South Africa. (iii) To develop an algorithm to quantify salt-affected soils.

Methodology

Of the original more than 40 000 soil data points, only 22 404 data points were used due to the stringent cleaning protocol. To compile the 1:1 000 000 scale primary salt-affected soil map of South Africa, the following maps were used: 1:1 000 000 scale topographical map as base map, 1:1 000 000 scale geological map; electronic inverse distance pH, ESP and EC maps on a 1:1 000 000 scale maps. For each soil observation point the climate parameters rainfall, aridity and evaporation; geological formations; and topographic parameters were calculated.

Results

Primary salt-affected soils do not occur extensively in South Africa. The majority of salt-affected soils occur west of longitude 26° in areas that can be considered mainly, although not entirely, as arid or hyper-arid. Nearly 60 percent of the soils are non-saline, 23 percent slightly saline, 5.1 percent saline, 1.4 percent moderately saline, 0.4 percent strongly saline, 3.8 percent saline-sodic (non-alkaline), 6.3 percent saline-sodic (alkaline), and only 0.4 percent can be considered as sodic. Geological material is an important soil formation factor, but for salt-affected soils its effect is probably overshadowed in many areas by rainfall and position in the landscape. There is a tendency that some of the most sodic and alkaline soils develop from geological units rich in granite and gneiss. Sodic soils developed on geological units with a marine depositional environment characterised by mudstone, siltstone, and shale. There is a decrease in salinity and sodicity, from the lowest annual rainfall class to the highest annual rainfall class; an increase in salinity and sodicity from the lowest annual evaporation class to the highest annual evaporation class; and a drastic decrease in salinity and sodicity from the hyper-arid to the humid aridity zones. There is an increase on a national scale in EC, ESP and pHwater from the highest elevation class to the lowest elevation class.

Discussion

Saline and sodic soils in South Africa mostly occur only in relatively small areas due to localised factors, making the mapping on a national scale problematic. The relative area affected by primary salt-affected soils in South African is much more favourable, compared to other countries. The main reason for this condition is probably the fact that South African soils are mostly derived from geological material that is Ca dominant and not Na dominant. Regression relationships for EC, ESP, and pHwater versus rainfall, evaporation, aridity index, elevation and slope show weak linear correlations on a national scale.

Conclusions
All of the five natural soil-forming factors affect and are affected by water. The flux factors of soil formation (vegetation and climate) as well as the site factors (parent materials and topography) can be linked to landscape hydrology, which is further modified by the internal soil hydrological environment. Soil-forming processes such as transformation, translocation, additions and deletions that have a strong influence on the development of salt-affected soils, or the lack thereof, are all influenced by water to a significant degree.

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Minerals (carbonate and palygorskite) induced natural soil degradation (sodicity and poor drainage) in Vertisols of semi-arid Central India

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Keywords: Vertisols, soil degradation, hydraulic conductivity, sodicity, carbonate, palygorskite.

Introduction, scope and main objectives

Field observations during the land resource inventory indicated that Vertisols of semi-arid tropical (SAT) areas of India are less productive than their counterparts. Natural degradation of Vertisols due to subsoil sodicity is one of the major causes for such low productivity (Pal, 2017). Therefore, this study aims to identify the cause-effect relation of such degradation through a systematic approach by analyzing the physical, chemical and mineralogical soil properties and assist soil managers for developing innovative management protocols to make these soils resilient.

Methodology

Five Vertisols (two Typic Haplusterts and three Sodic Haplusterts) from SAT central India were selected from toposequence representing pediment and alluvial plain landform. The texture, pH, organic carbon, $CaCO_3$ equivalent, exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ and cation exchange capacity (CEC) were estimated by standard methods. The saturated hydraulic conductivity (K_s) was determined by the constant head method (Klute and Dirksen, 1986). The X-ray diffractograms (XRD) of water-dispersible clays were deconvoluted using the curve decomposition method (Paul ***et al.***, 2020) to detect trace amount of any mineral.

Results

The K_s of these spatially associated clayey Typic Haplusterts and Sodic Haplusterts are poor to very poor in the range of 0.01–8 mm/hr. High pH (8.2–9.3) and base saturation (BS) (> 100 %) were observed in all soils. The sodic soils contain 3–14 percent $CaCO_3$, which decreases with depth, and non-sodic soils contain 3–15 % $CaCO_3$, which however increases with depth. The sodic soils have ESP in the range of 4.5–10 and 20–33 in the surface (0–30 cm) and sub-surface horizons (30–100 cm), respectively. Although the XRD diagrams indicated the presence of clay size smectite, mica and kaolinite, the deconvoluted X-ray diffractogram of sodic and non-sodic soil clays showed multiple smaller peaks of palygorskite at 1.04, 1.01, and 0.99 nm in trace amount (2–2.5 percent). The exchangeable Ca/Mg ratio of surface and sub-surface horizons varied from 1.5 to 6 and from 0.7 to 3.5, respectively. Sodic soils exhibited higher Ca/Mg ratio than non-sodic soils and it decreased with depth. Enrichment of Mg in subsoils suggests the translocation of very fine clay palygorskite in preference to smectite (Paul ***et al.***, 2021).

Discussion

The sodic soils are naturally degraded due to the development of sub-soil sodicity because of the formation of pedogenic $CaCO_3$ in SAT environment, which ultimately impaired the hydraulic properties of soils. As a result, a considerable reduction in crop productivity is observed. In addition, the Mg bearing palygorskite clay mineral adversely affects the soil drainage (K_s < 10 mm/hr) due to the presence of more Mg^{2+} ions than Ca^{2+} on the soil exchange complex in non-sodic soils. Thus, the ratio of exchangeable Ca/Mg decreases with pedon depth, likewise the K_s, but with an increase in BS (> 100 percent) (Zade, Chandran and Pal, 2017).

Conclusions
The present study demonstrates a unique case on cause-effect relation of mineral induced natural soil degradation in terms of drainage impairment in non-sodic Vertisols of SAT central India. This novel information may help natural resource managers to innovate management protocols in order to enhance their production potential.

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Examination of chemical and physical properties of halomorphic soils in the Surčin area– Republic of Serbia

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Keywords: salt affected soils, solonchak, solonetz, reclamation measures

Introduction, scope and main objectives

Halomorphic soils, as stated in a recent survey (Škorić, Filipovski, Ćirić, 1985; Miljković, 1996) are divided into three classes: the class of saline soils–solonchak type of soil, the class of alkalized soils–solonetz type of soil, and the class of dealkalized soils–solod type of soil. This research was conducted in the area of the Surčin municipality, CM Petrovčić and CM Progar, Belgarde city, in order to determine its suitability for intensive agricultural production on saline soils as stated in a recent survey (Group of authors, 2019). According to pedological map of the Republic of Serbia, in the area of CM Petrovčić, of 2086 ha of agricultural soil, 34.88 percent belongs to solonchak and solonetz soils, while within CM Progar, of 3587.24 ha of agricultural soil, 8.24 percent belongs to mentioned soil types. Saline soils are used mainly as pastures and meadows with very low grass yields and less often as arable soils. On these soils (Belić, Nešić and Ćirić, 2014), agricultural production is difficult and depends on the method of cultivation and agricultural techniques, the distribution of moisture during the year, and the selection of appropriate crops that can thrive in the given conditions.

Methodology

Composite soil samples at pre-determined locations (CM Petrovčić–104 locations, CM Progar–21 locations) were taken in disturbed condition from a depth of 0–30 cm, according to standard sampling methods and available professional literature. In the prepared soil samples, the following analyzes were performed: granulometric composition (%) of the soil, by the combined sieving and pipette method, after preparation with Na pyrophosphate (JDPZ, 1997); pH in 1M KCl and H_2O–potentiometric; $CaCO_3$ (%)–volumetric; P_2O_5 (mg/100 g)–spectrophotometric; K_2O (mg/100 g)–flame photometric; total carbon and nitrogen content (C, N, %), using CNS Analyzer; humus (%)–by calculation from total C; electrical conductivity (EC, µS / cm)–conductometric; hydrolytic acidity (TS, cmol/kg) and the sum of base cations (S, cmol/kg)–by the Kappen method; total cation adsorption capacity (CEC, T, cmol/kg)–by calculation; degree of saturation with base cations (V, %)–by calculation; ion balance (Na, mekv/L)– flame photometric; Ca^{2+} and Mg^{2+}–spectrophotometric; SAR (Sodium Adsorptio Ratio)–computational (JDPZ, 1966; Jakovljević, Pantović and Blagojević, 1985; Džamić, Stevanović and Jakovljević,1996).

Results

The presence of total sand, silt and clay soil fractions indicates a relatively uniform texture composition, where 94– 98 percent of the samples belong to the texture class of light clays. A more unfavorable ratio of total sand: clay fractions is noticeable, where the clay fraction dominates.

The largest number of tested samples has a strongly acidic, moderately acidic and acidic reaction. The soils are moderately provided with total N whose value is in the range of 0.12 to 0.41 percent, which makes 80–85 percent of the samples. Humus supply ranges from 1.82 to 4.59 percent and is present in 97–98 percent of the examined samples. In relation to P_2O_5 content, the largest number of samples taken from the area of CM Petrovčić has a very low P_2O_5 content, which makes 94 percent of the samples, while in the area of CM Progar this amount is 77 percent. In relation to K_2O content, the largest number of samples (80 percent), taken in the area of CM Petrovčić, is moderately provided, while 11 percent of samples have high K_2O provision. In the area of KO Progar, the largest number of samples is moderately (61 percent) to highly (28 percent) provided with K_2O.

Ninty-two–ninty-eight percent of the analyzed samples are carbonate-free and have these values below the detection limits. The determined values for EC are in accordance with the obtained values for pH and $CaCO_3$.

The values of the soil adsorption complex parameters indicate the highest representation of samples with moderately saturated and moderately unsaturated base cations (85–87 percent). Na^+ content is low in all soil samples and ranges from 0–1 meq/L. In accordance with this, the SAR values were obtained, which are also very low in all tested samples.

Discussion

Based on the conducted examinations, the basic indicators of characteristics of solonchak and solonetz were obtained. Since the examined area is mostly flat terrain, swamps often occur. The conversion of solonchak into arable soil should include eliminating the causes of soil salinization (lowering saline groundwater below the critical depth, application of chemical ameliorative measures, leaching of salt from the soil profile using various measures such as drainage, irrigation, etc., ameliorative fertilization with organic and mineral fertilizers). Salt leaching can also have negative consequences, such as deterioration of the structure, reduction of the amount of humus and nutrients, which should be taken into an account by applying appropriate agrotechnical measures. The time required for soil reclamation of solonetz depends on climatic conditions, applied reclamation measures, as well as the degree to which its properties are to be improved, then, on the classification of solonetz type according to salt content, lime content, reaction of the environment and possibilities of individual soil horizons.

Conclusions

Due to the unfavorable water-air regime on the examined soils, agricultural production is limited and the yields are uneven. Permanent results of saline leaching can generally only be ensured by the application of appropriate drainage. The efficiency of the drainage system can be enhanced by the application of the so-called "biological drainage" by growing trees along irrigation canals and roads, planting protective belts, growing grass, crops, etc. The application of reclamation measures must be based on the specifics of the area such as climatic factors and they include the application of chemical reclamation measures, scattering compacted and monolithic Bthorizon, installation of drainage and open canal network, irrigation, ameliorative fertilization with organic and mineral fertilizers and cultivation of appropriate plant species.

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Numerical phytoindication of soil salinity: the case study in the dry steppes of Russia

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Keywords: Assessment of soil salinity; Electrical conductivity; Plant species and communities; Indicators of salinization depth and degree; Machine learning; CART and Random Forest; Solonetzic complexes; Caspian Lowland

Introduction, scope and main objectives

Phytoindication is a method that uses information about vegetation as an indicator of an environmental variable (e.g. ground water table, salinity, texture, mineralogy etc.). This method has been widely used in soil research, including salinization assessments, due to the close relationship between vegetation and soil properties.

Plant indicators of saline soils have been identified in many studies (Bui and Henderson, 2003; Goryaev, 2021; Novikova *et al.*, 2017; Piernik, 2003). The indicative value of plant species and communities in soil salinity assessments is high, although the published data on the confinement of species and communities to quantitative salinity values and their validity as indicators are very scarce, and there are no commonly accepted methodical approaches to the acquisition of such data. In this regard, the purpose of this study was to identify the strength of the relationship between vegetation and the salinity depth and degree in soils of the solonetzic complex and to explore the possible production of quantitative predictions of the soil salinity based on the presence of plant species typical of the Caspian Lowland (Russia).

Methodology

A 64-m transect was laid from the center of one roundish hollow to the center of another. At each meter, the geobotanical description and soil sampling has been done. The electrical conductivity was measured in aqueous suspensions 1:5 of collected samples.

The Classification and Regression Tree (CART) and Random Forest (RF) methods were used to identify the species importance to indicate the degrees of soil salinity at various depths and to assess the possibility of numerical prediction. The CART and RF models were produced with the sklearn library in Python.

Results

Analysis of the plant species by CART method to identify their confinement to different soil salinity degrees (from non-saline to very strong saline) based on data on the presence or absence of predictor plants allowed the correct classification 78 percent observations in the layer 0–30 cm, 78 percent in the layer 0–50 cm 58 percent in the layer 0–100 cm.

The RF method made it possible to correctly classify 88 percent observations in the layer 0–30 cm, 89 percent in the layer 0–50 cm, 81 percent in the layer 0–100 cm. Thus, the RF algorithm, compared to the CART, worked much better in all layers. The best prediction is of a layer 0–50 cm with 89 percent prediction accuracy.

Discussion

The use of modern computer programs and methods for the processing and analysis of data on plant distribution and soil salinity made it possible to obtain the numerical value of the soil salinity range and quantitative values of its statistical parameters for the studied species and communities. It also made it possible to identify a close relationship with the degrees of salinity at different depths, and to the validity of their indicatory importance. Communication models between individual species and salinity of soils were produced, and their usability for indication was assessed. Further modification of this algorithm will make it possible to create an application that will predict the degree of salinity based on species data.

Conclusions

The application of machine learning methods made it possible to identify the indicatory importance of species for various soil salinity degrees and to produce models reflecting their confinement to different soil salinity degrees.

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Characterization and classification of Natural and Altered wetland soils (Kaipad soils) of north Kerala, India

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Keywords: coastal wet lands, kaipad, profiles, physical properties, natural, altered

Introduction, scope and main objectives

The Kaipad tracts, characterized by the unique saline hydromorphic soil covers the north Malabar districts of Kozhikode, Kannur and Kasaragod. These coastal wetlands are located approximately between the GPS coordinates 11.25°N 75.77°E and 12.5°N 75.0°E. The Kaipad tract covers an area of about 4100 hectares, a major extent of which about 2500 hectares is located in the Kannur district of Kerala. These are brackish water tracts embellished with high inherent organic matter content and essential nutrients thereby having a high production potential. Pedologically, these soils are dominated by the presence of different iron and Sulphur containing minerals like pyrite and jarosite. These natural wetlands are altered for different land uses and the land use changes results in significant changes in soil properties. The study aims at classifying the soils of altered and natural wet lands of *Kaipad* soils of north Kerala according to USDA soil taxonomy.

Methodology

Kaipad tracts, comprising the saline hydromorphic soils are coastal wetlands lying between 11.25°N 75.77°E and 12.5°N 75 (Vanaja, 2013). 0°E.As a part of the study, two representative soil profiles (natural and altered) were opened and horizon wise soils samples collected from these profiles of Kaipad areas comprising of Kalyasseri and Kannur. The soil samples collected from each profile, dried under shade, labelled and stored in clean polythene bags. The moisture percentages of the fresh soil samples were estimated gravimetrically. The various physical and chemical properties of soil samples such as bulk density, textural classification, pH, electrical conductivity, organic carbon, available N, P, and K were estimated using the standard procedures.

Results

The bulk density varied from 1.10 Mg/m^3 to 1.06 Mg/m^3 in Natural and altered wetland ecosystem profiles respectively. The texture varied from clay to silty clay in natural wetland ecosystem and sandy loam to clay in altered wetland ecosystems of these selected profiles.The soil reaction of the samples ranged from 4.74 (A) to 7.90 (BCg) and 5.97 (BCg) to 7.15 (Bw1) horizons in natural and altered wetland ecosystems respectively. The range of electrical conductivity recorded in the soil samples of Kaipad was from 5.14 to 17.00 dS/m and 5.00 to 14.40 dS/m in natural and altered wetland ecosystems respectively. The organic carbon status of the sampled locations of Kaipad varied between 0.86 (Bw3g) to 1.43 (A) and 0.79 (Bw2g and Bw3g) to 2.50 (BCg) percentages in natural and altered wetland ecosystems respectively. The available nitrogen status of the sampled locations of Kaipad regions varied from 324.30 kg/ha to 630.00 kg/ha and 283 kg/ha to 693 kg/ha in natural and altered wetland ecosystems respectively. The available phosphorus content varied from 15.00 to 77.52 kg/ha 0.58 kg/ha to 56.73 kg/ha in natural and altered wetland ecosystems respectively. The available potassium content observed in all the sampled soils was high ranging from 290 to 1152 kg/ha and 320 to 672 kg/ha in natural and altered wetland ecosystems respectively.

Discussion

The natural profiles were classified as Fine, mixed, acid super-active isohyperthermic Typic Sulfaquepts and altered profile was classified as Fine, mixed, acid super-active isohyperthermic Sulfic Entaquepts. The soil reaction of the samples analyzed with standard procedure and ranged from 4.74 (A) to 7.90 (BCg) and 5.97 (BCg) to 7.15 (Bw1) horizons in natural and altered wetland ecosystems respectively. The slightly acidic pH noticed in Kaipad soils might be attributed to the presence of lime shell depositions (Iyer, 1989) as a result of frequent saline water intrusions during the monsoon period. The ultra-acidic pH noticed in Kaipad soils might be related to the presence of pyrite and other iron bearing minerals such as jarosite, limonite etc. The range of electrical conductivity recorded in the soil samples of Kaipad was from 5.14 to 17.00 dS/m and 5.00 to 14.40 dS/m in natural and altered wetland ecosystems respectively. This high salinity recorded might be attributed to the extremely high accumulation of salts during these periods. Similar findings on electrical conductivity of Kaipad soil was reported by Chandramohan and Mohanan (2012). They reported that the electrical conductivity of these soils ranged from 10.9 to 19.9 dS/m during the summer months. These salts get washed away during the onset of monsoon and thus cause a reduction in electrical conductivity of soils, which favours rice cultivation. The organic carbon status of the sampled locations of Kaipad varied between 0.86 (Bw3g) to 1.43 (A) and 0.79 (Bw2g and Bw3g) to 2.50 (BCg) percentages in natural and altered wetland ecosystems respectively. The relatively high organic carbon in the Kaipad soils might be attributed to the incorporation of stubbles and straw after harvest of rice crop in the field itself or from the remnants of the rice shrimp cultivation practiced in Kaipad during the high saline regime prevailing from November to April. It may also be attributed to the diverse flora and fauna present in the soils of Kaipad.The available nitrogen status of the sampled locations of Kaipad regions varied from 324.30 kg/ha to 630.00 kg/ha and 283 kg/ha to 693 kg/ha in natural and altered wetland ecosystems respectively. This medium to high value of available nitrogen content may be due to the presence of high amount of organic matter in these soils and the faster mineralization of nitrogen due to the activity of micro-organisms (Leiros *et al.*, 1999). The available phosphorus content varied from 15.00 to 77.52 kg/ha 0.58 kg/ha to 56.73 kg/ha in natural and altered wetland ecosystems respectively. Chandramohan and Mohanan (2012) reported that the available soil phosphorus content in Kaipad soils ranged from 7.2 kg/ha to 34.2 kg ha1. Samikutty (1977) reported that the saline soils of Kerala were deficient in phosphorus contents.The available potassium content observed in all the sampled soils was high ranging from 290 to 1152 kg/ha and 320 to 672 kg/ha in natural and altered wetland ecosystems respectively. This may be linked to the incorporation of paddy stubbles in the soil after paddy cultivation or due to the excrements which get deposited during the practice of aquaculture in the high saline periods of November to April. It was reported by Samikutty (1977) that the sodium and potassium contents in these soils are higher than those of the other paddy soils of Kerala. He explained that this is due to the continuous submergence of these soils with salt water for over six to eight months in a year and the recurrent barrage by the brackish waters owing to the tidal effect.

Conclusions

The natural profiles were classified as Fine, mixed, acid super-active isohyperthermic Typic Sulfaquepts and altered profile was classified as Fine, mixed, acid super-active isohyperthermic Sulfic Entaquepts. This difference can be contributed to anthropogenic alteration for this altered profile development. Relatively high values of pH, organic carbon, available nitrogen, potassium can be attributed to the natural sampled sites compared to other altered sites.

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Natural resource management and monitoring at salt-affected inter-channel depressions of Amu Darya delta under desertification for the liquorice restoration

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Keywords: Licorice, salinization, environment engineering, remote sensing

Introduction, scope and main objectives

One of the consequences of the Aral ecological crisis is the degradation of the Amu Darya delta. Decrease of natural river flow, termination of floodplain regime, wide use of the drainage water for the lakes and wetlands watering leads to anthropogenic desertification, reduction of biodiversity and deterioration of soil quality (Reimov and Fayzieva, 2014). One of the most vulnerable components of the delta geosystem is inter-channel depressions bounded by levees. These landscape units are important as pastures and a source of wild herbs, especially licorice (*Glycyrrhiza glabra*). Even under unfavorable desertification conditions, the yield of licorice massifs reaches 6 tons per hectare (Bachiev, Dauletmuratov and Mamutov, 1980). Licorice, being a halo-tolerant phreatophyte, has considerable ecological resilience and until recently formed licorice-karellinia, licorice-camelthorns and other plant communities that occupied considerable areas in the non-irrigated part of the Amudarya delta. However, deterioration of edaphic conditions as well as uncontrolled harvesting of plant material led to significant decrease of licorice stocks in the wild.

Restoration of licorice in natural habitats, both independent and combined with measures on pastures phytomelioration after overgrazing, requires considerable efforts and means, therefore it is important to zone the restoration area according to optimal edaphic conditions for the Licorice vegetation, considering dynamics of groundwater level, soil salinity, soil mechanical composition and species composition of phytocenoses that replace economically valuable species.

Methodology

To solve this important problem of environment engineering, we propose combining geoecological models of landscape transformation with model-oriented recognition of remote sensing data. This geosystem-adapted approach has been developed earlier for the non-stable landscapes of the desertified delta of Amu Darya (Reimov *et al.*, 2021).

We used high-resolution space imaging from LANDSAT-7 and SETNTINEL satellites, SRTM-based DEM products and some retrospective information on Amudarya delta landscape transformation, including field data.

We calculate NDVI, SAVI, BI, COSRI salinity indexes, enhanced built-up and bareness index (EBBI) and Modification of normalized difference water index (MNDWI). Also, we used MODIS-derived annual NDVI sequences to discriminate type of flora (Xue and Su, 2017; Konyushkova, 2014).

Results

Connection of landscape transformation model with optical change detection based on a spatial distribution and long-term dynamics of vegetation can be effective tool for natural resources mapping and support of phytomelioration measures. Comparison of the obtained results with sparse field data for key points demonstrates good correlation of the predicted environment conditions with licorice occurrence.

Discussion

Extended landscape mapping based upon both space images interpretation and landscape transformation model demonstrates better prediction powers then common methods of multi-spectral images classification.

Conclusions

Use of the remote sensing data classification could me more effective being assembled with models of landscape transformation and soil map to predict soil salinity and groundwater level. This approach has a good predictive ability to select most suitable sites for licorice thicket restoration in Amu Darya delta.

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Preliminary study of salt-affected soils in the Zona Bananera, Magdalena (Colombia)

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Keywords: sodic soils, soil mapping, tropical soils, wetlands, remote sensing, water use

Introduction
In the Zona Bananera in the Magdalena region, the presence of soils affected by salts is common, especially in coastal areas and in mangroves subjected to soil use changes (wetlands to banana plantations). This soil-use dynamic makes a precise mapping of the soils affected by salts necessary for crop management purposes. In Colombia, a soil salinity map at the country level has been carried out (IDEAM, 2016). Our preliminary study proposes an initial diagnosis of the salinity problems in the banana zone of the Department of Magdalena, with the purpose of using and managing the soil under banana cultivation.

Methodology
The study area (44 600 ha) is located in Zona Bananera Municipality, Magdalena Department, Colombia, covered by different ranges of soils affected by salts including Entisols, Inceptisols (IGAC, 2009), Ustic and isohypertermic. The precipitation is 1332 mm a year, evapotranspiration 1820 mm a year, and at a temperature of 27.3 ºC under tropical dry forest (Holdridge). Digital data was used to identify the distribution of salts in relation to soils and geomorphology, Landsat 8 images (2020) Band 1 to 11 (U.S. Geological Survey®) were used. The images were processed with the software Grass GIS version 7.8.5 (Grass GIS®), supported by 236 soil samples and field observations.

Results
The results showed greater salt-affected soils in the western part of the municipality. The unaffected soils are found in the foothills of the Sierra Nevada de Santa Marta under colluvium alluvial fans and granitic materials. The soils affected by salts are frequently found in the tidal plains and floodplains that mostly have a lake fluvial and marine fluvial origin.

Soil pH values fluctuate between 4.7 and 9.6, with 16 percent having limitation in relation with salts (under low EC values); while 84 percent do not present limitations in terms of possible effects of salts. The studied geomorphological zones of flood plains and tidal plains, mangroves and wetlands present the highest concentration of the problem. Regarding electrical conductivities, 96.6 percent report low EC and 4.4 percent, medium EC values.

Discussion
Our preliminary results showed that electrical conductivity is not a good predictor for soils affected by salts. The pH provides the most important auxiliary data for the prediction of salt-affected soils especially for sodic soils. High salts in lowlands, wetlands, mangrove and sites with high water tables are associated with sea level incidence and flood plains. In this way, the geomorphology map is a useful predictor for mapping possible soils affected by salts which might be due to the geomorphological surface formed during the Holocene. These also have a good relationship with soil processes in the semiarid regions in relation to water use related to the introduction of irrigation on banana plantations.

Conclusions

Preliminary results show the utility of easy acquisition data such as pH and EC together with information from free-use satellite images in determining the problems of soils affected by salts, and their possible use in monitoring the progress of this problem at the regional scale. Detailed scale information and complementary analysis is necessary. In the case of the presence of bare soils or without vegetal cover, it is possible to identify salt-affected soils easily; nevertheless, in areas under mechanization or urban areas, this methodology has limitations. For future studies it is necessary to generate geomorphological maps at more detailed scales, and other calibration laboratory parameters.

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Mapping Salt-Affected Soils of the United States of America

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Keywords: soil mapping, salinity, machine learning, digital soil mapping, soil properties

Introduction, scope and main objectives

The United States of America (USA) has many agricultural regions that contain extensive salt affected soils (SAS), such as the San Joaquin Valley and Northern Great Plains. Therefore, many programs within the USA exist to support the sustainable development of SAS, such as the US Salinity Laboratory (USSL) to conduct research, the National Cooperative Soil Survey (NCSS) to inventory soil resources, and the University Cooperative Extension System to educate the public.

Methodology

Soil salinity indicators (pH, EC, and ESP) were predicted for the continental USA (CONUS) using a digital soil mapping (Kienast-Brown, Libohova and Boettinger, 2017; McBratney, Mendonça Santos and Minasny, 2003) approach. Machine learning methods were employed in combination with training and validation data derived from pedon observations with laboratory measurements of the salinity indicators and covariate data layers representing multiple environmental factors. SAS classes were then calculated using the resulting pH, EC, and ESP predictions.

Results

According to our estimates, approximately 38 percent of CONUS includes SAS within 0–100cm, of which 64 million hectares (158 million acres) is cropland. The majority of SAS in the US (29 percent), according to the FAO classification scheme, are only slightly saline.

Discussion

Past estimates for SAS on cropland within the USA have ranged from approximately 2.2 to 6.39 million hectares (or 5.4 to 15.8 million acres) (FAO and ITPS, 2015; NRCS, 2011; Lal, Iivari and Kimble, 2010). Our current estimate using the USDA classification system is higher than past estimates (NRCS, 2011), but should not be interpreted as an increase in salinity due differences in the data source and methodologies used for both estimates. In addition, the current estimate may be low, as indicated by a visual comparison with a map of EC produced by Scudiero et al. (2017) for the western San Joaquin Valley, which shows more extensive areas of the USDA class moderately saline. Lastly, many of the areas identified as 'slightly saline' include significant local variability which is not captured at the resolution of 1km used in this study.

Conclusions

Future modeling of SAS for the USA would benefit from incorporating additional data, as there are areas of missing laboratory data for EC. Even many saline areas, such as the San Joaquin Valley, do not have extensive laboratory data. Currently, many USDA Soil Survey Offices are actively collecting data on dynamic soil properties (DSP) (Wills, Williams and Seybold, 2017), which are intended to evaluate changes in soil properties due to management. Salinity indicators, such as EC, are considered DSPs and therefore will also continue to be collected.

To enhance future estimates of SAS and other soil properties throughout the USA, an initiative is currently underway to map soil properties using digital soil mapping (DSM) (Thompson et al., 2020). The SAS assessment and the methodology discussed above is part of that effort. This information will be critical to addressing the threat of increased salinization due to climate change (Corwin, 2020) and saltwater intrusion (Tully et al., 2019).

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Digital assessment of soil salinity across Paraguay

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Keywords: soil salinity, dry lands, digital soil map, soil depth, Paraguayan Chaco

Introduction, scope and main objectives
Salinization represents an important form of soil degradation. According to FAO and GTIS, (2015), salinity and sodicity are some of the most important threats to soil health. Paraguay has two different edaphoclimatic regions. The Western Region with a dry climate with an average rainfall of 850 mm and the Eastern Region with a humid climate (Grassi, 2020). Although the presence of salts is known in Paraguay, a soil salinity map is not available. Therefore, soil salinity mapping is a first step to generate new knowledge and monitor the expansion of soil salinity. Thus, the main objective of this study is to develop a digital soil salinity map at the national level in Paraguay.

Methodology
The methodology used to map salt-affected soils (SAS) was based on the Global Soil Partnership approach proposed by the Global Soil Partnership (Omuto, 2021), which emphasizes three steps: a) harmonization of input data, b) spatial modelling of input soil indicators using spatial predictors, and c) classification of soils affected by salts. The study data included 80 soil sampling sites with measured EC values and 204 sites with measured pH and PSI values that are standardized to 0–30. Environmental predictors are through remote sensing imagery, thematic maps, geomorphometry and climate surfaces. The algorithm used for modelling is an ensemble of regression trees based on bagging known as Quantile Regression Forests (Meinshausen, 2006).

Results
Most of the soils of Paraguay (97.49 percent), at depths of 0 to 30 cm, do not show salinity or sodicity. However, low sodium levels can be observed in soils of the lower Chaco, likewise, low salinity levels are found east of the middle Chaco, occupying only 1.60 percent and 0.91 percent of the national territory, respectively. Thus our results represent a benchmark to assess the expansion of salt-affected soils across the country.

Discussion
The presence of salts and sodium in Paraguay soils could indicate relate to the level of soil moisture. As various studies demonstrate, the amount of precipitation is closely related to the salinization of soils (Wenquan *et al.*, 2020; Bannari and Al-Ali, 2020).

Conclusions
The first salinity and sodium map of soils in Paraguay shows that the highest concentrations are found in the western region or the Paraguayan Chaco.

Considering the scale of this first work, with low quantity and insufficient updating of available data, as well as the superficial study, it is recommended that monitoring programs are promoted with updated and more detailed information, and with more in-depth studies.

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Prediction of soil salinity using a Random Forest-based model between 2000 and 2016: A case study in the Great Hungarian Plain

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Keywords: Soil salinity, Optical, Radar imagery, Sentinel-1 SAR, Environmental monitoring, Statistical modeling, Random Forest.

Introduction, scope, and main objectives

Saline stress causes significant agricultural losses yearly by inducing slower growth, premature leaf senescence, and reduced tillering (Schmöckel and Jarvis, 2017). Due to its rapidly evolving nature, it is crucial to continuously monitor salinization in order to mitigate its effects and preserve food security. While traditional monitoring methods are time-consuming and expensive, remote sensing tools have emerged as a viable solution for more efficient and affordable methods. In this context, researchers have intensively investigated the spatio-temporal distribution of salinization using optical and radar sensors coupled with geostatistics, statistical modeling (Sahbeni, 2021a, 2021b), and machine learning techniques (Szatmári *et al.*, 2020). This study aims to predict soil salinity between 2000 and 2016 using remote sensing tools combined with random forest (RF) based models over the Great Hungarian Plain.

Methodology

Field data are collected within the 30 cm upper layer in the Hungarian Soil Monitoring System framework. Salt content values are determined using saturated paste according to the Hungarian Standard MSZ08-0206/2-1978 (IPTS, 2013). Nine Landsat images were acquired between 2000 and 2016. Once Landsat images are converted to Top of Atmosphere (TOA) Reflectance, we applied a Fast line-of-sight atmospheric analysis of spectral hypercubes (FLAASH) for atmospheric correction (Young *et al.*, 2017). Twenty-one spectral indices were calculated using ENVI IDL 5.3. Principal component analysis (PCA) was applied on stacked images to compress information from vis-NIR and SWIR bands. Medium Resolution Image (IMM_1P) and Ground Range Detected (GRD) products retrieved from ERS-1/2 and Sentinel-1 SAR sensors were radiometrically calibrated and geometrically corrected using Sentinel-1 Toolbox (SNAP). Once values corresponding to sampling sites were extracted, the dataset was divided into 80 percent for training and 20 percent for validation. We employed RStudio to train the models and calibrate their hyperparameters. An optimization technique based on the random search method and Recursive Feature Elimination (RFE) was conducted to optimize the hyperparameters and extract the most important features. The root-mean-square error (RMSE) and the correlation coefficient (r) between predicted and measured values were computed to assess the models' performance.

Results

RF-based models showed an acceptable goodness-of-fit. The highest fit was found for RF model of 2016 ($RMSE_{Training} = 0.14$, $RMSE_{Test} = 0.16$, and $r = 0.81$), followed by RF model of 2008 ($RMSE_{Training} = 0.19$, $RMSE_{Test} = 0.49$, and $r = 0.8$), and RF model of 2000 ($RMSE_{Training} = 0.28$, $RMSE_{Test} = 0.49$, and $r = 0.73$).

Discussion

The developed models performed well in terms of RMSE and correlation coefficient (r), while the 2016-RF-based model yielded the most accurate results compared to other proposed models due to remote sensing platforms upgrades, i.e. Landsat 8 OLI and Sentinel1 SAR. Regardless of random forest vulnerability to overfitting and changes, a significant relationship between spectral response and salinity has been well-established.

Conclusions

This study gives an overview of machine learning potential in monitoring salinization expansion towards more sustainable agriculture. Nevertheless, the dataset size and the samples low variance limited the complexity to be modeled, which will be investigated in future studies. Further work must be conducted to validate the approach's applicability on the regional scale.

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Characterisation of different land uses in *Pokkali* ecosystem

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Keywords: Pokkali, acid saline soils, land use systems, soil characterization

Introduction, scope and main objectives

Pokkali fields are tidal wetlands of Kerala, where a traditional indigeneous organic method of rice-fish rotational cultivation is being practiced. Pokkali soils are highly fertile with high organic carbon. It is now facing the challenge of prawn monoculture at the cost of the traditional rice-prawn farming system. Though this provides higher net returns over the traditional system in the short run, it is unstable in the long run. The study was undertaken to characterise the soils of different land uses in Pokkali ecosystem.

Methodology

Soil sampling

Pokkali tract is found in the parts of Thrissur, Ernakulam and Alappuzha districts and is situated between a latitude of 9°45" N and 10°15" N and a longitude of 76°10" E and 76°20" E. This study was carried out in three major land use systems of Pokkali, which include Rice + Prawn (L1), rice alone (L2) and prawn alone (L3). Georeferenced samples were collected from Kumbalangi (L1), RRS Vyttila (L2) and Kadamakkudy (L3). In total, five composite samples were collected from each land use at a depth of 0–20 cm using core auger in January 2020. The samples were sealed and labelled for further analysis.

Soil characterization

Soil pH and electrical conductivity was measured by using pH meter and EC meter respectively. Bulk density of samples collected were measured following the method used by Blake and Hartge, 1986. Particle size analysis was done as per standard procedure. Soil organic carbon (SOC) content was determined by the wet oxidation method described by Walkley and Black's (1934). Microbial biomass carbon (MBC) was determined by chloroform fumigation extraction method (Jenkinson and Pawlson, 1976). Dehydrogenase activity was estimated by procedure outlined by Casida, Klein and Santoro, 1964.

Results

The mean pH of L1, L2 and L3 were 6.88, 6.41 and 6.84 respectively. The observed mean EC value for L3 was 2.44 against 1.34 and 1.82 dSm^{-1} in L2 and L1 respectively. Texture analysis showed that both L1 and L2 had a clay texture while L3 had a sandy clay loam texture. The bulk density of the L1 was the least (0.68g/cm^3) compared to L2 (0.89 g/cm^3) and L3 (1.23 g/cm^3). SOC was higher in L1 (1.649 percent) than L2 (1.476 percent) and L3 (0.981 percent). MBC of L1 ranged from 140-292 µg/g soil with a mean of 235.827 µg/g soil whereas the MBC of L2 ranged from 150-231 µg/g soil with a mean of 204.87 µg/g soil. MBC of L3 ranged from 72-249 µg/g soil with a mean of 158.07 µg/g soil. Mean of Dehydrogenase activity of L1, L2 and L3 were found to be 2740.9, 3575.2 and 2132.49 µg TPF/hg soil.

Discussion

Pokkali soils are saline acid sulphate soils which belong to fine loamy, mixed, iso-hyperthermic acid family of Sulfaqueptic Tropofluents as per Soil Taxonomy (Varghese, Thampi and Money, 1970). These low-lying lands are naturally connected to the Arabian sea through canals and backwaters which makes them saline. The pH of Pokkali soil from L1, L2 and L3 was found close to neutral values. Sasidharan (2004) reported that tidal action significantly increased pH of Pokkali soils. Acidity in acid sulphate soils get neutralised with the seawater intrusion (Wong *et al.*, 2010). The observed EC values for L1, L2 and L3 were <4 dS/m. Shylaraj, Sreekumaran and Annie (2013) reported that EC values varied from 0.001 to 7.80 dS/m during low saline phase (June–October) and 0.10 to 9.80 dS/m during high saline phase (November–May). Joseph (2014) reported that the mean bulk density in Pokkali soils varied from 0.56 to 1.17 Mg/m^3 and the presence of organic matter attributes to the variation. Rice+Prawn land use showed lowest bulk density compared to other land uses which indicates better soil quality. Rice+prawn land use has an upper hand in soil organic carbon content compared to other land use systems. Krishnani *et al.* (2014) reported higher organic carbon content (0.22 to 3.74 percent) during paddy culture than shrimp culture. The diversity and richness of microbiome in *Pokkali* soils are the cause of higher dehydrogenase activity and MBC. Increased SOC, nutrient status and litter accumulation can be attributed to the high dehydrogenase activity in rice+prawn and rice alone systems.

Conclusions

The research findings show that rice+prawn land use system have good soil properties compared to other land use systems. The continuous monoculture of prawns in these Pokkali fields can lead to deterioration of soil quality. These valuable wetland resources can be protected and the ecological balance maintained by adopting organic Pokkali + prawn rotational farming practice.

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Soil electrical conductivity EC modelling based on LUCAS topsoil (2015–2018) using machine learning approach to classify salt affected soils

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Keywords: Digital soil mapping, Electrical conductivity, LUCAS, machine learning, salt-affected soils, WRB, soil water content.

Introduction, scope and main objectives

The accumulation of soluble salts in the soil can imbalance nutrient uptake for the majority of field crops. Soil data has an intrinsic within-field variability that jeopardizes the production of reliable data for monitoring purposes. Topsoil Electrical Conductivity (0–20cm) is subjected to seasonal and other sources of variability at European scale which are reported for the average EC of the years 2015 and 2018 in the Land Use and Coverage Area frame Survey LUCAS (Orgiazzi *et al.*, 2018).

To contribute to the efforts of the International Network on Salt-affected Soils (INSAS), which is based on a country-driven support and to cope with inter seasonal variability, we performed a modelling exercise based on soil Electrical Conductivity (EC) collected during the soil LUCAS surveys. The aim of this work is to predict potential salt affected soils (EC >0.5 dS/m) and unaffected (<0.50 dS/m) for the European countries using a digital soil mapping approach. The reduced threshold (0.5 dS/m instead of 0.75 dS/m as proposed by FAO) reflects the possible early sign of salinization state in European soils which shows a moderate salinity (2–4 dS/m) in the worst cases. Furthermore, we try to define local scale cut-off values, to halt land degradation such as secondary salinity that is a rising problem due to irrigation with poor quality water.

Methodology

The LUCAS soil survey includes a regular, harmonised soil collection across all Member States to gather information for soil monitoring purposes. The EC training data used in this work, consisted in the mean ECs of two surveys, (15435 points). To model the EC, we adapted the FAO classification (Vargas *et al.*, 2018) which allowed us to split the data in salt-affected and unaffected soils. We used a classification-based machine learning approach and the most related environmental variables to model the presence or absence of salinity, to be able in a second phase to map quantitatively the EC in each susceptible area at a better spatial and temporal resolution (Lück *et al.*, 2009).

The model selected is the gradient boosting machine (GBM) model, there are few tuning parameters such as number of iterations, complexity of the tree, learning rate. To train the model, a set of environmental variables (30) at 500 m spatial resolution was used: topography and related indices (Farr *et al.*, 2007), Soil hydraulic properties (Tóth *et al.*, 2017), Bioclimatic (Fick and Hijmans, 2017) and Sentinel-2 derived soil moisture (Garajeh *et al.*, 2021) at seasonal intervals, CORINE Land and the World Reference Based classification (FAO and IUSS, 2014). Each of the levels of CORINE and WRB reference Soil Groups (RSGs) (ESDAC, 2007) were binarized to carry out the classification. GBM results were evaluated using: Accuracy, Cohen's Kappa, Precision, Recall and F1 (Vermeulen and Van Niekerk, 2017).

Results

In general, 97.5 percent of soil samples have EC below 0.75 dS/m, and 94 percent below 0.5 dS/m, and this suggests that soils in the study area are not severely salt affected. We trained and test the model based on a random selection of (70/30) respectively and showed that the performances allowed for the detection of the most susceptible areas to salinity with an Accuracy of 0.946, Kappa, of 0.18, precision 0.95, recall 0.995 and F1 of 0.972. In particular, the model was able to identify 99 percent of the unaffected soil and 20 percent of the salt-affected. Furthermore, the 10 percent (EC > 0.75 dS/m) were identified. The list of the most important variables showed that in addition to climatic (rainfall and temperature), topographic indices, legacy soil information (WRB soil orders), soil moisture derived by Sentinel-2 were the most important covariates.

Discussion
Water related indicators were the most important variables in terms of predictive ability. Annual average precipitation and saturated water content (80 percent of predicted points are above the average), soil moisture of the summer season, elevation and the WRB-RSGs Gypsisols, which shows accumulation of moderately soluble salts or non-saline substances and Gleysols were the most represented WRB groups that hosts European salt affected soils. The fact that other WRB groups (Solonchak, Solonetz) are not guiding the classification is due to their unbalanced distribution over the training data.

Conclusions
Deepening the understanding in the Salinity mapping approaches using a large scale monitoring dataset in EU is crucial for the definition of local scale cut-off values to map land degradation.

Acknowledgements
European Soil Data Centre (ESDAC), Land Use and Coverage Area frame Survey (LUCAS) Soil.

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Survey and characterization of underground waters of north western part of Jodhpur, Rajasthan

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Key Words: Underground Waters, Characteristics, Water classes, Effect on soil properties

Introduction

Water is important valuable and natural resource for human life and economic development. People around the world have used ground water as a source of drinking water, and even today more than half the world's population depends on ground water for survival (Dagar, 2009). Water is the elixir of life (Vidvan and Vishvam, 2003) and plays a vital role in the earth's ecosystem. Majority of the underground tube well waters contain high concentration of salts and their continuous use for irrigation adversely affects the crop production and causes soil deterioration. The use of underground water of marginal (saline or sodic) and poor (highly saline, highly sodic or both) quality for irrigation degrades the soils. It gives rise to some apparent and hidden soil problems. Periodically diagnosis and subsequent management is of paramount significance. Jodhpur district is situated in North-Western Rajasthan, comprising fourteen tehsils, viz, Balesar, Baori, Bap, Bhopalgarh, Bilara, Denchu, Jodhpur, Lohawat, Luni, Osian, Phalodi, Piparcity, Shergarh, and Tinwari. Keeping all these points in mind, the present investigation entitle "Survey and characterization of underground waters of north western part of Jodhpur, Rajasthan" was undertaken with the following objectives: (i) Evaluation and categorization of underground waters of north-western part of Jodhpur district (ii)To find out the inter-relationship between quality characteristics of underground waters and some important soil properties (iii) To suggest the appropriate measures for better utilization of underground waters and soils.

Methodology

A field-based survey was carried out for evaluation of underground irrigation waters quality and its effect on soil properties of north western part of Jodhpur Rajasthan, 170 water samples were collected during March, 2019 from one hundred thirteen villages of Bap, Phalodi, Lohawat, Denchu, Balesar and Shergarh tehsils of Jodhpur district from the tube wells which were used for irrigation purpose. One hundred fifty- seven composite soil samples from 0–15 cm depth were also collected from the cultivated fields irrigating with the above mentioned tube well water and fifty two composite soil samples were also collected from un-irrigated fields on same time. The water and soil samples were analyzed for various characteristics by adopting standard methods and procedures.

Results and Discussion

The majority of irrigation waters were found good to marginally saline, saline and high SAR saline water quality. The majority of soils were non-saline, moderate to strong sodic in nature with loamy sand in texture. About 38.71, 58.06 and 3.23 percent water samples in Balesar tehsil are under good, marginally saline and saline; 6.25, 6.25, 62.50 and 25.00 percent water samples in Bap tehsil lies under good, marginally saline, High SAR saline and highly alkali; 12.90, 58.06, 3.23 and 25.81 percent water samples in Denchu tehsil lies under good, marginally saline, saline, High SAR saline; 71.87, 18.75 and 9.38 percent water samples in Lohawat tehsil lies under good, marginally saline, High SAR saline; 10.34, 41.38, 20.69, 27.59 percent water samples in Phalodi tehsil lies under good, marginally saline, High SAR saline and highly alkali and 3.33, 33.33, 3.33, 56.68 and 3.33

percent water samples in Shergarh tehsil lies under good, marginally saline, saline, High SAR saline and marginally alkali. The concentration of Fluoride in water samples ranged from 0.02 to 1.34 (mean 0.46), 0.02 to 1.85 (mean 0.75), 0.04 to 0.85 (mean 0.47), 0.30 to 0.90 (mean 0.56), 0.03 to 1.50 (mean 0.63) and 0.02 to 2.52 (mean 0.71) mg/L, whereas, Nitrate content of water samples ranged from 1.10 to 114.40 (mean 52.67), 5.30 to 53.10 (mean 33.92), 1.50 to 128.20 (mean 31.79), 2.10 to 130.50 (mean 42.56), 2.70 to 120.60 (mean 32.93), and1.40 to123.00 (mean 46.65) mg/L, respectively for Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils of Jodhpur district.

Conclusion

The majority of irrigation waters were found good to marginally saline, saline and high SAR saline categories alkali. The majority of soils were belongs to loamy sand in texture with normal to alkaline in reaction. Both irrigated and unirrigated soil having no salinity and moderate to strong sodicity problems. Continuous use of this type of water may lead to formation of sodic soils. Based on soil and water characteristics of the area, three major land management units are suggested.

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Assessment of ground water quality for irrigation in Alappuzha district of Kerala, India

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Keywords: Ground water quality, Alappuzha RSC, SAR, Spatial variability, Cations, Anions

Introduction, scope and main objectives

The Coastal Zone in Kerala extending over 560 krn, with a height of less than 8 m from the MSL, covers about 15 percent of the total geographical area of the state. Alappuzha is one of the coastal districts in southern part of Kerala state. The present study was an attempt to evaluate the quality of groundwater for irrigation purpose on a scientific basis for its optimal utilization.

Methodology

Georeferenced ground water samples from 52 locations of coastal areas of Alappuzha district were collected. The samples were analyzed as per the standard procedures. The water quality indices viz., SAR and RSC were calculated and classified as per the classification of CSSRI.

Results

The pH of water samples varied from 5.20 to 8.10 with a mean value of 7.10. The electrical conductivity of water varied from 0.02 to 1.03 dS/m with mean value of 0.27 dS/m. The sodium adsorption ratio (SAR) was recorded in the range of 0.25 to 4.36 with mean value of 1.51. The residual sodium carbonate was recorded in the range of 0 to 4.54 me/L with the mean value of 0.80 me/L. According to CSSRI classification, out of 52 water samples 49 were of good quality, one of marginally alkali and two were alkaline in nature.

Discussion

The pH variations in ground water samples collected are considerably small and the alkaline pH is particularly due to presence of bicarbonate ion in huge amounts (Ahmad and Qadir, 2011). The EC of all the samples collected recorded <2 dS/m. It was also found that 45 samples were of safe category (RSC < 2.5 me/L), 7 were unsuitable (RSC >2.5 me/L) for irrigation purposes. Isaac *et al.* (2009) ascertained that the SAR of soil solution is increased with the increase in SAR of irrigation water which eventually increases the exchangeable sodium of the soil. Naseem *et al.* (2010) reported that pH, EC and SAR of the irrigation water are significantly influenced by RSC.

Conclusions

The groundwater analysis of Alappuzha district, the 86 percent of groundwater can safely be used for irrigation purpose.

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Current state of degraded soils of the Aral region and technologies for improving their fertility

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Key words: meadow alluvial soils, desertification, degree of salinity, lower reaches of the Amu Darya, chemical properties, nutrients, agricultural ores

Introduction

At present, intensified desertification processes are taking place in the territory of the Aral Sea region. This has attracted the attention of scientists from all over the world, wanting to study the reasons that contribute to the manifestation of these processes and find ways to prevent or weaken desertification processes in the lower reaches of the Amu Darya (Tashkuziev and Sharafutdinova, 1993).

In this regard, it becomes necessary to thoroughly study the soil cover of the lower reaches of the Amu Darya on the territory of the Republic of Karakalpakstan in comparison with previous years (World Bank, 2001; AN RUz, 1996).

Methodology

The object of the study is the irrigated soils of the Dustlik massif of the Khodjeyli region, which are under the influence of desertification. The research used the generally accepted genetic, geomorphological and chemical analytical methods.

Results

Developed meadow soils in the territory are widespread, although differing in texture. The upper horizon of the studied soils is mainly medium and heavy loam, although sometimes light loams are found. The lower soil horizons vary from light loam to sandy loam and sand.

When studying the reclamation state of soils, their fertility, the content of water-soluble salts and their reserves are of great importance. The results of the analysis of the water extract showed that the old-irrigated meadow soils widespread in the territory are mainly non-saline (0.18–0.298 percent) and slightly saline (0.364–0.798 percent) in the arable soil horizon. In the subsurface horizon of the old-irrigated non-saline soil, the dry residue content is 0.11–0.31 percent, and in slightly saline soils, it is slightly higher, 0.266–0.860 percent. Towards the bottom, the amount decreases and is equal to 0.226–0.520 percent.

In the subsurface and underlying horizons of these soils, the amount of dense residue decreases slightly and amounts to 0.340–1.010 percent. Newly irrigated and newly developed meadow soils are moderately saline, with a dry residue 1.026–1.320 percent. According to the content of dry residue and chloride ion, the soils are characterized as slightly saline. The soils are of the sulfate type of salinization.

Discussion

It is known that the accumulation of humus in the soil and its quality depend on many factors, such as climatic conditions, terrain relief, the quantity and quality of decomposed plant biomass, the chemical composition of the soil, its water-physical properties and thermal regime, as well as the period of biological activity (PBA) in the zonal row of soils (Tashkuziev, 2006; Tashkuziev, Berdiev and Ochilov, 2017).

It has been established that the distribution of salts along the profile of irrigated soils is associated with the nature of their solubility for economic use. Under arid irrigation conditions, high irrigation rates violate the stability of the salt profile of oasis soils, and the leaching of readily soluble salts (Kuziev and Sektimenko, 2009).

It is known that there are deposits of natural agricultural ore in Karakalpakstan; there are bentonites and glauconites in Krantau and Khojeyli. The use of this raw mineral material has a positive effect on the physical, chemical, water-physical, etc. and properties of the soil.

Conclusions

To improve the water-physical, chemical, physicochemical and other properties of degraded, low-fertile soils of Karakalpakstan, agricultural technology has been developed and introduced, aimed at enriching the soil with organic matter using local agricultural ores and organic fertilizers.

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Mapping salt-affected soils of Italy

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Keywords: Italian Soil Partnership, salinity, sodicity, cubist, stratified random splitting

Introduction, scope and main objectives

Soil salinization and sodification risks are two of the main threats in agricultural soils of Italy (Dazzi, 2008). In Italy they are mainly due to irrigation with saline waters (Dazzi and Lo Papa, 2013), to seawater intrusion (Castrignanò *et al.*, 2008, Dazzi and Lo Papa, 2013, Selvaggi *et al.*, 2010), and to saline parent materials (Dazzi and Fierotti, 1994). The water level is strictly regulated by channels and pumping stations (Vittori Antisari *et al.*, 2020; Buscaroli and Zannoni, 2010; Teatini *et al.*, 2007), and seawater intrusion along rivers, canals and in the groundwater aquifer is exacerbated by subsidence (Teatini *et al.*, 2005). The salt-rich parent material can be exposed due to soil erosion (Piccarreta *et al.*, 2006; Cocco *et al.*, 2015). In the last decades, several Italian regional authorities for soil data produced soil salinity (risk) maps, resorting to different mapping approaches. Previous examples of salinity risk maps of Italy have been also attempted (Dazzi, 2008, Costantini *et al.* 2009). This works presents the maps of salt-affected soils of Italy, as part of the 1k grid GSSmap, realized adopting the procedure proposed by the Global Soil Partnership (GSP), and involving the Italian regional authorities, which are part of the Italian Soil Partnership.

Methodology

12,324 point-data were collected from existing soil databases, with Electrical Conductivity (EC) measured on different soil: water ratios (1:2, 1:2.5, 1:5, saturated) extracts. The EC 1:2.5 and 1:5 data were converted to the saturated paste using conversion functions calibrated for Italy (Staffilani *et al.*, 2015), the EC 1:2 using Datta *et al.* (2017). The average values for the reference depth intervals (0–30 cm and 30–100 cm) were calculated fitting data with a mass-preserving spline (Malone *et al.*, 2009). The EC dataset were integrated with point-data retrieved from the LUCAS 2015. The final dataset of ECe sums up to 13,784 and 10,024 point-data for the 0–30 cm and 30–100 cm depth intervals respectively; to 31,239 and 22,533 pH data points for topsoil and subsoil, respectively; and to 12,563 and 10,403 ESP data points for topsoil and subsoil, respectively. The R script provided by GSP (Omuto, 2020) was used for the identification and application of Digital Soil Mapping models. Cubist model types, calibrated and validated on normalized transformed data, returned the lowest RMSE and highest R^2 by *stratified random splitting*. They were used to estimate the normalized target variables (EC, pH, and ESP). An inverse transformation was then applied to produce the final maps. Standard deviation and uncertainty map were obtained resorting to a bootstrap approach.

Results

Salt free soils (ECe<0.75) represent 55 percent and 77.8 percent of topsoils and subsoils, respectively; slight saline (ECe 0.75–2 dS/m) the 44.5 percent and 20.5 percent, moderate saline (ECe 2.0–4.0 dS/m) the 0.35 percent and 0.79 percent, slightly sodic soils (ECe <4.0, ESP 15–30, pH >8.2) the 0.005 percent and 0.001 percent, slightly saline-sodic (ECe 0.75–2.0, ESP >15, pH <8.2) the 0.066 percent and 0.005 percent, moderately saline-sodic (ECe 2.0–4.0 ESP >15, pH <8.2) the 0.016 percent and 0.027 percent, saline sodic (ECe>4.0, ESP 15–70) the 0.010 percent and 0.007 percent, of topsoils and subsoils, respectively.

Discussion

ECe is on average slightly overestimated, but local underestimation is observed in particular in the coastal plains of Tuscany, Latium and Apulia. As for ESP, a slight underestimation is observed, but in most cases differences are below 1 percent, and therefore do not affect the overall risk classification for sodification.

Conclusions

The GSP procedure applied on soil data collected from local authorized data owner allowed to produce an authoritative and good quality map of salt-affected soils of Italy.

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Characterization and Management of Salt Affected Soils of Kurnool District of Andhra Pradesh in India

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Keywords: Salt affected soils, Kurnool district, SAR, RSC, ESP

Introduction, scope and main objectives

It is estimated that total area under salinity/sodicity is 831 million ha at the global level. An area of 6.74 million ha in India suffers from salt accumulation, out of which 3.78 million ha was sodic while 2.96 million ha was saline soils (Mandal *et al.*, 2010) and in Andhra Pradesh, it was 0.27 million ha.

The study aims to develop precise scientific information on characteristics, potentials, limitations and management of different soils that are indispensable for effective utilization of soil resources sustaining crop productivity and food security for growing population. Soil characterization identifies soil related problems and aids in the development of management strategies for food security and environmental sustainability.

Methodology

Geographically Kurnool district lies between northern latitudes of 14^{0} 54' to 16^{0} 11' and eastern longitudes of 76^{0} 58' to 78^{0} 25'. Surface soil samples (0–25cm) and sub-surface (25–50 cm) from 53 locations in salt affected patches of Kurnool district were collected. The survey of India (SOI) topographical sheets in 1: 50,000 scale was used to collect topographic information. The soils were analyzed for different physical, physico-chemical and chemical properties including ionic composition (Jackson, 1973; Richards, 1954). The parameters like RSC, SAR and ESP were calculated (Gupta *et al.*, 2019). The correlations were worked out (Panse and Sukhatme, 1985)

Results

Among the salt affected surface soils with varied textures sandy clay loam, clay and sandy loam were dominant textural groups of the surface soils with the corresponding proportions of 32, 26 and 15 percent followed by clay loam (9.4 percent), loamy sand (9.4 percent) and sandy clay (7.6 percent).

Soil reaction varied from strongly acid (pH 5.5) to very strongly alkaline (pH 11.0) in surface soils, 43.4 percent surface soils are with moderately alkaline in reaction, 20.7 percent surface soils with slightly alkaline reaction, 13.2 percent soils with strongly alkaline in reaction, 7.5 percent soils with slightly acid, 7.5 percent soils neutral and 7.5 percent soils with strongly alkaline in reaction. The cation exchange capacity of surface soils ranged from 2–39.1 c mol (p^{+}) /kg.

Residual sodium carbonate of surface soils ranged from 0 to 50.2 me L^{-1}, while in subsurface soils it ranged from -4 to 38.6 me/L. The sodium adsorption of surface soils ranged from 0.25 to 79.8 and in subsurface soils it was 0.19 to 57.5. The surface soils ESP ranged from 1.88 to 21.59 with mean value of 19.27, majority of the soils (98.11 percent) were having slight to moderate alkali hazard. In subsurface soils, ESP ranged from 5.09 to 26.1 with mean value of 26.93.

The reaction (pHe) of the soil having highly significant positive correlation with HCO_3^- ion concentration (r = 0.369**) and Residual Sodium Carbonate (RSC) (r= 0.384**). Electrical conductivity (ECe) of the soil has highly significant positive correlation with Ca^{+2} (r = 0.769**), Mg^{+2} (r= 0.624**), Na^{+} (r= 0.968**), K^{+} (r= 0.540**), Cl^{-} (r= 0.977**), SO_4^{-2} (r= 0.924**), SAR (r= 0.854**) and significant positive correlation with RSC (r= 0.350*).

Discussion

Majority of the surface soils (98.11 percent) were slight to moderate alkali hazard, while among the subsurface soils, 26.41 percent soils are slight alkali hazard, 49.05 percent soils slight to moderate alkali hazard, 16.98 percent soils are moderate to high alkali hazard and 5.65 percent soils under high to extremely high alkali hazard.

Conclusions

The dominance of major ions was in the order of $Na^{+} > Cl^{-} > HCO_3^{-} > Ca^{+2} > SO_4^{-2} > Mg^{+2} > K^{+}$ in surface and $Na^{+} > Cl^{-} > Ca^{+2} > SO_4^{-2} > Mg^{+2} > HCO_3^{-} > K^{+}$ in subsurface soils in salt affected soils of Kurnool District of Andhra Pradesh in India. Management of different categories were proposed for soil health improvement and sustaining soil productivity.

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Informational support of rational use of salt-affected soils in Ukraine

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Keywords: informational support, salt-affected soils, rational use

Introduction, scope and main objectives

About seven percent of the arable land area in Ukraine is salt-affected. The distribution area of saline soils is dynamic, as soil desalinization can be accompanied by the appearance of new areas of salinity on adjacent territories (Balyuk *et al.*, 2012). We need to get efficient, reliable, accurate and prompt information data on the status of Ukrainian salt-affected soils, as well as know the causes of the negative processes in it. In this regard, the analysis of informational support of the present-day use of salt-affected soils becomes one of the main objectives of research.

Methodology

To evaluate the informational support for rational usage of salt-affected soils, we employed an experimental expert assessment approach. We reviewed extensive material on salt-affected soils in Ukraine from several narrow-departmental natures. Field investigations in the Forest-Steppe and Steppe zones of Ukraine were also been undertaken.

Results

The area of saline soil in Ukraine without a morphologically marked Solonetzic horizon is 1.92 million hectares, while the area of saline soils with a morphologically Solonetzic horizon is 2.8 million hectares. Most Ukranian salt-affected soils are plowed, with only relatively small areas of natural highly saline areas such as salt marshes (Balyuk, Truskavetskiy and Tsapko, 2012).

In the land and reclamative cadastres covered by Ukranian soil maps, saline, saline-sodic and alkaline (including Solonetz) soils (Balyuk *et al.* eds., 2010) are separately taken into account. Saline and alkaline soils are differentiated between natural and anthropogenous (secondary) origin. All the listed soils shown and portrayed on different scale maps are a result of information gathered between 1957 and 1961 (Petrichenko *et al.*, 2013), but they do not reflect the real present-day condition of soil cover.

Since 1970s, the monitoring of irrigated and adjoining rainfed croplands has been performed. The monitoring program covers a wide range of parameters (Medvedev, 2012) but only applies to irrigated areas. We also have the data from scientific institutions and higher educational academies, but it fails to characterize the salt-affected soil of Ukraine as a whole.

Discussion

Information about salt-affected soils is of a narrow-departmental nature, obtained by different methods and non-correlated observation programs. These disadvantages present strong constraints against the consistent and rational usage of materials for evaluation and forecasting changes to salt-affected soils.Therefore, there is a necessity to undertake repeated soil observations based on modern methodological approaches, using remote sensing, aerial photography and GIS technologies, as well as experience gained internationally. Monitoring of salt-affected soils, aimed at a systematic control over their condition and early detection of negative changes should be conducted as part of monitoring of all soil cover, in line with unified programs and methods. It is necessary to create and employ a systemic up-filling of databases and information systems, including those harmonized with European and world soil-science resources.

Conclusions

Contemporary informational support as to the condition of salt-affected soils in Ukraine is estimated. It is necessary to improve the system of information support for the rational use of salt-affected soils, through assessing their condition, and of forecasting, managing and protecting soil resources.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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The changing of the meliorative condition of soil by influencing of anthropogene factors in downstream of Kashkadarya

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Keywords: saline soils, melioration, water-physical properties, irrigated areas, soil respiration

Introduction, scope and main objectives
According to this statement Karshi steppe is one of the largest territories in growing cotton and producing agricultural products, but meliorative condition of soil is in its difficult position. Especially, it can be observed in soil in the west part of Karshi steppe. Eliminating of irrigated areas, avoiding coming up to existence of salt accumulation in soil layers, and eliminating all bad processes are important obligations that can’t be postponed for developing agriculture.

Methodology
Exploring the layer of soil thoroughly it should be kept the the fertility of soil, it should be created and increased new methods. By analysing Kashkadaryadownstream’s natural – irrigational agriculture conditions, we may come to such conclusion.

Results
According to the quantity of salt the soil, that is being stated, in the layer that plant’s root spreads are basically little and medium salinized and some positions they are strongly salinized. In upper cultivated soil layers the quantity of salt is from 0.110–0.130 percent to 0.560–0.730 percent; the amount of chlorine is from 0.014–0.09 percent to 0.880–1.235 percent increases. According to branch, it has got a large amount salt to ground water and it is strongly and medium salinized soil in 80 cm layers. According to the type of salinity, salinity are devided into these: chloride – sulphate (74.2 percent), with sulphate (19.77 percent) and seldom with chloride (5.81 percent).

One of the type of the soil using in a collective farm indownstream of Kashkadarya is salinated and salinated grassy soil. And they are the soil irrigated in different period and still irrigating heavy, sandy salinated (we name it as considering the changes in soil) soil are dissalinized soil in some areas according to the quantity of thawing salt in water. It can be observed in the information of the table, in the silty ploughing layer of salinated grassy soil, (part-1) the quantity of thawing salt in water doesn’t increase according to remainder from 0.23 percent and 0.066 percent, by chloride from 0.02 percent and 0.004 percent. The quantity of soil according to dry remainder of soil under ploughing and irrigating to one metre of depth isn’t so high and it swings from 0,064 percent to 0,012 percent. It is observed accumulating of sulphate salt in only some layers of irrigating salinated grassy soil.

Discussion
In general meliorative convenience of land that is irrigated of Kashkadarya and districts that have been learned aren’t constant beacuse of land’s keeping ground water’s medium (3–10 g/l) and strongly (>10 g/l) mineralized structure. For centuries, existence of ground water stream and its spending in steaming, territory’s weak drainage caused a large amount of salt accumulation.

Conclusions
According to all information that’s been taken, it can be stated the value of meliorative condition of irrigated territory of Kashkadarya. Even tough there is a little medium and strongly salinized soil in every collective farms (in district), it is convenient to make success in agriculture in the

future. The salinity of the ground water should be eliminated and meliorative actions in these areas should be done.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Theme 2. Integrated soil – water – crop solutions in rehabilitation and management of salt-affected areas

Agrobiotechnology to restore the fertility of irrigated saline soils of the gold steppe

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Keywords: fraction, humus, nitrogen, phosphorus, potassium, mineral fertilizers, bioinoculant, biohumus, microorganism, bacteria

Introduction, scope and main objectives

The prospects for the development of almost all regions of the Republic of Uzbekistan will be associated with high yields from agricultural products. However, pollution of the environment, deterioration of the ecological situation and the intensity of the soil salinity process adversely affects agricultural productivity (Gafurova *et al.*, 2007; Gafurova *et al.*, 2012; Narkulov, 2018). For example, salinity negatively affects crop yields in the arid and semi-arid areas of the world, causing 1–3 percent of the soils to be made unsuitable for agriculture every year (Akhmedov, Abdullaev and Parpiev, 2005).

Methodology

For the object of the study, weakly saline, irrigated gray-meadow soils of the southern Mirzachul were selected. The bioinoculants were used in three pairs, as follows; Azospirillum, Maxim, biohumus, Microzyme-1, Rizokom-2 and Novostil, on the winter wheat variety Chillaki. Phenological observations were carried out to determine the effects of these bioinoculants on plant growth, development, tolerance and yield, as well as the biotic and abiotic effects on beneficial microorganisms living together with the plants.

Results

For the samples treated with bioinoculants, the number of yield elements compared to the control was higher, and it was determined that the yield was significantly higher. The application of bioinoculants was relatively low in the control. the rapid germination of the seed, especially in the case of the Microzym-1+$N_{180}P_{90}K_{60}$ treated with 70.9 percent and was seen more clearly. Growth and development during the recovery period showed an upward trend in the wheat treated with Azospirillum +N_{180} P_{90} $K_{60..}$. Compared to the control, the productivity increased to 2 c/ha, when the Rizokom-2+$N_{180}P_{90}K_{60}$ biosubstrate was used, while the Microzyme-1+$N_{180}P_{90}K_{60}$ increased the wheat yield to 4.41 c/ha. And this is due to the fact that the micro-organisms have a high influence on the yield of winter wheat.

Discussion

Applying microbiological bioinoculants helps in restoring and increasing soil fertility, the humus status, agrochemical properties and the biological activity of the soil (Gafurova *et al.*, 2012; Kuziev *et al.*, 2006). Soil structure and density are improved, water and nutrient supply that can be assimilated are optimized, microbiological processes are improved and soil fertility is increased.

Conclusion

In addition to the plant-stimulating property of biosubstrates, there are a number of other important properties. In particular, they provide flexibility of plants to various unfavorable conditions and increase their immunity, protect them from various fungal and bacterial pathogens. The advantage of bioinoculants over other chemical pesticides and fertilizers is that they have a high efficiency and complex effect.

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Effects of different microbiological biopreparates on the salinization and meliorative condition of gray-meadow soils

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Keywords: Gray-meadow, fraction, humus, nitrogen, phosphorus, potassium, mineral fertilizers, bacteria

Introduction, scope and main objectives

The prospects for the development of almost all regions of the Republic of Uzbekistan will be associated with high yields from agricultural products. Fertilizers are used in increasing the yield of agricultural crops and improving the quality of products (Smith, 1992). In addition, pollution of the environment, deterioration of the ecological situation, the intensity of the soil salinity process adversely affects agricultural productivity. If we take only one salinity negatively affects the yield in the arid and semi-arid areas of the world, causing 1–3 percent of the soils to be out of agriculture every year (Shirokova and Morozov, 2006). According to the data, about 47.5 percent of the irrigated lands in our republic are saline at different levels, of which less saline lands are 31.5 percent, on average saline lands are 12.1 percent and strongly saline areas are 2.1 percent. The main part of the irrigated land areas in the steppe region of the republic is prone to salinization, salinized areas of different sizes are 711 percent in the Republic of Karakalpakstan, 100 percent in Khorezm region, 85.8 percent in Bukhara region, 97 percent in Sirdarya region, 81.7 percent in Navoi region and 76.9 percent in Jizzakh region (IEJRD, 2021; Kulmatov *et al.*, 2015).

Salinization is one of the reasons for the deterioration of land reclamation and soil fertility in the Mirzachul region. The process of natural salinization of soils was found to be related to climate change, rising groundwater levels, and as a result groundwater level increased and the migration of primary reserve salts intensified, resulting in varying degrees of salinization of soils and later salinization (Egamberdieva *et al.*, 2010; Egamberdiyeva, Garfurova and Islam, 2007). Salinization processes in Khavas district of Syrdarya region is 86.1 percent, of which non-saline soils– 13.7 percent, weakly saline soils–15.9 percent, moderately saline soils–65.9 percent, strongly saline–5 percent (Egamberdieva *et al.*, 2010; Kulmatov *et al.*, 2015).

With the application of microbiological biopreparates in restoring and increasing soil fertility, the humus status, agrochemical properties, biological activity of the soil, soil structure and density are improved, water and nutrient supply that can be assimilated are optimized, microbiological processes are improved, and soil fertility is increased (Egamberdieva *et al.*, 2010).

Methodology

As the object of the study there was selected weakly saline, irrigated gray-meadow soils of the southern Mirzachul. The study objects were used in three pairs, the following–Azospirillum, Maxim, biohumus, Microzyme-1, Rizokom-2, Novostil biopreparates in the winter wheat variety named Chillaki. Phenological observations were carried out to determine the effects of these biopreparates on plant growth and development. Moreover, authors analyzed the tolerance, yield and activity of beneficial microorganisms living together with plants on the biotic and abiotic effects of this variety.

Results

According to the results obtained, in the samples treated with biopreparates, the number of yield elements compared to the control was higher, and it was determined that the yield was significantly higher. The application of microbial biopereparates has affected the growth, development and formation of crop structural elements in a variety of ways. On the basis of the technology of application of mineral fertilizers and biologically active preparates in the winter wheat, all sorts of sprouts of winter wheat planted on irrigated gray-meadow soils.

The application of biopreparates was relatively low in the control option, the rapid germination of the seed, especially in the case of the Microzym-1+$N_{180}P_{90}K_{60}$ treated with 70.9 percent and was seen more clearly. Growth and development during the recovery period showed an upward trend in the variant treated with Azospirillum +N_{180} P_{90} K_{60} .

According to the results obtained, in the samples treated with bio substrates, the number of elements generated compared to the control was more, while the total number of stems accounted for 311.4 in the control variant, we can see the higher result in the variant treated with Rizokom-2+$N_{180}P_{90}K_{60}$, that is, it was 372.3. Including the number of fertile stems, the weight of grains in the spike, grain yield gave a higher result than others in this sample. With regard to control, we can see that the productivity increased to 2 c/ha, while the Rizokom-2+$N_{180}P_{90}K_{60}$ biosubstrate was used, the Microzyme-1+$N_{180}P_{90}K_{60}$ to 4,41 c/ha. And this is due to the fact that the micro-organism has a high influence on the yield of winter wheat.

Conclusions

In addition to the plant-stimulating property of biosubstrates, there are a number of other important properties. In particular, they provide flexibility of plants to various unfavorable conditions and increase their immunity, protect them from various fungal and bacterial pathogens. The advantage of biopreparates over other chemical pesticides and fertilizers is that they have a high efficiency and complex effect.

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Restoration of salt-affected soils is a function of soil profile diagnosis, and residual sodium carbonate of irrigation water in arid and semi-arid environments

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Keywords: Soil diagnosis, duplex soils, water quality, RSC, prevention, management, rehabilitation, salt-affected soils, arid semi-arid environments

Introduction, scope and main objectives

About 260 million ha of soils in Indo-Pak, Australia, Middle-East, and The Near-East and North-Africa region is affected by various forms of salinity (Dang *et al.*, 2010; FAO, 2017; ACIAR, 2018; Hussain *et al.*, 2019). Despite technological advancements, salinity is on hike and decelerating crop-productivity and food system resiliency. Three unsustainable management practices emerged from our work. Each practice pertains to author(s) geographical representation where such unsustainable-practice(s) have been witnessed. These practices relate to three components: Prevention-Management-Rehabilitation to achieve Complete-Restoration, and Regeneration of improvised-lands.

Methodology

Surveys by the UN-Food and Agriculture Organization, Pakistan (2017–2019), dialogues with multiple stakeholders of the key projects that were implemented in arid and semi-arid environments during 2000–2020. These projects focused on soil-features, salt precipitation-index and irrigation water-quality.

Results

Practice 1: Prevention
No pre-diagnostics of soil profile before growing barley
District Sargodha, Punjab-Pakistan; Cereals-based cropping system, Australia

Practice 2: Management
Application of gypsum in standing rice-crop
Increased salt-precipitation index and thus crop-burning witnessed
District Sargodha, Punjab-Pakistan

Practice 3: Rehabilitation/Management
Irrigation with higher Residual-Sodium-Carbonate (RSC) water
Increased patchy salinity, and decreased resilience of production-system was noticed with the prolonged irrigation with high-RSC water across all region

Discussion

Dilemma of textural-contrasting-soils

In the Indo-Pak region and Australia, clay-pans, and lithified sand in the Middle-East is challenging while recommending Ca-based amendments. Duplex-nature can affect NRM-plans for salt-affected soils (SAS) as if it is not taken into consideration through pre-project soil-profile detailed diagnosis; it could waste time, money and energy while growing halophytes.

Rice crop burning: an implication of increased salt-precipitation

Gypsum increases infiltration and is not widely-recommended in riziculture (puddled rice). Paddy rice is best-grown on clayey-soils which are impermeable and keeps salinity-level low. If gypsum is applied in standing crop the salt-precipitation index is increased which results in crop-burning. Presence of aluminum in gypsum may also lead to crop-burning due to toxicity.

Prolonged-irrigation with high RSC water

Quality of irrigation-water relates to EC, SAR and RSC (USDA, 1954; Ayers and Westcot, 1985). Protracted application of high RSC water in arid and semi-arid ecosystems leads to sodium-accumulation which alters physico-chemical properties, and induces patchy-salinity (Ghafoor *et al.*, 2011; Murtaza *et al.*, 2010). About 15–39 percent water samples in Indo-Pak have been reported with RSC > 2.5 mmolc/L (unsuitable level) (Murtaza *et al.*, 2021). Irrigation @ 2.5 mmolc/L RSC can potentially add 219 kg Na/ha for wheat.

Conclusions

Soil salinization and soil modification are two different issues, need different solutions. Region-specific NRM-frameworks should be implemented with farmers and extension agents' trainings on diagnostic profile-assessments. Cost-effectiveness of gypsum should not be taken for granted, rather its application be promoted on pre-soil profile and water quality diagnosis. RSC should be considered a key criterion for water quality as early warning in arid to semi-arid environments due to the destructive nature of Na.

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Amelioration of sodic soil and conjunctive use of canal and alkali ground water for sustainable rice production

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Key words: Sodic soil, conjunctive water use, Gypsum, green manure, Distillery spent wash

Introduction, scope and main objectives

Soil degradation resulting from salinity and/or sodicity is a major environmental impediment with severe adverse impacts on agricultural productivity and sustainability in arid and semiarid climates (Qadir *et al.*, 2006, 2007; Suarez, 2001). At the present time, there is no commercially available commercial mined gypsum in India for reclamation of sodic soil. Phosphogypsum, an industrial by product, which also limited in supply is being used for sodic soil reclamation. Therefore, a substitute for gypsum needs to be found that can be readily used as an external source of Ca2+ for this region. Distillery spent wash, a by-product of distillery industry an alternative source. We therefore conducted a study to determine how effective distillery spent wash over the traditional application of phosphogypsum as well as application of Phosphogypum+Green manure for reducing sodicity as well as conjunctive use of poor quality alkali ground water with good quality canal water for irrigation to rice crop.

Methodology

The field experiment was laid out in Factorial Randomized Block Design with the treatments viz., Factor A,: Irrigation scenarios (4) I_1:Canal water alone, I_2:Canal water: Alkali water (1:1 cyclic mode), I_3:Canal+Alkali water combined (50+50 percent) per irrigation, I_4:Alkali water alone and Factor B: Soil amendments (4) S_1: Control, S_2: Green / green leaf manuring @ 6.25 t/ha, S_3: Sodic soil amelioration with Distillery spent wash @ 5 lakh litres / ha and then leaching, S_4:Gypsum 50 percent GR (soil application and leaching) + Green manuring with Daincha @ 6.25 t/ha.

Results

Among the irrigation management practices, application of alkali water alone (I_4) recorded a lowest grain yield of 4536 kg/ha. The other treatments viz., I_3;Applicatiion of canal water +Alkali water (50+50), I_2; application of canal and alkali water as 1:1 cyclic mode and I_1; application of Canal water alone recorded with a grain yield of 4815, 4948 and 5318 kg/ha respectively. Among the irrigation treatments I_1 recorded significantly highest yield followed by I_2 and I_3 which are statistically on par. I_4 recorded with least yield which is statistically has significant difference between I_1, I_2 and I_3. Among the soil amendments, the treatment S_3, application of distillery spent wash @ 5 lakh litres/ha recorded with a significantly highest grain yield of 5473 kg/ha followed by S_4; application of gypsum 50 percent GR+green manuring @ 6.25 kg/ha, S_2; green manuring @ 6.25 t/ha and S_1; control with a respective grain yield of 5091, 4866 and 4187 kg/ha.

Discussions

The treated distillery spent wash has sufficient quantity of of Calcium, which has the sodic soil reclamation potential and its chemical action with sodic soil has favoured the soil to become free from sodium hazard. Similarly application of phospho gypsum+ green manure has reclaimed the sodic soil. This resulted in improved growth and development of rice crop and resulted in higher yield when compared to the growth of rice under unreclaimed sodic soil. As an irrigation management conjunctive use of good quality water with poor quality alkali ground water reduced the ill effect of application of poor quality alkali water by dilution effect.

Conclusions

a) Sodic soil can be amended with Distillery spent wash @ 5 Lakh lit/ha (or) one-time application of Gypsum 50 percent GR+ Green manure. b) Conjunctive use of canal water and alkali water in 1:1 cyclic mode (or) mixed with poor quality Alkali ground water @ 50+50 percent at each irrigation can be practiced.

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Screening of Selected Rice Genotypes for Salinity Tolerance Using Morpho-physiological traits

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Keywords: Soil salinity, Rice, Growth, Relative water content, membrane stability index, proline

Introduction, scope and main objectives

Soil salinization is a serious hindrance to agriculture and identification of saline-tolerant varieties helps to overcome the decline in crop production due to salinity stress. Salinity intrusion adversely affect the coastal agriculture through limiting fresh water availability and it is a major threat to farmers in coastal areas. Rice is traditionally cultivated in Kerala, however, total production is steadily decreasing (GoK, 2019). Identification of tolerant varieties is important for sustaining the food security in less favorable environments.

Methodology

Pot experiment with five salinity level viz. Control(C), 1000(T1), 5000(T2), 20000(T3) ppm NaCl and 1:1 sea water (T4) through irrigation was conducted to assess the salinity response in four rice cultivars namely *Uma, Jyothi, Vaishak, C. Modana*. Different morphological, physiological and biochemical parameters were taken after salinity stress of 32 days. Standard evaluating score for salinity (IRRI, 1997), morpho-physiological traits number of leaves, tillers, leaf area, relative water content (RWC), membrane stability index (MSI) along with biochemical parameters as chlorophyll and proline content were estimated using standard procedures after stress.

Results

Based on scoring, all the four genotypes survived inT1 and T2 and as salinity extent increased in T3 and T4, *C. Modana* was susceptible compared to *Uma, Jyothi* while *Vaishak* as most tolerant. Salinity caused significant effect on plant height, leaf area, MSI and RWC. Proline was significantly higher in T2, T3, and T4 treatments. Higher fold change in proline in T3 (3.0–4.1) and T4 (3.3–5.2) over control in all genotypes was noted. *C. Modana* showed increased proline in T1 and T2 (1.8 and 3.6) over control but plants didn't survive after 32 days in T3 and T4. Conversely, *Vaishak* showed high proline content (4.1 and 5.2) over control in T3 and T4 treatment and survival too. This suggests that *Vaishak* might have some intrinsic tolerance under salinity stress.

Discussion

Salt tolerance is the sustained plant growth in the soil with NaCl and injury in rice is caused by both osmotic imbalance and accumulation of chloride (Cl^-) ions. Present study revealed that there is distinct behavior of rice varieties. Morphological traits as decreased plant height under salinity supports the previous findings with other crops (Hassen, 2018). MSI reduced in a manner of imposing period as well as severity under stress. Salinity results in malfunctioning of the cellular membranes by increasing their permeability to ions and electrolytes (Tabaei-Aghdaei, Harrison and Pearce, 2000). However, *Vaishak* could maintain its water content and reduce membrane injury. Earlier results with *Pokkali* rice variety suggest that it could maintain lower shoot Na^+ accumulation and lower shoot Na^+/K^+ ratio under high salinity (Kavitha *et al.*, 2012). In our study, we found that enhanced level of osmoprotectants such as sugars, amino acids (proline), as higher proline content in rice genotypes under salinity stress, could assist to overcome the salinity stress.

Conclusions

Salinity stress caused significant changes in morphology, physiological attributes of rice genotypes. Through screening different traits we found reduced leaf number and total leaf area hampering the overall growth. Leaf RWC and MSI confirmed membrane damage under salinity stress. Field experiments are warranted to understand the tolerance mechanism in *Vaishak*.

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Effective halophilic microbes for bio-amelioration of coastal saline soils

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Keywords: Salinity, bio-remediation, Gujarat, halophytes, rhizosphere soil

Introduction, scope and main objectives

In India, 6.73 m ha of land is salt affected of which 33 percent, or 2.22 m ha is located in Gujarat state. Of this 2.22 m ha, about 70 percent area is affected by coastal salinity and the remaining 30 percent area is affected by inland salinity. Neither physical nor chemical remediation methods are cost–effective for saline/sodic soil reclamation (Arora *et al.*, 2016). There is an urgent need for better methods to raise plants/crops on salt affected soils to meet the food, fiber and livelihood demand of growing population.

Halophilic microorganisms are salt tolerant bacteria and fungi having potential for bio-amelioration of salt stress that has been reported by researchers (Arora and Vanza, 2017). The applications of halophilic bacteria include recovery of saline soil by directly supporting the growth and stress tolerance of vegetation, thus indirectly increasing crop yields in saline soil. Plant-microbe interactions are beneficial associations between plants and microorganisms and also a more efficient method for reclamation of saline soils. Bacteria are more commonly in this technique than fungi (Arora *et al.*, 2014b). The study was conducted to assess the impact of halophilic plant growth promoting microbes in alleviating salt stress in coastal saline soils.

Methodology

Soil samples were collected from the rhizosphere of several dominant halophyte plant species (Arora *et al.*, 2014a) from coastal saline soils and bacteria were isolated, tested for salt tolerance in halophilic agar media. The promising halophilic bacterial strains that showed positive for plant growth promotion were selected and tested for salt removal efficiency in broth media. To confirm about the sodium removal efficacy of these halophilic bacterial strains from soil, CSSRY1 and CSSRO2 were inoculated in sterile soil to test their efficacy for sodium removal from the soil containing different concentrations of NaCl (0 percent to 10 percent NaCl).

Results

Halophilic bacteria strain (CSSRO2; *Planococcus maritimus*) was more efficient in reducing sodium concentration from 112230 ppm in supernatant to 100190 ppm at 24 hours while strain CSSRY1 (*Nesterenkonia alba*) reduced Na concentration to 92,730 ppm at 48 hours in halophilic broth with 15% NaCl. This shows that inoculation of strains in liquid media resulted in removal of 12040 and 19500 ppm of Na by halophilic bacterial strains CSSRO2 and CSSRY1, respectively. The halophilic bacteria strains CSSRY1 and CSSRO2 were also shown to have high potential for removal of sodium ions from soil. CSSRY1 efficiently removed sodium at higher (6%, 8%, 10% NaCl) salt concentration in comparison of CSSRO2 and association of both organisms. This was also confirmed by reduction of electrical conductivity or total dissolved salts (TDS). It was observed that inoculation of strain CSSRY1 decreased soluble sodium content up to 31 percent at 4 percent NaCl concentration while at 10 percent NaCl concentration, it reduced only 19 percent sodium from soil (Table 1).

Table 1. Effect of halophilic bacterial inoculation on soil sodium content (ppm)

NaCl concentration	Control	CSSRY1	CSSRO2
0%	5011	3389	4096
2%	6539	4575	4830
4%	7683	5235	7100
6%	8534	7591	7952
8%	9596	8665	9543
10%	10620	8563	10068

These selected cultures were further studied in greenhouse pot experiments for plant growth promotion. Results showed there was increase in plant growth parameters and yield of wheat when halophilic bacteria were inoculated with seeds and saline water irrigation was applied. It was observed that there was 10–12 percent increase in yield attributes and yield of wheat at 6% NaCl as compared to 2% NaCl. In the 5% NaCl treated soil, only the growth of the *Zea mays* was observed. Plants inoculated with a consortium of halophilic bacteria also showed growth at 10% NaCl, whereas inoculation with single isolates did not promote plant growth at this salt concentration. The maximum fresh weight, dry weight, shoot length and root length of plant were found in the case of "Consortium 5% NaCl" treated pot, 194.5% percent increase in fresh weight, 98.97 percent increase in dry weight, 15.37 cm increase in shoot length and 7.4 cm increase in root length as compared to the uninoculated control plants.

Discussion

The sodium ion concentration is reduced in rhizosphere soils, plants were able to resume nutrient and water uptake as evident from results. The isolated bacterial strains have plant growth promoting traits that resulted in enhanced plant growth in salt affected soils. In addition to removing Na from the rhizosphere, their inoculation increases the root growth due to production of hormone auxin. Another very likely mechanism may be alleviation of salinity stress via their ACC deaminase activity (Sahay *et al.*, 2018). This enzyme removes stress ethylene from the rhizosphere. A combination of halophilic bacteria increases N-availability, solubilise soil phosphorus and reduce Na^+ in the rhizosphere holds a big promise towards bio-amelioration of moderate saline environment.

Conclusions

Halophilic bacteria inoculation with crop plants helps in rhizospheric stress alleviation and enhancing growth and yield to moderately sensitive crops.

Acknowledgements

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Biochar effect on soil EC in pesticide polluted soils of the microcosm experiment

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Introduction

There is great gap which requires comprehensive research and investigations tracking the persistent pesticides in agricultural soils especially where intensive cropping system has been dominated over several decades. Problem of pesticide contamination has been worthening in the conditions of climate change, secondary salinization and desertification (UNECE, 2001, 2020). Shrinking of the Aral Sea, causing to catastrophic consequences for the second source of land contamination and salinization by wind deposition of small particles containing toxic residues and salts transporting them through atmospheric deposition to surrounded areas, thus, their levels in the environmental components including soil, water and air have been found alarming (UNECE, 2020; FAO, 2021). Furthermore, excessive use of mineral fertilizers and organic amendments can contribute soil salinization and contamination (Buvaneshwari *et al.*, 2020). As an emerging bioremediation tool of contaminated and salt affected lands, biochar application is gaining popularity with its high capacity to revitalize soil properties and highly adsorption of toxic compounds in soil (Egamberdieva *et al.*, 2021). Considering above statements, we provided a microcosm experiment investigating the effects of the biochars derived from different feedstocks including wheat straw and poultry litter on the soil electrical conductivity after pesticide application to the soils transported from Syrdarya region in 2021.

Methodology

Selected feedstocks for biochar production were poultry litter (PL) and wheat straws (WS), and they were pyrolyzed in a muffle furnace (Nabertherm 30–3000 □C, Germany) up to 450 □C. Biochars were applied to the soils considering the pot area with 10 t/ha rate. An Entopic Super herbicide was applied to the pots. Periodically, electrical conductivity of the soil samples in the pots were measured with Hanna EC meter (Hanna Instruments, Germany).

Results

Soil electrical conductivity (EC) were measured in the following days of the microcosm experiment: 1^{st} week (at the beginning), 2^{nd} week, 6^{th} week, and last one 11^{th} week. In total, experiment lasted 74 days in a controlled laboratory condition. Results suggested that soil EC was affected with the type of biochar in comparison to each other. For example, soil EC in the pots treated with PL biochar was lower in comparison to the H control and WS biochar, throughout the experimental period (Figure 1). Moreover, soil EC was increased in the pots with H control and WS biochar.

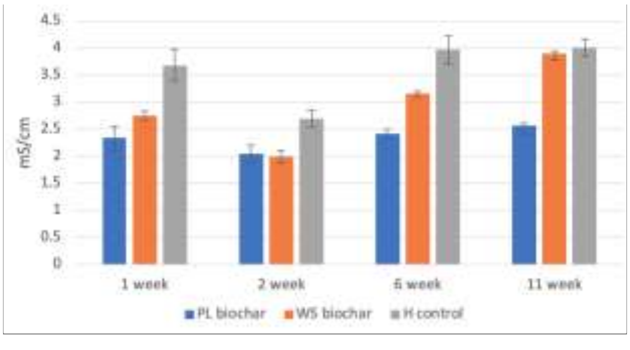

Figure 1. Change in soil EC depending on biochar type

Discussion

Main reason why soil EC was increased over the experimental period might be the evaporation of the water applied on the pots due to the high temperature. Another reason is probably the biochar type.

Conclusion

In conclusion, biochar addition may decrease the soil EC, however, it might be dependent on the feedstock type, pyrolysis temperature, and final biochar properties.

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Effects of different types of composts, phosphogypsum and mineral fertilization on the chemical and biochemical properties of an acid sulphate soil and the yield of rice in Djibélor (Lower Casamance)

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Keywords: Oryza sativa L, Salinity, Compost, phosphogypsum, mineral fertilization, productivity

Introduction

Rainfall variability has accentuated the reduction in cultivable areas due to the salinization of the lowlands in the ricegrowing valleys in Casamance. Our study is a part of the fight against weakness and poverty and the achievement of food selfsufficiency in Senegal. The aim is to determine the effects of two composts formulas (F1 and F2), phosphogypsum and mineral fertilization on the chemical and biochemical parameters of the soil and on the agromorphological parameters and the yield of rice (War 77) in salted sulphate-acid rice fields.

Methodology

A trial was performed using a Fisher block device with four replicates. A single factor was studied, organomineral fertility with five modalities. This is a control without input (T0), a recommended dose of mineral fertilization (FM) (200kg / ha 15N-15P-15K + 150 kg/ha Urea 46% N), a recommended dose of phosphogypsum (1t/ha), a dose of 7t/ha of compost of formula one based on rice straw and crushed oyster shell in powder (F1) and a dose of 7t/ha of compost of formula two based on Andropogon gayanus Khunt (F2) phosphogypsum and urea straw.

Results

The results showed that the salinity was more reduced by phosphogypsum (42.37 permille) and F1 (48.42 permille) in the 0–20 horizon and by FM (42.81 permille) and F1 (52.50 permille) in 20–40. However, the supplementation significantly influenced the pH (Pr = 0.0001), and the activities of β-glucosidase (Pr = 0.0001) and of acid phosphatase (Pr = 0.0023). These chemical and biochemical parameters were further improved by the addition of compost, in particular formula F1 with one of the pH values = 4.9 in the 0–20 horizon and 4.03 in the 20–40 horizon; β-glucosidase = 114.13 μg p-Np / gsol sec / h; phosphatase = 76.42 μg p-Np/gsol sec/h in 0-20 and for F2 pH = 4.63 in 0–20 and 4 in 20–40; β-glucosidase = 128.58 μg p-Np/gsol sec/h in 0–20; phosphatase = 38.61 μg p-Np/gsol sec/h in 20–40). In fact, the supply of phosphogypsum does not meet the nutrient deficiencies for the plant compared to composts. From an agronomic point of view, the rate of plant mortality is higher in the control (21.7 percent) than in the treatments with the addition of composts (F1 = 10.28 percent; F2 = 19.69) and mineral fertilizers. (17.67 percent). The lowest rate is obtained with phosphogypsum (3.02 percent). The rate of increase in grain yield is 162.14 percent for F1 compared to control (T0) followed by FM (124.1 percent) compared to T0 and the lowest rate is recorded at the level of the treatment with phosphogypsum (46 percent) and F2 (24. 7 percent).

Discussion

Organic amendments from compost increase pH, density and microbial activity. This promotes good behavior of the rice plants and better yields. These results show that the amendment in compost (F1) enriched with shells rich in Ca^{2+} not only improves the chemical parameters and the microbiological activities in acid sulphate soils, but also the rice grain yields. This is not the case with phosphogypsum which acts only on the leaching of salt.

Conclusion

The addition of organic amendments based on improved compost formulas could be an alternative to the use of phosphogypsum (polluted with heavy minerals) for the valorization of degraded lands, in particular by salinity in Senegal.

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Evaluation of Sorghum (*Sorghum bicolor* L.) varieties for their tolerance to sodicity level for sustained productivity in salt affected soils

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Keywords: Sorghum varieties, sodicity tolerance, ESP levels

Introduction, scope and main objectives

More than 800 million hectares of land throughout the world are salt affected, either by salinity (397 million ha) or the associated condition of sodicity (434 million ha) (FAO, 2005). Utilizing the uncultivable barren land due to sodicity, by identifying the crops and varieties suitable for sodic soil condition to enhance the livelihood security of rural poor people living in the salt-affected land is the need of the day. Accordingly, a field experiment was initiated at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli under ICAR-AICRP on Management of Salt Affected Soils and use of saline water in Agriculture. The experiment is permanent and several crops and varieties were evaluated for the benefit of the farming community. Presently, Sorghum (*Sorghum bicolor* L.) cultivars were evaluated for the tolerance levels of sodicity based on the Exchangeable Sodium Percentage (ESP) of 8, 16, 24, 32, 40 and 48 percent.

Methodology

In existing experimental field, based on the ESP existed in the different main plots, the sodium bicarbonate was applied to main plots and mixed thoroughly with the soil to create different gradient ESP levels viz., 8, 16, 24, 32, 40 and 48 were artificially. Further, the ESP 8 and 16 were created through application of gypsum and leaching with good quality water. The experimental plot was thoroughly ploughed individually to bring optimum soil tilt and the ridges and furrows were formed and seeds of sorghum varieties viz. K12, Co30, Local-Red and Local-Irungu (Black) were sown in the strip plot with a spacing of 4515 cm. Uniformly 90:45:45 kg N, P_2O_5 and K_2O per hectare were applied basally to all the plots (50 percent of N at basal and remaining 50 percent at 30 DAS). The Atrazine herbicide has also been applied in order to control the weeds.

Results

The results during 2019 revealed that the interaction of ESP and Cultivars, the highest grain yield of 1433.7 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 26.3 kg per ha recorded by Irungu local at 48 ESP level. However, 50 percent grain yield was recorded in the cultivars viz., Co 30, Red-local and Irungu-local at the ESP of 32 per cent whereas in the cultivar K12 recorded 50 percent yield at 24 ESP level. Similarly, during 2020 the results revealed that the interaction of ESP and Cultivars, the highest grain yield of 1340 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 22 kg per ha recorded by Irungu local at 48 ESP level. However, 50 percent grain yield was recorded in the cultivars viz., Co 30, Red-local and Irungu-local at the ESP of 32 percent whereas in the cultivar K12 recorded 50 percent yield at 24 ESP level. The results of haulm yield revealed that the 50 percent haulm yield was recorded in the cultivars viz., Red-local and K12 at the ESP of 32 percent whereas, Co 30 and Irungu local recorded 50 percent yield at 48 and 40 ESP level respectively.

Discussion

The increased ESP has negative correlation with the yield of grain and haulm, however, the critical ESP was assessed based on the 50 per cent of maximum possible yield under the same climatic situations (Singh and Khan, 2002).

Conclusions

It is concluded that the sorghum cultivars Co 30, Red local and Irungu local could be recommended to the farmers for growing in the sodic soil having the ESP up to 32 percent whereas the cultivar K12 can be recommended to the sodic soil having the ESP level up to 24 percent for grain production.

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Agricultural gypsum application in soils with exchangeable sodium: study in microlysimeters

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Keywords: calcium, calcium sulfate, lysimeters, leaching

Introduction, scope and main objectives

Excess sodium ions (Na) in the cationic exchange complex negatively affect crop development. The highly hydrated nature of the Na ions inhibits the flocculation of aggregates and causes a high dispersion of soil colloids. In Uruguay, soils with excess Na are of natural origin.

The remediation of soils with excess Na in the exchange complex is achieved by applying gypsum. The objective of this study was to evaluate, by a study using microlysimeters, the effect of the application of agricultural gypsum in a soil with excess Na, under controlled humidity and temperature.

Methodology

For this research, the experiments focused on the Ap horizon of a soil located within a field at the Mario A. Cassinoni Experimental Station (EEMAC) of the Agronomy Faculty of the University of the Republic (Paysandú, Uruguay). Soil was added to each microlysimeter, having been mixed with doses equivalent to 3 000 and 6 000 kg/ha of two agricultural gypsums from different companies (Source A and Source B) as well as providing a control treatment (without gypsum). Each treatment was replicated three times.

Periodic leachates were made, with 100 ml of deionized water added gradually and homogeneously through the use of a diffuser in order to adequately moisten the system. The soil of the microlysimeters was maintained at field capacity, with the addition of deionized water every 15 days.

Results

The content in kilograms of Na displaced from the soil by Ca was plotted a function of collection moment of leachate water, in days. After 30 days of treatment, it was observed that the highest displacement measured was Na content, which then decreased to almost equal the control treatment. The exchangeable Na in the soil decreased by 35 percent when comparing the initial value with the value obtained at the end of the experiment. There was no significant difference in the effect of Na decrease between applied doses or between the different sources of agricultural gypsum. But there was significant difference between the treatments and the control (22 percent less exchangeable Na in the soil with gypsum compared to control). There was a linear and positive correlation (Pearson's index 0.80) established between total Na content displaced from the soil in leachate water and exchangeable Ca present in the soil after 360 days of treatment application.

Discussion

Gypsum is a soluble material and due to effect of dilution over time, the largest replacement of Ca ions by Na ions in a soil's cationic exchange complex occurs in the first cycles of leachate. The results of Qadir, Qureshi and Ahmad (1996) agree that the greatest loss of Na ions occur during the first leaching.

However, despite the solubility of gypsum, the effect that its application has on physicochemical properties is long term. The decrease in the concentration of Na and ESP occurs in soils that were under treatment for a longer period of time. This is due to the fact that the exchange of Ca by Na is a complex and continuous process, so the effectiveness of gypsum is directly related to the length of the experiment. (Arévalo *et al.*, 2009; Mao *et al.*, 2016).

There is a correlation between the exchangeable Ca in soil with the Na contained in the leachate. From which it can be determined that the higher the concentration of Ca from the gypsum, the greater the amount of ions Na is able to displace during leaching (Mahmoodabadi *et al.*, 2013).

Conclusions

The agricultural gypsums used were effective for the displacement of Na ions in exchange complexes in natural Uruguayan soils with excess Na.

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Deficit saline irrigation and mulch affect soil microbial activities under zero-tilled saline soil

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Keywords: Saline soil, tillage, mulch, deficit saline, microbial biomass C and N, sorghum

Introduction

Soil biological process is the major determinant for sustainable crop production in salt-affected soils of arid and semi-arid regions. The restoration of soil microbial activities is inevitable for productive utilization of these soils. The zero tillage, mulch and deficit saline irrigation effect the primary productivity of these soils by moderating the soil biological activities under rainfed sorghum-irrigated wheat cropping system.

Methodology

The field experiment was conducted in split-plot design with three replications consisting of irrigation with 100 and 60 percent of water requirement of wheat and mulch at 5 Mg/ha rice straw combination in subplots since 2014 at Experimental Farm, ICAR-CSSRI, Panipat, Haryana, India. Soil samples of surface layers (0–5 and 5–15 cm) were collected after sorghum harvest (October) in 2020 and analysed of soil biological properties using standard protocol.

Results

Application of good quality water significant decreased EC_e (2.47 dS/m); whereas, irrigation with saline water maintained similar values of EC_e (4.2 to 5.6 dS/m). Soil organic carbon (SOC) content of the fallow in 0–5 cm soil depth was greater compared to other treatments. The SOC content was increased by 1.4 times over the period of five years. The SOC was similar in GW (good quality water), 100WRSW (100 percent water requirement through saline water) and 60WRSW. Microbial biomass carbon (MBC) and N (MBN) in 0–5 cm soil depth was in the order of fallow> GW> 60WRMSW >100WRMSW. The 60WRMSW and 100WRMSW were having higher MBC: MBN ratio compared to fallow, GW and saline irrigation without mulch. Dehydrogenase (DHA) activity was greater in GW in both soil layers ($P < 0.05$). Its activity was at par in saline water irrigated plots and fallow. The β-glucosidase activity (β-glu) was higher in GW; however, fluorescein diacetate hydrolysing activity (FDA) was lowest in GW and fallow in both the soil depth. Mulching favored for higher values of SOC and soil enzymes β-glu and FDA than no-mulch ($P < 0.05$).

Discussion

The SOC content maintained after of the converting the barren saline soil to cultivation was mainly because of SOC protected in soil aggregates under no tilled. Increased adsorption of SOC on numerous Lewis acid sites was also favored because of presence of HCO_3^- and SO_4^{2-} ions. Increase in salinity causes matric and osmotic stress and reduced microbial activity in fallow. Suppressive effect of mulch on these stresses further improved these soil microbial activities.

Conclusions

Benefit of improvement in soil biological properties with a reduced cost of cultivation practices viz. deficit saline irrigation and mulching is advocated for productive utilization of saline groundwater and greening barren saline land.

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Linkages between land use/land cover with soil sodicity development and soil carbon build-up

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Keywords: soil carbon, sodicity, plant cover, land use, phytoremediation, exchangeable sodium percentage, electrical conductivity

Introduction, scope and main objectives

Soil salinity poses a threat to the sustainable management of agricultural landscapes and has an effect on soil carbon storage. This study investigated land use/land cover (LULC) relations with soil organic carbon (C) in a salinity-rich landscape with inter-linked vegetated and non-vegetated land areas.

Methodology

A sodic area (~100 ha) along Sharda Sahayak canal in Uttar Pradesh, India was selected for studying LULC effects on soil organic carbon (C) and soil properties to 60 cm soil depth. The area was divided into a grid of 100 m × 100 m, and soils were sampled and analyzed at 140 geo-referenced points representing five LULC classes. The LULC dominant in the representative area were barren-coverless (BC), barren-grass cover (BG), rice-fallow (RF), rice-wheat (RW), and rice-okra-mentha (ROM).

Results

The soil organic C decreased with depth, with a corresponding increase in soil pH and exchangeable sodium percentage (ESP). The effects were highly significant in the surface layers (0–0.3m). Similarly with electrical conductivity (EC), soil organic C had a negative correlation. Soil organic C varied significantly with LULC. The soil organic C content decreased in the order: ROM>RW>RF>BG>BC. As the intensity of crop/plant cover increased, the soil salinity (ESP, pH and EC) decreased. The average soil ESP was highest in BC (44 percent) followed by BG (30 percent), RF (15 percent), RW (8.5 percent), and ROM (7.0 percent).

The cumulative probability trends indicated lesser ESP with an increase in vegetative cover/ primary productivity. A strong ($p<0.001$), and negative relationship was observed between soil organic C and pH in rice-based systems. Analysis of soil organic C stock in 60-cm soil depth for the studied LULCs indicated a 4–70 percent (grass cover to rice-wheat cropping sequence) increase in total soil organic C stock just by supporting vegetative cover on barren sodic land.

Discussion

Land use significantly interacted with soil organic C content and ESP, especially in rice-fallow and rice-wheat systems where there were highly favorable changes (increased organic C and decreased ESP). This could be attributed to a two-step interlinked process with (i), an increased intensity of cropping, decreased soil ESP and pH due to the aforementioned mechanisms, and (ii), a decrease in ESP and pH leading to the higher storage of organic carbon in the soil.

Rice-based LULCs had a significant relationship between ESP, pH and organic C. Rice, in general, is considered to be a reclamative crop because it can tolerate higher amounts of exchangeable Na^+. A higher production of bicarbonate (HCO_3^-) in soils under rice cultivation, as well as an increase in the partial pressure of CO_2 due to submergence (as in case of paddy rice), and biological activity of roots results in a higher solubility of soil calcium (Ca) through its conversion into Ca $(HCO_3)_2$. Calcium ions (Ca^{2+}) from solubilized Ca $(HCO_3)_2$ lowers soil ESP by replacing Na+ from the clay complex. Plant roots also increase permeability via root-carved channels. The effects of management intensity (directly related to biomass turnover), and salinity characteristics, both ESP and EC, were distinct in this study. For both pH and EC, significant changes were observed due to changes in LULC from natural land cover (BC, BG) to managed land uses (RF, ROM, RW).

Conclusions

Land use/land cover choices seem to provide a cost-effective and viable alternative to expensive gypsum application-based reclamation strategies for degraded sodic soils of the Indo-Gangetic plain. Based on this study, the following specific conclusions can be drawn;

(1)Soil exchangeable sodium percentage (ESP) and soil pH are inversely related to soil organic C.
(2)Cropping systems favouring enhanced build-up of C via root and litter biomass addition expedited the mitigation of sodicity.

There is large scope for carbon sequestration in salt-affected areas of the Indo-Gangetic region by the adoption of appropriate steps, including rice-based and grass-based cropping systems. Carbon stock in the soil can be increased significantly (35–70 percent) by the introduction of any grassy vegetation. Increased management intensity could have its own reclamative effects. Rice-based agricultural cropping systems should be preferred for achieving steady and long-term benefits for sodic lands.

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Purslane as a super-high K accumulator Halophyte

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Keywords: Haloculture, Medicinal Plants, Salinity Stress

Introduction, scope and main objectives

Purslane (*Portulaca oleracea* L.) is a valuable, nutritive vegetable crop for human consumption and for livestock forage. It is widely distributed around the globe and is popular as a potherb in many areas of Europe, Asia, and the Mediterranean region. This plant possesses mucilaginous substances which are of medicinal importance. It is also a rich source of nutrients such as potassium and magnesium as well as antioxidant (Quan *et al.*, 2020). It is widely used in folk medicine most probably because of the efficacy of some of its constituents. Purslane has been classified as a moderately salt tolerant plant with a threshold of 6.3/dS m and a slope of 9.6 percent (Maas and Grattan, 1977; Kumamoto *et al.*, 1990). In addition, it is reported that purslane tolerance to salinity increases after first cutting (Grieve and Suarez, 1997). Grieve and Suarez (1997) introduced Purslane as an excellent candidate for cropping with highly saline waters.

Iran's agricultural section is negatively affected by water scarcity and salinity and it is estimated that around 55 percent of its agricultural lands are suffered (Qureshi *et al.* 2007). In addition, Iran imports huge amount of livestock foods while tries to decrease its dependence. At the same time, it is estimated that around 75 m^3/sec of saline drainage waters are available in Khuzestan province (Howeizeh *et al.*, 2017), in the future. So, using saline drainage waters for halophyte plant production such as Purslane towards decreasing dependence to livestock food import seems to be a good strategy for Iran. In this line, the present study was carried out to quantify the effect of salinity stress on Purslane performance.

Methodology

To evaluate the response of Purslane to salinity stress the effect of different irrigation water salinities including 0.44 (control), 3, 6, 9, 12, 15 and 18 dS/m on Purslane properties was studied under outdoor conditions. The salinity treatments arrange in a completely randomized design with three replications. Sodium (Na) and potassium (K) content were measured using a flame photometer.

Results

<u>Effect of salinity on Purslane K content</u>

The results showed that Purslane top K content at lowest salinity level of 0.3 dS/m of irrigation water was the highest and it was equal to 11.4 percent. The results also showed that salinity stress had negative effect on Purslane top K content. It decreased successively as salinity of irrigation water increased and significantly followed the non-linear quadratic regression model ($Y=11.82 – 0.63X+0.021X^2$, $R^2=0.83^{**}$). The minimum Purslane K content (7.17 percent) was observed at highest irrigation water salinity of 18 dS/m.

<u>Effect of salinity on Purslane Na content</u>

In contrast with Purslane K content, the top Purslane Na content was increased as salinity stress increased and it followed a non–linear quadratic regression model ($Y=1.45+ 0.76X-0.026X^2$, $R^2=0.84^{**}$). The Na content at the lowest salinity level of 0.3 dS/m was equal to 1.9 percent and successively increased to 6.7 percent at highest salinity level of 18 dS/m.

Purslane Na and K content correlation:

As Purslane top K and Na content in response to salinity stress was in reverse, the hypothesis of negative effect of Na on K absorptions is form. To document this, the Na and K content of Purslane was correlated. The results confirmed the high and significant correlation between Na and K content of Purslane under different salinity stresses. So, it can be concluded that low K content of Purslane is due to higher sodium absorption as a result of increasing salinity stress.

Discussion

The potassium content of Purslane shoot dry weight under conditions of our experiment was around 11 percent at nonsaline conditions and it is around ten times of average potassium content in plant shoot dry matter sufficient for adequate growth (Marschner, 2012). Our results is in line with Kafi and Rahimi (2011). They reported the Purslane K content of 7.3 percent at lowest salinity level of zero Na content. They also showed the significant decrease in Purslane leaf K content with increasing salinity stress. With increasing Na content of irrigation water from 0 to 240 mM, the Purslane leaf K content decreased by 64 percent.

Conclusions

It was concluded that Purslane is a super high K accumulator plant that can be produced with saline water.

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An economic analysis of the yield of eight varieties of potato grown under saline conditions

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Keywords: Salinity, potatoes, varieties, compost, economic analysis

Introduction, scope and main objectives

Salinity negatively affects yields of almost all crops. Salinization of soils and water is an increasing problem around the globe and predicted to get worse under climate change scenarios. This is particularly so in dry and hot regions of the world, such as in Northern Africa.

To alleviate salinity stress on crops, management practices can be adopted that are beneficial to crop performance under saline conditions. One such practice is the application of compost to the soil. Compost has a whole range of beneficial effects, some of the most important ones include an improved availability of soil cations such as Ca^{2+}, Mg^{2+} and K^{+}, better water retention of the soil, improved microbial activity and in clay soils it protects against soil dispersion. However, compost is not for free and it is thus necessary to evaluate the economic viability of relatively large quantities of compost application.

Methodology

Eight varieties of potato (Bernice, Lotus, Spunta, Cara, Dido, Metro, Actrice and Picobello) were cultivated on a salt affected field of a biodynamic farm in Egypt in the winter season of 2020/2021. The seasonal mean salinity level of an extract of a saturated paste (the EC_e) was 5.5 dS/m. Two levels of compost application were applied, equivalent to 1.8 and 4.5 kg/m^2. The following parameters of the crops were evaluated at the end of the growth season: number of stems per plant, number of tubers per plant, average tuber weight and size classes of tubers. Potatoes were fertilized and irrigated according to the biodynamic standards throughout the growing season. After harvest, costs of applied compost were taken into account to determine if the higher compost application treatment was an economically viable choice, i.e. if there was an improvement in yield and if that improvement was large enough to offset the additional cost of compost.

Results

Seven of the eight varieties showed higher yields in the higher compost treatment, with an average increase of 38 percent (Table 1). There was no effect of higher compost application on the size distribution of the tubers.

The increased production led to higher profits for the farm, based on the price of compost cost as determined by the farm itself (they produce their own). Table 2 shows the difference in profit of the two different compost treatments for both the area that was actually cultivated, and per feddan, for all eight varieties tested. This cost-benefit analysis has been done making use of the real production costs and prices of the cultivation of potatoes at the farm. It must be noted though that these numbers are based on an extremely low market value for the potatoes; on an average year, the profits would be significantly higher.

Table 1. Yield in t/ha of the different potato varieties at the different compost treatments, and the difference between the two compost treatments in %.

	Compost (kg/m^2)		
	1,8	4,5	
	yield (t/ha)	yield (t/ha)	increase double compost (%)
Bernice	15,1	24,7	63,7
Lotus	15,3	25,1	63,9
Spunta	13,0	17,0	30,9
Cara	10,2	9,3	-8,8
Dido	22,5	31,8	41,0
Metro	25,2	32,2	27,4
Actrice	20,4	31,5	54,4
Picobello	23,7	31,6	33,6

Table 2. The difference in profit in Egyptian pounds (EGP) between the two compost treatments of all eight varieties

Difference	Bernice	Lotus	Spunta	Cara
Area cultivated	EGP 251.22	EGP 155.73	EGP 829.45	EGP 364.96
Per feddan	EGP 4425.98	EGP 4295.31	-EGP 1251.84	-EGP 5894.48
	6%	11%	-3%	-12%

Dido	Metro	Actrice	Picobello
EGP 1118.49	EGP 835.99	EGP 1118.49	EGP 920.99
EGP 5935.50	EGP 2498.49	EGP 5685.30	EGP 3077.67
14%	6%	13%	7%

Discussion

Dealing with salt-affected soils is a daily reality for farmers all over the world. Identifying appropriate measures and management practices that improve yields and soil health is therefor of vital importance. Here we show that adding large amounts of compost significantly increases potato production under saline conditions, and that this translates into higher profits for the farmers. However, it must be noted that the availability of high-quality compost can be a limiting factor. There is a need for more studies such as the one presented here to evaluate the options for management of saline soils and their economic viability.

Conclusions

The application of a relatively large amount of compost on a salt-affected soil improves the yield of most potato varieties. Furthermore, the improvement in yield is such that it offsets the additional investment that is required. We recommend more studies to include this economic analysis in their assessment of management practices aimed at adapting to salinity.

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Saline-sodic soils rehabilitation using a rubble barrier and organic amendments

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Keywords: saltgrass, construction debris, pyrochar, hydrochar, compost, gas emissions

Introduction, scope and main objectives

The addition of biochar or compost has been a promising alternative to improve salt-affected soils (Lakhdar *et al.* 2009; Saifullah *et al.*, 2018). However, the effects of these amendments are unknown in detail. Additionally, in areas where the main source of salinity comes from groundwater, reducing or stopping the capillary rise is essential (Guo *et al.*, 2006). An example of extreme saline-sodic soils (>100 dS/m; pH >9; sodium adsorption ratio >200) occurs in the former lake of Texcoco, near Mexico City, where soils hinder the colonization by native or exotic halophytes leaving the area prone to degradation (Cruickshank, 2007; Fernández-Buces *et al.*, 2006). In this work, we evaluated if the implementation of a barrier made with crushed rubble and the addition of compost or biochar mitigate the topsoil salinization and allow the development of the native grass *Distichlis spicata*.

Methodology

We evaluated *in-situ*: i) changes in soil properties (pH, electrical conductivity, sodium adsorption ratio and soil moisture), ii) survival and development of *Distichlis spicata*, and iii) greenhouse gas emissions in experimental plots with or without barrier and with the addition of pyrochar, hydrochar and compost (20 and 40 t/ha) during 24 months.

Results

The amendments did not reduce the soil salinity, but improved the grass survival and plant cover, which in turn decreased the topsoil moisture content, and increased the C and N content without affecting the CO_2 emissions. The barrier allowed the growth of the grass, decreased the topsoil salinity and the CO_2 and NH_3 fluxes. However, the soil pH increased at the beginning of the experiment and the topsoil moisture decreased in the dry season but increased during the rainy season.

Discussion

The non-significant effect of the amendments on the soil salinity was probably due to their alkaline pH and to the small doses (Ippolito *et al.* 2014; Qayyum *et al.* 2015). The lower grass transpiration and the salt crusts on the topsoil could favor the higher moisture of the control plots (Zhang *et al.* 2013; Kowaljow *et al.* 2017). The effect of the barrier on the moisture content could be attributed to the capillary rise interruption during the dry season and a delay in the water infiltration in the rainy season, affecting the soil salinity and the grass survival (Guo *et al.* 2006). Although the pyrochar increased the grass survival, the opposite happened with the plant cover, likely due to its high surface area, which could induce nutritional stress (Ramlow *et al.* 2018).

Conclusions

Higher doses or acid amendments could decrease the soil salinity at the site. Pyrochar and hydrochar additions can improve the establishment of vegetation and the soil C content without affecting the CO_2 emissions. The use of compost is not recommended due the NH_3 emissions. The barrier is an effective tool to decrease the salinity and increase the plant cover. However, it could hinder the root growth. Irrigation is needed to sustain plant growth during the dry season.

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Producing a Tailored soil, with an underused saline Fluvisol, for the conservation of a critically endangered species

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Keywords: Estuarine water, Limonium daveaui, Plant restoration, Saline soil, Soil Technology, Wastes

Introduction, scope and main objectives

Fluvisols are incipient soils developed on fluvial, lacustrine or marine deposits (IUSS Working Group WRB, 2015). Those from marine deposits present high salinity, mainly in concentration of Na^{+} and Mg^{2+}, and high electrical conductivity, being underused soils. Man-made tailored soils are an alternative to saline Fluvisols management since can be elaborated as a combination of soil and wastes for using in the recovery of degraded soils (Macía *et al.*, 2014; Cortinhas *et al.*, 2020). *Limonium daveaui* Erben is a halophyte species critically endangered endemic, narrowly distributed in Tagus estuary marsh (Lisbon) (Caperta and Carapeto, 2020). This study aims to assess the potential of a tailored soil (TAIL) produced with a saline Fluvisol (FLU) and irrigated with estuarine water (Ew), in *L. daveaui* conservation.

Methodology

The TAIL was produced with a FLU, collected in Tagus estuary marsh, and a mixture of wastes, previously analysed: sludge and waste kieselguhr from breweries, sand, gravel limestone and residual biomass. The FLU and the TAIL were potted and incubated at 70 percent of the maximum water-holding capacity, in the dark, for 28 days. Seedlings were obtained by germination on filter paper with deionised water. After the incubation, substrata's samples were analysed and the seedlings were transplanted to the substrata irrigated with Ew. The Ew was collected in the Tagus estuary and analysed. At the end of this experiment, samples of substrata were analyzed again and the number and size of leaves, the number and length of scape and dry biomass were determined.

Results

The FLU was slightly alkaline, with a high EC and low values of C_{org}, N_{total}, P_{ext} and K_{ext}. By comparison with the FLU, the TAIL presented a significant increase in the concentration of all determined elements. The Ew was saline, had a neutral pH and high concentrations of Cl^{-}, HCO_3^{-} Na^{+}, Ca^{2+} and Mg^{2+}. At the end of the assay, the concentrations of nutrients did not show significant variations compared to the beginning, except extractable K, which increased significantly. Plants grown in the TAIL presented higher number of leaves, smaller leaves, more and larger scapes and higher flowers production, than the plants cultivated in the FLU. The roots of the latter ones were concentrated in the bottom of pots while roots of plants grown in the TAIL spread all over the substrate.

Discussion

The lack of the FLU structure, due to colloid dispersion, was unfavourable to roots penetration and oxygen circulation leading to a low plant development. In contrast, the permeability and aeration of the TAIL due to sand, gravel and biomass, and the good fertility due to high content of N_{total}, C_{org}, P_{ext} and K_{ext} in sludge and waste kieselguhr, allowed a better plant growth and development.

Conclusions

This approach that uses cost-effective wastes contributes to enhancing soil fertility and structure by valuing underused resources such as saline soils, not used in conventional reintroduction schemes, but appropriate to this halophytic species.

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Introducing salt tolerant okra as a summer crop to coastal Lebanese area

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Keywords: summer vegetables, salinity management, salt tolerant crops, irrigation with saline water.

Introduction, scope and main objectives

Urban expansion and pressure on Mediterranean coast caused seawater intrusion into coastal groundwater, often used for irrigation of crops (El Moujabber *et al.*, 2006). Meeting the targets of the sustainable development goals requires the use of saline water for irrigation (Darwish and Fadel, 2017). Many growers fallow their land when ECw reaches higher salinity values (7 dS/m). To reduce this livelihood loss, we introduced a salt-tolerant okra to the coastal Lebanese farming systems.

Methodology

The study area is located in Jieh at 23 km south of Beirut. The experiment was carried out in an open field on loamy soil for the summer growing season of 2019 (between May and September). Four water salinity treatments were considered with the electrical conductivity of the irrigation water (ECw) comprised between 6 (T_c), 9 (T_1), 12 (T_2) and 15 dS/m (T_3). A total of 15 effective plants per treatment were selected for measurements. Crop performance of okra (PI 534521) was measured by non-destructive readings of the chlorophyll contents, canopy temperature and yield.

Results

As the salinity increased to 15 dS/m, chlorophyll contents significantly decreased as compared to Tc, T1 and T2 treatments. Okra canopy temperature in each treatment increased over time. At the beginning, canopy temperature was significantly different between all the treatments. At full harvesting, temperature in T_2-T_c, T_3-T_c, and T_3-T_1 was significantly different. Treatments T_c, T_1. and T_2 had maximum and similar yields throughout the study ($p>0.05$), while T_3 fresh yield decreased by 60 percent with respect to other treatments.

Discussion

Chlorophyll content was affected by the highest salinity level (15 dS/m), which is beyond the threshold this okra variety can withstand. Salinity tolerance in okra varieties can be done in a short time, three weeks after the onset of salt exposure. This study suggests that yield of okra subject to increased water salinity did not differ from the control up to 12.4 dS/m, which is twice the average value recorded in the wells in Jieh. Beyond this level, okra yield was significantly affected by higher salinity. The form of the pods, being similar with the local variety, they will readily find access to the consumers' desire.

Conclusions

Salt tolerant okra can be grown on the Lebanese coastal area witnessing higher salinity levels of irrigation water. ECw for this type of okra genotype should not exceed 10–12 dS/m. Moderate salinity did not affect okra pod quality nor yield. This provides one more opportunity to support farmer's income and encourage crop diversity on farmer's fields. For the first time, salinity tolerant genotypes were propagated and tested for salinity tolerance on the Lebanese coastal area and on farmer's fields.

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Improvement effect of vermicompost co-applied with coconut chaff and coconut-shell biochar on moderately salinized soil in coastal areas

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Keywords: vermicompost, coconut chaff, coconut-shell biochar, salinized soil

Introduction, scope and main objectives

Land salinization has become a key problem for the soil environment. At present, the improvement measures mainly include engineering (Pu *et al.*, 2014), chemistry (Zhu, 2017), physics (Pang *et al.*, 2015) and biological measures (Li, 2013; Radić *et al.*, 2013). The biological measure is generally believed to be the most effective way (Wang *et al.*, 2020; Wu *et al.*, 2008). However, the improvement effect of vermicompost co-applied with coconut chaff and coconut-shell biochar on salinized soil is unknown. The objectives of this study were to determine the optimal application ratio of three biomaterials, and investigate the improvement effect and mechanism of the optimal combination on salinized soil.

Methodology

The tested soil was taken from the 0–20 cm tillage layer from Nanxi Village (N 19°59.014′, E 110°37.453′), Wenchang City, Hainan Province. The tested plant was cherry tomato. The pot experiment with orthogonal test was conducted from November 2019 to May 2020. Nine treatments were set according to the volume ratios of the vermicompost, coconut chaff and coconut-shell biochar to moderately salinized soil. Each treatment was repeated three times. The potted soil samples were collected at the last harvest of cherry tomatoes. Soil physicochemical indexes were determined by reference to the agricultural industry standards. Corresponding kits were used to analyse soil enzyme activities. Soil microbial diversity was sequenced by a high-throughput sequencing.

Results

The pH value and nutrient amounts were significantly increased in coastal soil after adding the vermicompost, coconut chaff and coconut-shell bioch at a volume ratio of 3 : 3 : 1.5, with the soil pH value changing from acid to neutral. The amounts of OM, AN, AP and AK were significantly increased, with the soil salinity decreasing by 72.8 percent. The concentrations of soil Cl^-, Na^+, K^+, Ca^{2+} and Mg^{2+} were also significantly decreased, while the activities of urease and catalase were significantly increased. The soil bacterial richness and diversity were improved and the bacterial community structure was optimized. The results of RDA analysis showed that the amounts of soil organic matter, available nutrients, enzyme activities and bacterial diversity indexes all had significant negative correlation with soil salinity, but the concentrations of soil salt ions were positively correlated with soil salinity.

Discussion

The preparation process of this soil conditioner is very simple to popularize and apply in a large area.

Conclusions
The improvement effect was the best in coastal soil after adding the vermicompost, coconut chaff and coconut-shell biochar at a volume ratio of 3 : 3 : 1.5.

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Different furrow irrigation modes help soil salinity management in permanent raised beds in salt-affected irrigated drylands

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Keywords: skip-furrow irrigation, salt-leaching, cotton, raised bed-planting, Uzbekistan

Introduction, scope and main objectives

Mismanagement of irrigation water and the ensuing secondary salinization are threatening the sustainability of irrigated agriculture especially in many irrigated dryland regions. The permanent raised-bed/furrow system, a water-wise conservation agriculture-based practice, is gaining importance for row- and high value-crops in irrigated agriculture. However, because of additional surface exposure and elevation, raised beds may be more prone to salt accumulation especially under shallow water table conditions. The objective of the study was to investigate the effect of different modes of furrow irrigation and leaching techniques on salt dynamics and crop performance on permanent raised bed systems of salt-affected soil.

Methodology

The study was conducted in Khorezm region, Uzbekistan in saline soil, with average soil salinity in the top-30 cm soil >12 dS/m. Three different irrigation methods, i.e. (i) Every-furrow irrigation (EFI), (ii) Alternating skip furrow irrigation (ASFI) and (iii) Permanent skip furrow irrigation (PSFI) was used in the study. In EFI, water is applied uniformly to all furrows, in ASFI, one of two neighboring furrows was alternately irrigated during each irrigation event and in PSFI method, one of the two neighboring furrows was permanently skipped for watering and kept dry until it became desirable to leach the salts out of the root zone. After applying four irrigation cycles the accumulated salts on top of the beds were leached from all treatments. For leaching, irrigation water was applied in all furrows at the same time in the EFI and ASFI treatments. Under PSFI, leaching started by applying water to the permanently irrigated furrow first. After filling these furrows, the dry furrows were filled with water to leach the accumulated soluble salts from the dry furrows. Leaching was performed by keeping 5–6 cm of standing water for about 24 hours to leach down the salts with water. A boundary was made at the end of the furrows that prevented runoff. To analyze salinity level, soils were sampled from seven points (center of the bed, two sides of the bed, slope of both furrows and center of the furrows) before each irrigation event and leaching and three days after leaching.

Results and Discussion

The EFI method increased salt accumulation on the top of the raised beds. In contrast, the PSFI method allowed an effective salt leaching from the top of the raised beds. After leaching, salinity on top of the bed sunder PSFI was reduced to <3 dS/m compared to 5–6 dS/m under ASFI and EFI indicating effective leaching with the PSFI method. Raw cotton (*Gossypium hirsutum* L.) yield was higher under the PSFI (2003 kg/ha) method having yield increases of 984 kg/ha (96 percent higher) and 787 kg/ha (64 percent higher) than under EFI (1216 kg/ha) and ASFI (1019 kg/ha) methods, respectively. Better crop performance with PSFI was linked with the lesser salinization of the raised beds and a larger salt free root zone before the leaching events.

Conclusions

Soil salinity on top of raised beds increased when irrigation water was applied to both furrows flanking the beds. In permanent skip furrow irrigation, salts accumulated towards the dry furrows and hence, this technology has the potential to reduce salt concentrations on the top and the side of the raised beds by two–three times compared to EFI and ASFI. In addition, the soil salinity level on the irrigated side of the furrow under PSFI was always low, and crop roots can grow in the direction of the low saline environment, resulting in higher yield of cotton under PSFI. PSFI facilitated efficient leaching and concurrently reduced the amount of irrigation water and also helped to minimize secondary soil salinization. Thus, PSFI could be an effective method to manage the salt under raised beds in salt-affected irrigated drylands.

The PSFI practice could be possibly more beneficial to farmers if cultivating plant salt-sensitive crops on the side of the irrigated furrows and a salt-tolerant less water requiring crop, for example, cotton, on the side of the dry furrows. Further research is however needed to identify the combination of the salt-tolerant and susceptible crops to cultivate on raised beds with PSFI and its benefits to the farmers and the environment.

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Potential of biochar application to mitigate salinity stress in soybean

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Keywords: maize biochar, plant growth, nitrogen, phosphorus, nutrient uptake, salinity

Introduction, scope and main objectives

Soybean is an important legume and is widely grown in China and other countries of the world as a source of food, oil, and as a forage crop. Several studies reported that abiotic factors including drought and salinity might cause nodulation failure and decrease legume production (Bouhmouch *et al.*, 2005; Hashem *et al.*, 2016). Biochar application has been repeatedly reported as an effective means of restoring saline lands and increasing plant tolerance to salt stress (Ullah *et al.*, 2018). The aim of our study was to evaluate the effect of biochar on plant growth, symbiotic performance and nutrient uptake of soybeans under saline soil conditions.

Methodology

The soil used in the study was sandy loam, with the following contents: C org (0.6 percent), total N (0.07 percent), P (0.03 percent), K (1.25 percent), and Mg (0.18 percent), with a pH of 6.2. The biochar was produced from maize by heating at 600 °C for 30 minutes and had the following properties: Dry matter (DM percentage of fresh matter)– 18.42; total organic carbon content (percentage)–75.47, N (percentage)–1.80; C/N ratio–41.93; Ca (g/kg) 9.26; Fe (g/kg)–11.40; Mg (g/kg)–4.91; K (g/kg)–32.26; P (g/kg)–5.26; pH–9.89; EC–3.08 (Reibe *et al.*, 2015).

The following treatments were set up: (i) plants grown in soil without biochar (BO), (ii) plants grown in soil amended with 2 percent (BC). The soybeans were grown under non-saline and saline (50 mM NaCl) conditions for 40 days at a temperature of 24 °C/16 °C (day/night). The dry weights of root and shoot, N and P uptake and the number of nodules were determined from each plant.

Results

In non-saline soil amended with BC, both the shoot and root growth of the soybean were significantly ($p < 0.05$) increased, by 15 percent and 20 percent respectively, compared to plants grown in soil without biochar addition. Under saline soil conditions, biochar improved the soybean shoot and root biomass by 17 percent and 22 percent, respectively. Notably, soil salinity inhibited nodule formation in the plant, with no nodules being found on roots grown in saline soil without biochar addition. However, soil amended with biochar increased nodule numbers to 8.1 ± 1.2 per plant. Significant increases ($p< 0.05$) in the N and P content of plant tissue over the controls were observed after biochar amendments under non-saline conditions, being 21 percent and 16 percent higher, respectively. Under saline conditions, the soil amended with biochar showed an increased concentration of plant N and P content by 15 percent and 19 percent.

Discussion

Several other reports demonstrated the positive impacts of soil amendments with biochar on plant growth and development under salt stress (Farooq *et al.*, 2020). Similar findings were observed for the halophytes Sesbania (*Sesbania cannabina*) and Seashore mallow (*Kosteletzkya virginica)*, where the shoot growth under salt stress was improved by biochar application (Zheng *et al.*, 2017). The application rate of biochar increased the N and P content in plant tissues under both non-saline and saline conditions. The positive effect of biochar on plant growth was explained by the increased availability of essential nutrients for plant growth and development.

Conclusions

The results of our study revealed synergistic effects of biochar amendments on plant growth and nutrient uptake of soybeans in sandy loam soil under both non-saline and saline conditions. This finding underpins the notion of an elaborate interrelationship between biochar concentration and enhanced plant growth, nutrient acquisition and the symbiotic performance of soybeans.

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eHALOPH

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Keywords: salt tolerance, halophytes, database.

The earth has an abundant supply of water, but most of this is seawater, dominated by the presence of Na^+ and Cl^- (480 mM and 560 mM, respectively). Since seawater covers around 70 percent of the surface of the planet, salts have, over the millennia, reached the land caried by wind or brought by changes in topography. In more recent times, irrigation has also contributed to salinisation. In plants, tolerance of salt has evolved but appears to vary continuously across species–from those killed by just 25 mM (the most sensitive cultivars of chickpea; Flowers *et al.*, 2010b) salt to those that tolerate twice seawater salt concentrations (e.g. *Tecticornia*; English and Colmer, 2013). Within this range, arbitrary lines have been drawn separating groups of plants: those tolerating around 80 mM NaCl are salt-tolerant, those that can grow in 200 mM NaCl, halophytes (Flowers and Colmer, 2008) and those growing in seawater concentrations of salt we call euhalophytes. Plants intolerant of salt are known as glycophytes.

While salt-tolerant plants have been recognised for many years (Huchzermeyer and Flowers, 2013), it was not until the early 1970s that a list of halophytes was compiled by Peta Mudie (Mudie, 1974). Later, James Aronson built on this list to produce the database HALOPH, "for anyone growing or planning to grow halophytes" and which was published as a book in 1989 (Aronson, Arizona Univ. and Whitehead, 1989). In order to facilitate the use of the database, HALOPH was converted to an electronic format between 2006 and 2014. Information in the original database on plant type, life form, maximum salinity tolerated, photosynthetic pathway economic uses and distribution has been extended in eHALOPH by adding information on antioxidants, secondary metabolites, molecular data, compatible solutes and habitat, and whether or not there have been publications on ecotypes, germination, the presence or absence of salt glands, microbial interactions and mycorrhizal status and bioremediation (Santos *et al.*, 2016). eHALOPH is freely available at https://www.sussex.ac.uk/affiliates/halophytes/.

In updating the database, we have revised the names to those currently in Plants of the World Online (http://www.plantsoftheworldonline.org/) and tried to ensure that information is supported by a publication. New species have been added from Menzel and Lieth (2003) and Kefu, Fan and Ungar (2002), but the database does not include most crop species. Currently, eHALOPH contains information on about 1200 species in 421 genera and 93 families. Of the approximately 365 000 species of higher plants, around 625 species in 249 genera and 74 families, are halophytes and tolerate the equivalent of 200 mM NaCl. So, halophytes are rare at just 0.2 percent of plant species.

How is it, then, that most plants cannot tolerate seawater, when almost all the water on the planet is salty? An explanation of why most species are not salt tolerant is that the colonisation of land by plants occurred from fresh, rather than salt water and so salt tolerance of terrestrial species has evolved as a secondary trait (Flowers *et al.*, 2010a). Apart from the academic challenge, there is a practical reason for trying to understand this conundrum: it has proven difficult to enhance the tolerance of our current crops to salt. We need to understand the physiology and biochemistry of salt tolerance in order to breed salt-tolerant crops as this trait is likely to be of increasing importance as our climate changes. eHALOPH provides information on traits contributing to salt tolerance as well as listing potential uses of economic value.

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Reclamation of saline-sodic soils with gypsum and sulphur

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Keywords: saline-sodic soil, chemical amendment, soil column, lixiviation, soil amelioration, ESP

Introduction, scope and main objectives

Saline-sodic soils have an excessive amount of sodium (Na^+) and soluble salts, and can be measured by the Exchangeable Sodium Percentage (ESP) and electrical conductivity (EC), respectively. According to the USSL classification, a saline-sodic soil has an ESP >15 percent and EC_e >4 dS/m. Loss of soil structure and osmotic stress in plants are some of the negative effects of salinity-sodicity, which can be treated by leaching with water and adding chemical amendments as gypsum (GY) as a source of Ca^{2+} to replace the Na^+ in the exchange complex. Sulphur (SU) as an alternative, is oxidized by microbes forming sulfuric acid to dissolve the calcite. The aim of the soil-column experiment was to evaluate the effect of GY and SU at two levels (50 percent, 100 percent) on reclamation of a saline-sodic soil from the High Valley of Cochabamba (Bolivia).

Methodology

The initial soil properties (20 cm) were: EC_e 20.5 dS/m, ESP 66.6 percent, pH 10.2, BD 1.3 g/cm^3, CEC 5.0 $cmol_c$/kg, OM 0.6 percent, clay 18.2 percent, silt 52.1 percent and sand 29.7 percent. The purity of GY was 92 percent (Ca^{2+} 18.5 percent) and 97.5 percent for SU. The GY requirement to reduce initial ESP to 15 percent was calculated through the equation of Hoffman and Shannon (2007) and for the SU was 5.38 times GY requirement (Richards *et al.* 1954). Fifteen soil columns (PVC tubes–15 cm Ø) were filled with 6.7 kg of soil (4 mm sieve) and the upper layer was mixed with respective amendment/dose, following the protocol of Ahmad *et al.* (2015). The volume of distilled water for the lixiviation was defined as a pore volume (PV) using the formula of Kahlon *et al.* (2013). After an initial soil saturation with 3/4 PV, four lixiviations were applied each of 1 PV. ESP was calculated using the formula by Sumner, Rengasamy and Naidu (1998). Treatments were evaluated as factorial using LSD–Tukey adjustment.

Results

Soil ESP, EC_e and pH differed significantly (p =0.05) with respect to the interaction between amendments and doses. GY100 decreased soil ESP by 65.5 percent followed by GY50 (55.2 percent), SU100 (47.1 percent), SU50 (33.4 percent) and control (26.3 percent) as sole water. GY100 and GY50 were more effective to reduce soil EC_e to 0.9 and 1.6 dS/m, respectively. SU100, SU50 and control, lowered EC_e in same magnitude (3.8–4.1 dS/m). Soil pH showed a reduction to 7.5 (SU100), 7.8 (SU50), and 8.1–8.4 (GY100, GY50, control). The evolution of Na^+_c in the leachates had higher concentration at the first lixiviation (900–1200 $mmol_c$/L) for all treatments, but from the second to fourth cycle there was a minimum increase. The EC showed similar behavior as Na^+_c in a range of 45–58 dS/m at first cycle.

Discussion

GY100 was the most effective to reduce the initial soil ESP by >98 percent and EC_e by >95 percent followed by GY50, confirming the influence of Ca^{2+} on displacing Na^+, besides the effect of washing soluble salts through lixiviation and the indirect effect of GY to improve the infiltration. SU was less efficient probably due to the insufficient incubation time and the low soil organic matter, but was more effective to improve soil pH maybe due to the acidic counteracting effect. Results agree with those obtained by Qadir *et al.* (1996), Tavares *et al.* (2011), Manzano *et al.* (2014) and Ahmed *et al.* (2016). Evolution of Na^{+}_{e} and soluble salts in the leachates was congruent with soil amelioration. The salinity-sodicity was considerably reduced at first lixiviation in >90 percent.

Conclusions

GY100 was most effective to improve soil ESP and EC_e also reaching the thresholds from the classification, followed by GY50 > SU100 > SU50. SU was more efficient to decrease the pH. Up to two lixiviations might be sufficient to remediate the soil.

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Crop production in sodic soils: Can the corn take the water of the Btn horizon?

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Keywords: corn, water absorption, ESP, Bt horizon

Introduction, scope and main objectives

At the end of the 20th century and the beginning of the 21st, the area under agricultural crops in Argentina grew exponentially, with greater importance as of 2005 in the Salado Basin. (MAGyP, 2019; Paruelo, Guerschman and Verón, 2005). The soils of this region have a natric (Bt) horizon with a high special heterogeneity, where sectors with a greater accumulation of sodium salts are observed, interspersed with sectors where these chemical limitations to the plant growth are absent (INTA, 1980). There is evidence that the Bt horizon limits the root growth and water absorption by the plants (Meinke, Hammer and Want, 1993; Micucci and Taboada, 2006). The aim of this work was to evaluate the role of the Bt horizon with different degrees of sodicity in the provision of water to the corn crop.

Methodology

An experiment was carried out in field plots in the Chascomús Integrated Experimental Farm (MDA-INTA) (35° 44' S; 58° 03' O), Buenos Aires province. The plots were arranged in a randomized complete design with three treatments and six repetitions:

1. Control: crop plots with water recharge due to rainfall.
2. Drought: crop plots with limited water recharge due to rainfall from V_{11} to harvest. Covering the space between rows with a polyethylene film (250 µm).
3. Bare soil: crop plots with rainwater recharge as Control Plots, but without crops.

The gravimetric moisture was determined every seven days, with measurements taken every 0.2 m, and up to 1 m depth, taking one sample per plot. The water absorption was calculated as the difference between treatment in each measurement moment.

To determine the hydric state of the crop, the water potential in the leaf was measured at pre-dawn and at noon with a pressure pump (Scholander *et al.*, 1965). The grain yield and the sodicity of the natric horizon were related.

Results

The corn crop was able to absorb, but left a remnant of 45 percent water in the Bt horizon. This residual water was higher due to increases in ESP, but higher levels of water stress associated with increases in ESP were not observed.

The yields were between 6848–10983 kg/ha, decreasing 1.2 percent for each unit increase in ESP. The corn roots were able to absorb to a 1 m depth in the soil profile. This absorption depth was reduced by 0.02 m for each increase in ESP.

Discussion

The magnitude of desiccation of the natric horizon differs from that reported by Taboada y Alvarez (2008), who mention much lower values. In our study, the natric Bt showed clay contents 10–12 percent lower and a thickness 10–15 cm less than those of the quoted work. These two parameters could have explained the differences in the results achieved.

The reduction in corn yield is similar to those reported for soybean and sunflower crops (Gupta and Sharma, 1990), However, these results are novel, since the information available in the literature regarding the effect of ESP on maize yield is still scarce (Page *et al.*, 2021).

Conclusions

The corn crop was able to extract water from the natric Bt horizon and consequently, access the groundwater from the deepening of roots in the soil profile.

Increasing ESP values reduced the productivity of the corn crop because of physical restrictions on water absorption and reductions of root deepening.

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Innovative technology for increasing the fertility of saline soils

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Keywords: Saline soils, satellite images, soil salinity map, agrochemical cartograms, crop yield

Introduction, scope and main objectives

The Turkestan region is the most densely populated in Kazakhstan, with a population density of over 17 people / km^2. At the end of nine months of 2020, the gross regional product per capita in the Turkestan region amounted to 729.2 thousand tenge–this is the minimum value among all regions of the country, below the national average by 70.2 percent (Tengrinews, 2021). The level of unemployment and poverty is one of the most unfavorable in the Republic. Thus, the share of the population with incomes below the subsistence minimum is within the critical 11.2 percent–almost two times more than the average for the Republic of Kazakhstan (5.7 percent) (Informburo, 2021).Most of the population is engaged in agriculture, and in the irrigated areas of the Turkestan region, due to salinization, soils on 42 912 hectares have an unsatisfactory meliorative state, due to the rise in the level of groundwater on 80 005 hectares, and due to both factors on 24 909 hectares. In this regard, the purpose of our research was to solve the problems of irrigated saline soils of the Turkestan region by applying innovative technology to increase soil fertility and corn productivity, taking into account the level of potential and effective soil fertility to ensure food security in the region.

Methodology

Field and laboratory generally accepted methods of soil and agrochemical research, geoinformation mapping technologies, remote (space) soil research were used. Work on the compilation of a map of the content of humus and nutrients in soils was carried out by carrying out a traditional ground soil survey of the territory of the study object according to (Varennikova *et al*, 1995), Guidelines for conducting (KazSSR, 1979) and Methodological Guide (RNMCAS, 2004). To determine the coordinates of the points of soil sampling, the GPS global positioning system “Garmin 62s” was used in tandem with the “ASUS” netbook. Soil sampling sites were mapped directly during field work using the MapInfo professional software. The obtained analytical data were subjected to variational-statistical processing (Dmitriyev, 1995) and calculated the average "background" content of humus, basic nutrients, pH and toxic salts. Thematic maps were compiled in the GIS-environment using the MapInfo professional computer program.

Results

The results of assessing the soils of peasant farms by the degree of salinity and the content of nutrients on an area of 1507 hectares were obtained. The soil database contains the results for 4897 soil horizons. On the territory of three pilot farms, a production test of the biological method of soil desalinization was carried out. A microbiological preparation has been developed that increases the biological activity of saline soils. On an area of 1507 hectares, a technology was introduced to increase the fertility of saline soils and the yield of agricultural crops in 70 peasant farms with an increase in the yield of corn for grain from 33.8 percent to 34.1 percent on weakly and moderately saline soils, and on highly saline soils–14, 5 percent. The analysis of the effectiveness of the developed technology is carried out, indicating the cost estimate per one hectare, the payback of costs due to increased productivity, indicating the payback period.

Discussion

The implementation of the project contributed to the conservation of soil cover as the main means of production of agriculture, water resources, bio-diversity, agro-diversity and also increased the possibility of sustainable livelihoods of the local population. According to farmers and heads of peasant farms, the yield of corn on saline soils, where earlier yields were low, are higher after applying the technology. This is due to the fact that the treatment of corn seeds and spraying at different stages of development with a special solution of the drug has a positive effect on faster growth in the field and the rapid growth of young shoots, and well-rooted plants give high yields.

Conclusions

On an area of 1507 hectares in 70 farms, an innovative technology was introduced into production, which provided an increase in the yield of corn for grain by 33.8 percent–34.1 percent on weakly and moderately saline soils, and on highly saline soils–14.5 percent.

The economic efficiency of the introduction of technology in the cultivation of corn for grain in comparison with the existing technology varied from 180.5 thousand tenge / ha on non-saline soils to 34.2 thousand tenge / ha on highly saline soils. The cost recovery with the existing technology ranged from 1.21 to 1.86 tenge, with innovative technology it ranged from 1.34 to 2.52 tenge.

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Effectiveness of indigenous soil amendments on soil salinity amelioration and performance of rice in vertisols

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Keywords: Soil salinity; amelioration; rice husk; rice straw, rice yield

Introduction, scope and main objectives

Vertisols are considered significant global resources for subsistence agriculture owing to their high surface area stickiness which could support higher crop production by increasing nutrients and water retention (Prasad, 2017). However, salinity problems noticeable in the Hadejia river valley Nigeria (with 4 million ha of Vertisols) pose constraints for the cultivation of rice in the area (Idris, 2020). Thus, this study was designed to assess the effect of rice husk and rice straw as soil amendments on amelioration of soil salinity and increase rice productivity in the Hadejia wetland area.

Methodology

The research was conducted in salt-affected vertisols within the Hadejia-river valley (N12.75°, E10.24°) of Jigawa State Nigeria. The experiment was arranged in RCBD with 2 amendments (rice husk (RH) and rice straw (RS) at 4 levels (0, 1, 1.5 and 2 tons/ha) labelled as RH1, RH2, RH3, RH4, RS1, RS2, RS3 and RS4 respectively, then replicated five times. The amendments were collected, chopped, sun-dried, ground and passed through a 5 mm sieve. Plots (3m x 3m) were earmarked using a measuring tape and each received an amendment based on the treatment.
Seedlings of FARO 44 rice variety were transplanted at 25 x 25 cm spacing. All agronomic practices were conducted using SRI procedures. Growth and yield parameters were collected using standard procedures. Soil samples were collected before and after experimentation and properties were determined using appropriate procedures. All data obtained were subjected to analysis of variance using SAS package (Gomez and Gomez, 1984).

Results

The result revealed that pH_{CaCl2} varied significantly between the treatments, ranging between 7.4 to 8.8, control (0 tons/ha) obtained the highest pH (8.8) and statistically different with RH4 (7.5) and RS4 (7.5) with the lowest pH. For K ($Cmol_{(+)}$/kg), RH4 (1.50) and RS4 (1.49) obtained the highest values and were statistically different with control (0.91) having the lowest K. The same trends as for K were observed in exchangeable Ca and Mg, total nitrogen (g/kg), and organic carbon (g/kg) with the ranges of 1.71–1.92, 0.55–0.72, 0.55–1.86 and 0.43–0.92 respectively. For Na ($Cmol_{(+)}$/kg), control (9.44) had the highest value and differ significantly with RS4 (6.82) which obtained the lowest value. This is similar to sodium adsorption ratio and EC (dS/m) with ranges of 12.6– 8.39 and 4.85–3.87 respectively. No significant differences were observed in bulk density.
The yield (tons/ha) and the number of tillers varied significantly and ranged between 1.45–3.1 and 15–39 respectively. Controls had the lowest while RS4 then RH4 outperformed all the others. Slight differences in plant height ($p<0.05$) was observed.

Discussion

The addition of 2.0 tons/ha rice husk and rice straw had significantly reduced soil pH, SAR and EC of the saline soil, due to higher retention of water and the polyfunctionality of the organic residue (Rekaby *et al.*, 2020). Furthermore, it also increases CEC, total nitrogen, organic carbon, yield and yield component of rice. This is due to organic residue addition, as it provides many functions to the soil (Urra *et al.*, 2019).

Conclusions

Application of rice husk and rice straw reduced salinity level of soils and increase rice growth performance under salinity status in the Hadejia wetland area, hence, can be used for soil salinity amelioration.

Acknowledgements

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Water- and energy-use efficiencies of drip irrigation of cotton on soils prone to salinization: case study from the Karshi Steppe

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Keywords: saline soils, drip irrigation, energy efficiency, water productivity, Kashkadarya river basin

Introduction, scope and main objectives

Irrigated land prone to salinization occupies over 50 percent of farm land in Uzbekistan, causing low yields of cotton and other crops. Growing water deficit may accelerate salinity built-up in the topsoil with economic losses for farmers. Under such conditions drip irrigation may become an instrument for preventing soil salinization. Crop cultivation on salt-affected soils using drip irrigation requires additional inputs; farmers, facing financial shortages and trying to avoid such expenses lose crops—plants become short and soil properties degrade. One way of convincing farmers to apply drip irrigation is to show mutual benefits of water saving. The objective of this study was to explore resource, including water and energy, saving benefits of drip irrigation.

Methodology

The study was implemented in 2011–2015 in Karshi Steppe. During 2011–2014 Gas Production Union 'Shurtangas' demonstrated drip irrigation on 100 ha of farm land in Karshi district, Kashkadarya province. Later in 2015, the research site was established in the same area on 5 ha farm field. The trial had three treatments with three replications: 1) conventional furrow irrigation; 2) drip irrigation without plastic film cover; 3) drip irrigation with plastic film cover.

The research consisted of three steps. In the first step, all farming practices were monitored during the crop growing season, including labor inputs, machinery use, application of chemicals and farmyard manure, using diesel oil, electricity and water for irrigation. In the second step, energy equivalents of different input and output values used in different farming practices were adopted from published researches implemented in similar environments. In the third step energy expenses were estimated using field data and the energy equivalents.

Results

The study results showed, that the energy expenses to cultivate cotton totals to 44000-64613 MJ per ha of irrigated land under furrow irrigation, 79081 MJ using drip irrigation without plastic film cover and 81698 MJ with drip irrigation covered by plastic films. There is the difference in the value of energy inputs, mainly due to application of polyethylene sheet and using electricity to pump water into the drip system.

The yield response to irrigation was 3.8 t/ha under furrow irrigation, 5.4 t/ha under drip irrigation without plastic film cover and 5.5 t/ha under drip irrigation covered by plastic film. Water productivity was 0.47–0.53 kg/m^3 under furrow irrigation, 1.01 kg/m^3 and 1.98 kg/m^3 under drip irrigation using plastic sheet, at farm field and the research site, accordingly and 1.65 kg/m^3 under drip irrigation without plastic sheet cover.

Discussion

The results of the study differ from those of Perry, Steduto and Karajeh (2017), Pfeiffer and Lin Lawell (2010), Ward and Pulido-Velasquez (2008), indicating that hi-tech irrigation may increase water consumption. This study found that adoption of drip irrigation improves the efficiency of energy and water resources if proper resources use policies in place.

Conclusions

Water saving technologies in combination with crop diversification and intensification, and management of plant residues for improving soil properties and carbon sequestration can be the pathway for gradual rehabilitation of productivity of salinized lands. Further system-level studies require understanding a long-term response of soil salinity to wide adoption of drip irrigation at an irrigation system and river basin scale.

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Opening a new door in the management of salt-affected soils with the use of pumice

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Keywords: Reclamation of salt-affected soils; Lucerne; Saline water; Irrigation; Soil Amendments

Introduction, scope and main objectives

The removal of soluble salts once added to a soil is difficult unless they are flushed out from the root zone by leaching with excess irrigation water, which is a challenge due to water scarcity in arid and semi-arid regions. Although the implementation of some reclamation strategies has been successful, most are either still unavailable or unsuitable for many poor areas of the world. The ability of pumice to retain water has been reported in previous studies but its influence on soil salinity has not been investigated at depth. This has motivated our team to investigate this further (Kong *et al.*, 2021a, 2021b). Here we report some key findings of Kong *et al.* (2021b) related to the influence of pumice on the growth of lucerne in a sandy soil irrigated with saline water under a simulated arid environment.

Methodology

An artificial saline irrigation water was prepared using Na_2SO_4, $CaCl_2$, NaCl and $MgSO_4$ salts with final EC of 6.4 dS/m. Lucerne seedlings at the first trifoliate stage were transferred to pots with treatments consisting of: T1 (sand–positive control), T2 (sand + 3 percent (v/v basis) PU), and T3 (sand + 12 percent PU). All pots were first wetted with deionised water until near-saturated conditions for one week (Phase I). Thereafter, plants were drip irrigated with saline water, through 14 wetting and drying cycles (Phase II). This was followed by one last week in which plants were drip irrigated with deionised water before harvest (Phase III).

Results

The EC of the residual sand (after the removal pumice from the pots) followed the order: T1 > T2 > T3 (differences significant at $P < 0.05$). T3 treatment showed a 33 percent reduction in soil compared with the control (T1). SAR values of the residual sand followed the order of T1 = T2 > T3 (significant at $P < 0.05$). The use of 12 percent PU rendered a significant increase ($P < 0.05$) in plant survival rate of 178.5 percent, compared with T1. Compared with T1 (shoot DW of 0.31 g/m^2), significant increases ($P < 0.05$) in shoot DW were observed in T3 (12 percent PU), these being of 145 g/m^2. No significant effect of T2 (3 percent PU) on plant shoot and root biomass was observed in the study compared with T1.

Discussion

The CEC of the pumice was low, as well as its surface charge, and therefore the chemical retention of ions through surface interactions cannot fully explain the differences observed. In a previous study conducted by our team (Kong *et al.*, 2021a), we showed that the saturation index values of salts such as halite, KCl(s), mirabilite and thenardite increased within the pumice cavities, and this could have helped alleviate salinity and sodicity stress. Kong *et al.* (2021a,b), based on the results of Doak (1972), hypothesised that several wetting and drying cycles could cause hydraulic connections within the water column to break, inducing the entrapment of air in pumice cavities during desiccation. This could have resulted in a significant volume of inaccessible solution becoming increasingly concentrated in the centre of pumice particles with respect to soluble salts and water than the external solution, thus reducing salinity stress. Pumice could additionally benefit plant growth by increasing the water-retention capacity of the soil. This could help mitigate both water scarcity stress, and salt-induced osmotic stress and ion toxicity to plants through its dilution.

Conclusions

Kong *et al.* (2021a, 2021b) proposed that pumice particles, once saturated with salts, could be removed from the soil using available technologies, such as the one currently used to harvest tubers. This would represent an alternative to the current flushing of salts down the profile through excess irrigation.

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Fertigation system for sustainable agriculture in saline-sodic soils

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Keywords: Biochar; Fertigation System; Irrigation water quality, micro-irrigation, poultry manure extract; saline-sodic soils

Introduction, scope and main objectives

Land degradation is one of the most serious concerns of the 21st century, and the extent of the degraded land is more than 33 percent of the global land (Abhilash, 2021). Maintaining soil health and restoring degraded lands are our prime goals to celebrate the United Nations Decade on Ecosystem Restoration during 2021–2030. The comprehensive review was conducted to find the gap and direct future research in the management of saline-sodic soils.

Methodology

We searched Top 100 Scopus articles with keywords biochar, fertigation, micro-irrigation, manure, and saline-sodic soils for the last 25 years data.

Results

The present study outlines a synergy among different agronomic practices like drip-irrigation water qualities, soil nutrients, PGPRs, halophytes, plant-residue management, leaching practices, conservation tillage, and active participation of farmers' community for sustaining agriculture in saline-sodic soils.

Discussions

Novel technological interventions in agriculture equipped with skilled farmers can harness the current emerging climate-resilient agricultural operations. Utilization of higher rainfall and frequent irrigations for higher leaching, the addition of composite-biochar to soils, and growing salt-tolerant crops (species of *Sesbania*, *Medicago*, and other halophytes), have the potential to reduce soil salinity below a threshold (<2 dS/m), and to attain soil sustainable development goals (Xu *et al.*, 2009; Lastiri-Hernández *et al.*, 2019). Wang *et al.* (2021) suggested a novel facile synthesis method for the commercial application of composite biochar and its modification strategies using microbes and green plant materials to sustain soil quality and immobile soil pollutants as well. Despite all available technologies, we are not focusing on the higher adoption of cost-effective technologies by the local farmers' community for increasing the livelihood of farmers under sustainable intensification (Bharucha, Mitjans and Pretty, 2020).

Conclusions

The authors conclude a novel scheme of sustainable intensification with maximum participation of community farmers leading to higher adoption of cost-effective agricultural technologies for sustainable agriculture for the best utilization of natural bioresources besides their alternative use for crop nutrition, and maximum returns for the social capitals through community farming rather than isolated conventional practices. The authors emphasize to sustain the availability of soil nutrients for harnessing maximum crop production in saline-sodic soils by adopting innovative strategies for sustainable agriculture, and optimization of soil nutrients applied through combination of biochar, vermicompost, and poultry manure extract through fertigation system harnessing sustainable agricultural production.

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Subsurface drainage technology for reclamation of waterlogged saline soils – A case study of alluvial region

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Keywords: Waterlogged saline soil, sub-surface drainage technology, crop yield

Introduction

The waterlogged saline soils occur in about two million hectare area in arid and semi-arid alluvial northwestern states of India and more than one million hectares each in coastal and black cotton heavy soil (Vertisol) regions of the country (Kamra *et al.*, 2019). Waterlogging and salinity are serious environmental threat adversely affecting the crop yield and soil productivity. The saline groundwater within the crop root zone restricts plant growth drastically. The improvement in physico-chemical condition is inevitable for sustainable crop production in waterlogged saline environment. Subsurface drainage (SSD), an effective technology practiced extensively worldwide, can be an effective option for amelioration of waterlogged saline areas.

Methodology

The implication of adopting SSD technology in alluvial condition was studied. The study area was located between longitudes of 76.675 E to 76.690 E and latitudes of 29.007 N to 29.0209 N, in the Rohtak district of Haryana, India. For this purpose, subsurface drainage network was installed in 2016 in 160 ha land which was divided in four operational blocks. The size of collector and lateral pipe was 160 mm and 80 mm, respectively. The laterals drains were installed at 60 m spacing at the depth of 1.2–1.5 m. In this part of country, pump -outlet was used to drain effluent from the field to surface drain network in absence of suitable natural drainage. Drainage effluent was pumped out from the sump situated at surface drainage network. Fluctuation in water table depth, spatiao-temporal changes in salinity of soil and improvement in crop yield were monitored to access the effect of SSD on amelioration of waterlogged saline soil for crop production and livelihood security of the farmers.

Results

Post installation monitoring and evaluation at large field scale reveals a significant change in soil salinity which was translated into good crop yield. The mean electrical conductivity (ECe) of subsoil (0–135cm) profile reduced to 3.2 dS/m from 5.4 dS/m within two years period of successful operation SSD. However, the major change (2.91 dS/m) was noticed in upper soil profile (0–75 cm) and below that it was almost similar. Similarly, water table in the study site varied between 0.42–1.45 m below ground level (bgl) during the period of October to June. Hence, SSD maintained conducive environment for wheat production. However, in September, it was within the root zone (22.5 cm bgl), because of excess watering of crop with portable water. The wheat crop yield was recorded to be 40.25 q/ha after three years of successful operation of SSD in comparison to merely 10.4 q/ha yield recorded during commencement of SSD operation. The yield of rice was recorded as 41.6 q/ha as compared to 18.5 q/ha of initial period of the project.

Discussion

This area was waterlogged and operation of SSD ensured flushing of salt out of crop root zone by controlling groundwater level and facilitating leaching process. Lowering water table below the root zone and adequate salt leaching improve soil physico-chemical condition and increase crop yield.

Conclusions

The overall results of the study clearly suggest that SSD is an effective technology for achieving sustainable crop production in waterlogged saline soils by improving physico-chemical condition within the plant rootzone.

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Development of a system for salt removal, crop cultivation, and salt production that does not rely on a large-scale irrigation and drainage network

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Keywords: Desalinization, Irrigation, Drainage, Salt tolerant crop, Salt production, Thailand

Introduction, scope and main objectives

The target area of this study, Ban Phai District, Khon Kaen Province, is located almost in the center of Northeast Thailand, where 336,000 ha of saline soils are distributed in the low-lying areas of the Korat Plateau (Arjwech, Everett and Wanakao, 2019). In the study area, the average landholding area of farm households is about 2–4 ha, and farmlands are irregularly arranged, making it difficult to construct a large-scale irrigation and drainage network.

The objective of this study is to develop and implement a system that can manage salt at the farm household level without relying on a large irrigation and drainage network, and to improve the cash income of farmers by removing salt, growing crops, and producing salt.

Methodology

This study was conducted on approximately 2.6 ha of plots with salinization in Ban Phai District. The study started in April 2018 and the approximate system was completed in May 2019. This system completes the irrigation and drainage system and salinity management at the farm household level (Kume *et al.*, 2019). Evaluation of the introduced system for salt removal and crop cultivation was done. Crop cultivation was done. A workshop was held to demonstrate salt production by farmers and to conduct interviews.

Results

Soil EC measured by EM38 decreased from an average value of about 1500 mS/m to 1100 mS/m within one year after excavation of the drainage channel (Nohara *et al.*, 2021). The soil EC1:5 in the surface layer decreased from 6.0 dS/m to 1.8 dS/m as measured using soil samples. Soil pH did not change significantly before and after excavation of the drainage channel, and was about 8.0 from the surface layer to 1.5 m depth.

Crop cultivation was started one year after the excavation of the drainage channel was completed. *Sesbania rostrata* grew up to 1.4 m in height during the rainy season in farmland that was completely white with salts and devoid of vegetation before the study.

A workshop was held with local farmers who are using traditional methods for salt production. In the workshop, the system was introduced to the farmers, government heads, and students. Interviews revealed that salt is sold to middlemen at 18 baht per kg.

Discussion

The system clearly reduced the soil salinity. This is due to the fact that rainfall in the wet season acts as water for leaching, and salts are discharged from the drainage channels. This indicates that the system is applicable to this region, which has both wet and dry seasons. During the cultivation of *Sesbania rostrata* in the rainy season, rainfall served not only as water for leaching but also as irrigation water for crop cultivation.

One of the unique salt management features of this system is the traditional salt production that takes place at the downstream end of the study plots. Since it is difficult to cultivate crops during the dry season, salt production and its sale is an effective way for farmers to earn cash.

Conclusions

This system has a high potential to be introduced not only in Khon Kaen Province but also in other areas where it is difficult to construct a large-scale irrigation and drainage network for salt removal, crop cultivation, and salt production. The accurate water and salt balance in the field will enable us to quantitatively calculate the amount of water used by rainfall and reservoir water. This will make it possible to cultivate crops in the dry season using reservoir water, which will further increase farmers' income.

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Physiological and Molecular Adaptations of Halophytic Grasses under Sodic and Saline Stresses

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***Keywords:** Antioxidant system, Halophytic grasses, Gas exchange, Gene expression, Photosynthetic attributes*

Introduction, scope and main objectives

Soil salinity and sodicity are the two most prolific abiotic soil-related problems affecting the crop yield and quality (Kumar *et al.*, 2021). Globally more than 6 percent of total land is salt affected which is more than 20 percent of the total cultivated land (FAO, 2007). Feasible solutions are urgently required to harness the productivity of SAS; use of halophytes is one of among them. Improved knowledge of halophytes is of importance to understanding our natural world and to enable the use of some of these fascinating plants in land re-vegetation, as forages for livestock, and to develop salt-tolerant crops. In this backdrop, the experiment was planned to evaluate three halophytes (*U. setulosa*, *L. fusca* and *S. Marginatus*) under saline and sodic stress at physiological and molecular levels.

Methodology

The halophytes *Urochondra setulosa* and *Sporobolus marginatus* (collected from the extreme saline habitat of Rann of Kutch, Gujarat, India) and *Leptochloa fusca* (from RRS, CSSRI, Lucknow, India) were categorised based on biomass production, gas exchange attributes, antioxidant system and gene expression under salinity (EC 30–50 dS/m) and sodicity (pH 9.5–10). Physiological and biochemical analyses of three halophytes were conducted to explore their tolerance as well as phytoremediation potential.

Results

L. fusca and *S. marginatus* produced slightly higher biomass under sodic condition of pH 9.5 while in *U. setulosa* it increased under salinity stress. Under sodic condition, *L. fusca* showed less reduction and maintained higher K^+/Na^+ ratio in their leaf tissues. Maximum reduction in net photosynthesis was observed in *L. fusca* (28.55 percent) at ECe ~ 50 dS/m while minimum in *S. marginatus* (13.73 percent) at pH ~ 10.0. Comparatively, *U. setulosa* showed higher stomatal conductance and transpiration rate than *L. fusca* and *S. marginatus*. At highest pH and salinity, the antioxidant activities of enzyme APX, SOD, GR and POX increased in all three halophytes. Quantitative gene expression of ***MnSOD, NHX1*** and ***FuSOS1*** genes in all three halophytes increased with increase in salt stresses.

Discussion

Several studies reported that halophytes played a major role in desalinization (Kumar *et al.*, 2018a, Kumar *et al.*, 2018b). Results of present study showed that *U. setulosa* showed increased biomass under salinity stress where as *L. fusca* and *S. marginatus* under sodicity stress and this increase might be due to increased ionic load. These halophytes maintained potassium concentration at sodic and salinity stresses by balancing the Na^+/K^+ ratio. It has been observed that Na^+ competes with K^+ uptake through Na^+/K^+ co-transporters and may also block K^+ specific transporters of root cells under salinity (Mann *et al.*, 2015). A reduction was observed in net photosynthesis, as pphotosynthetic system is the backbone of plant system and salt stress caused the damage of plant membranes and pigment system as a result inhibits gaseous exchange and photosynthesis. Reduction in Pn and Fv/Fm also described the effect of salt stress on these halophytic grasses.

Increased antioxidant activity with increase in salt stress was reported in this study, supported in several studies that plants have antioxidant defense system containing non-enzymatic and enzymatic antioxidants to mitigate salt induced oxidative effects (Dhansu *et al.*, 2020). Salt stress induces the A cascade of genes including *MnSOD, NHX1* and *FuSOS1* stimulated in these halophytes, which played defence responsive role under salt stress (Lata *et al.*, 2019; Mann *et al.*, 2021).

Conclusion

It is concluded from the results that since *Urochondra setulosa* produces more biomass with extra salt load under salt stress, it may be grouped as highly salt tolerant. *Leptochloa fusca* produced higher biomass by maintaining higher K^+/Na^+ under sodic condition and could be categorized as sodicity tolerant grass. On the other hand, *Sporobolus marginatus* showed tolerance to both the stresses of salt or pH.

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Reclaiming Coastal Saline Soils by Freezing Saline Water Irrigation: Mechanisms and Application

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Keywords: coastal saline soil, freezing saline water irrigation, infiltration, soil water and salt dynamics

Introduction, scope and main objectives

The unitization of saline groundwater has played an important role in overcoming freshwater scarcity (Qadir and Oster, 2004). While the local groundwater is often overhigh cannot be used for irrigation directly. To overcome the above issue, we developed a new method of freezing saline water irrigation (FSWI) to reclaim saline soil. Specifically, saline water is irrigated in winter, under its freezing and thawing process on the top of soil, the strong salt leaching is realized. The objectives of present work are to evaluate the saline ice melting process and its effect on the salt leaching for coastal saline soil.

Methodology

Long-term field experiment was conducted in coastal plain of Bohai Sea, Hanxing County, China, to investigate the changes of meltwater during saline ice melting, and its effect on soil leaching, the soil samples were collected monthly to evaluate the dynamics of soil water, salt and SAR under FSWI (Guo and Liu, 2015).

Results

The desalination of saline ice melting was obvious. The salt leaching mainly occurred in the initial 30 days after irrigation. After the meltwater infiltrated, the soil salinity (4 g/kg) and SAR (9) were decreased significantly, lower than those of non-treated soil. Combining with plastic mulching in spring, the low soil salinity and SAR were maintained, and the normal growths and yields of crops were obtained.

Discussion

The soil salt and water vary with changes in evaporation and rainfall. In the present study the natural soil salt and water movements were modified by FSWI. The saline ice mulching relieved the soil salinization induced by the soil freezing and thawing winter. And the meltwater infiltration resulted in effective soil salt leaching in spring, combining with the plastic mulching in spring, the lower soil salinity was maintained, which provided suitable conditions for plant growth.

Conclusions

The desalinization effect of melting saline ice was obvious. After irrigation, the continuous infiltration of meltwater from saline ice resulted in great salt leaching effect, combining with plastic mulching in spring the normal growth of crops in heavy coastal saline land were realized. The FSWI is an effective way to reclaim saline soils using local high salinity groundwater of coastal saline land.

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The use of saline water in the irrigation of triticale fodder crop, and its effect on growth, productivity and soil properties

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Keywords: alternating irrigation, salt water, Triticale, soil salinity, fodder crops

Introduction, scope and main objectives

Saline water is one of the unconventional resources of irrigation used in conditions of available water resources scarcity, especially for some crops of special economic value and relatively tolerant for salinity of irrigation water. Qadir and others (2007) showed that the use of salinity-tolerant plants is one of the reclamation techniques as the plants have ability to grow in salinity-affected soils, which leads to a decrease of soil salinity. The possibility of using saline water in irrigation, especially with rainfall more than 200 mm and proper drainage system installation (Hamdy, 1998; Miles, 1987; Abdel- Gawad and Ghaibah, 2001) confirmed that agricultural drainage water can be used by mixing with fresh water in a proportion that maintains irrigation water in a practically acceptable manner and below the salinity threshold of the cultivated crop. Therefore, the experiment aimed to clear up the effect of saline water used in alternative manner of irrigation on growth the production of *Triticale* crop and some soil properties in particular salt dynamics and its relation to water salinity in Deir Ezzor Governorate–Lower Euphrates Basin under semi-arid conditions. The study was conducted during the cultivation seasons of 2018–2019 at the Saalo Research Station of the General Commission for Scientific Agricultural Research.

Methodology

This experiments were conducted in complete random block design with three replications, with the following treatments, the first was fresh water of the Euphrates, the second saline well water with EC of 19.61 dS/m, and the third was alternative irrigation of fresh and saline water with salinity of water of 8.44 dS/m.

The following parameters of pH, EC and cations and anions in water before each of irrigation portion, pH, EC, cations and anions, NPK in the three depth of 0–30, 30–60 and 60–90 cm in the beginning, middle and the end of the seasons; more over particles sizes, bulk density once in the beginning of each experiment, using the methods certified in the GCSAR laboratories.

Results and Discussion

The results showed that the first treatment (I_1) excelled over the treatments (I_2) and (I_3) significantly with the differences of 5 percent for dry weight (grain+ straw) and weight of grain, where the yield of dry weight of grain + straw were 13.26 ,11.59, 11.29 T/ha, and the grain weight (4.17, 3.48, 3.17) T/ha for each treatment, respectively, where Zeng and Vonshak (1988) attributed the decline in the biological yield (plant dry weight) at higher salinity levels and the increase of the concentration of soluble salts in the root zone. It was also found that there was an accumulation of salts in the soil by about (450 percent) when irrigating with saline water (EC=9.61 dS/m). Goral and others (1999) also mentioned that *Triticale* is a medium tolerant crop of salinity and can tolerate up to 7 dS/m. However, the accumulation of salts with alternating irrigation of fresh and saline water of (EC=8.4 dS/m) was around 88 percent, this referred to the role of fresh water in leaching some of the salt given with saline water.

Conclusions

Triticale can tolerate the salinity of irrigation water reflected relatively low decrease of biomass with high water salinity of 19.61 dS/m, comparing to the treatment of fresh water. Alternative irrigation leaded to less salt accumulation and to leach some of the salt from soil profile, however salt accumulation was recognized during use of saline water for irrigation with 451 percent with EC of water equal19.61 dS/m. With the use of saline water for irrigation it is crucial to use some leaching portions of fresh water during the cultivation season.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Physiological parameters of salt tolerance of Sorghum: water status and gas exchanges

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Keywords: Osmotic adjustment. Photosynthesis. Salt tolerance. Osmotic potential. Glicophytes plants

Introduction, scope and main objectives

Salinity is one of the major environmental constraints, compromises soil quality and consequently agricultural productivity worldwide. *Sorghum bicolor* (L.) Moench is a C4 fodder with moderate resistance to salinity; however, the mechanisms underlying the salt tolerance in sorghum plants need further investigation. In this study, we aimed to elucidate mechanisms regulating the adaptability *S. bicolor* to salt stress.

Methodology

The experiment was designed in a randomized block design, with five replicates. Sorghum seedlings grown in greenhouse and were treated with seven concentrations of NaCl saline solution (0, 20, 40, 60, 80 and 100 mM). Water potential, osmotic potential and osmotic adjustment were determined. In addition, the effect of saline stress on plant gas exchange, chlorophyll-a fluorescence and pigments was evaluated.

The data were analysed normalized by the Kolmogorov-Smirnov test. One-way ANOVA was used to test the differences between control and NaCl-treated followed by Tukey post hoc test at $p < 0.05$. Correlation tests were performed. Linear and quadratic polynomial regression analysis was performed.

Results

The results showed that irrigation with saline water reduced gas exchanges and increases water use efficiency. External NaCl treatments had no adverse impact on leaf-relative water content, and this resulted from lower leaf osmotic potential. With increasing salinity, sorghum can maintain photosynthetic efficient and enhance osmotic adjustment which contribute to improvement of plant water status.

Discussion

The increase in salinity promoted changes in the water and osmotic potentials of the sorghum plants, which represents that the sorghum adopts counter mechanistic cascades of physio-biochemical signaling to overcome salinity stress (Khan *et al.*, 2019).

Moreover, the increase the potential pressure shows which makes it possible to maintain the water flow from the soil to the plant without presenting significant loss of the relative water content and in this way can maintain practically unchanged the pressure of turgor.

As a C4 plant, has photosynthetic genes that, in addition to playing an important role in the carbon fixation, also act in the modulation of abiotic stresses, which explains the *S. bicolor* performance under stress conditions imposed in this study up 40 mM NaCl (Yadav and Mishra, 2020).

The chlorophyll contents under control were higher than those in plants under salt stress and may explain why photosynthesis in sorghum plants was higher at control treatment compared to the highest salinity concentration.

The chlorophyll fluorescence data revealed that about photosynthetic capacity in sorghum was not inhibited under salinity stress. Our study demonstrated that reduction of F0 and Fm with increasing NaCl concentration is an indication that sorghum irrigated with saline solutions up to 100 mM NaCl are salt tolerance.

Conclusions

The osmotic adjustment is the main strategies physiological for *Sorghum bicolor* adapting to saline environments.

The maintenance of photosynthetic efficiency could also help plants cope with salt stress, implying that can be an important mechanism in salt tolerance of *S. bicolor*.

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Farmers' participatory assessment of nutrient management strategies for sustainable wheat production in saline environments

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Keywords: Soil salinity, nutrient, soil health, SSNM

Introduction, scope and main objectives

To evaluate the sustainability of agricultural practices, assessment of soil health with remedial practices, using various indicators of soil quality specifically mineral nutrients; a field experiment was carried out in participatory mode to validate and compare the farmers' perception to buffer the nutrient-based salinity management with exiting recommendations and site-specific nutrient management.

Methodology

In village Nain, Panipat, Haryana (India), grid-based composite soil samples (0–15 cm depth) were collected and analysed for extent and distribution of salt stress (EC_e, pH_s), macro and micro nutrients status. Following this, two fields were selected and divided into three equal parts for comparing the fertilizer requirements for wheat production considering the traditional farmer's practice (FP), existing recommendations (RD) and soil test based site-specific nutrient management (SSNM) for sustainable wheat production. Fertilizer requirements were calculated accordingly and recommended dose was applied if the nutrient level was at optimum level, 25 percent higher dose for low to medium level, and 50 percent higher dose for very low level for a particular nutrient.

Results

In Nain village, soils were moderately saline and sodic with pH ranging from 6.87 to 9.02 (29º18'43"N & 76º47'36"E) and soil EC in range of 0.31–6.03 (29º19'30"N & 76º48'04"E). Approximately 35% soil samples were deficit in available nitrogen with medium N levels in 50 percent soil samples with range of 75–301 (kg/ha N). These soils are rich in phosphorus and phosphate with mean value of 27.79 and 348.53 (kg/ha) respectively. Forty-three percent and 21 percent soil samples were deficit in Zn and Fe, respectively where Zn content ranged from 0.15–1.74 ppm. The tested soils of selected farmer's field were found low in available nitrogen (88–100 kg N/ha), low in available phosphorus (6.27–6.94 kg/ha), medium in available K (221–243 kg/ha), low in available Zn (0.22–0.23 kg/ha) and low to medium in available Fe (2.80–5.18 kg/ha). Accordingly, site specific nutrient management practices were decided with management of DAP, MOP and $ZnSO_4$ which resulted in 8–10 percent higher wheat yield elucidating net return of approximately Rs 7000/- per hectare.

Discussion

Site-specific nutrient management combines plant nutrient requirements at each growth stage and the soil's ability to supply those nutrients within a field with proper uptake (Ahmad and Mahdi, 2018). Analysis of 2, 51, 547 soil samples from different States in India, revealed that 48 percent of samples were deficient in Zn, 33 percent in B, 13 percent in Mo, 12 percent in Fe, 5 percent in Mn and 3 percent in Cu (Chandra *et al.*, 2012). The for fertilizer application are often based on crop response data averaged over areas in different regions which sometimes may lead farmers to over-fertilize or under-fertilize their soil or crop. Alternatively, SSNM is an optimized practice for supply of soil nutrients w.r.t time and space to match crop requirements through four key principles of "4 Rs", (IPN, 2012).

Conclusions

The present study revealed the superiority of soil test-based site-specific nutrient management over other options towards optimized nutrient feeding and augmented wheat yields, economic returns and soil health in salt-affected soils. Further, précised fertilization need to be strongly addressed to halt the salinity-induced land degradation, covering wheat yield gaps and eventually achieving the UN-SGDs of land degradation neutrality and food security.

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Evaluation of early growth of wild rice following various salinity levels

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Keywords: salinity, wild rice, salinity levels, seedlings, germination, sodium, potassium

Introduction, scope and main objectives

Oryza punctata is a highly salt-resistant wild rice species, commonly found in the coastal areas of India. The almost magical salt-tolerant level of the species means that it can be grown in saline water having an EC level 20–40 dS/m submergence for quite a long period. It was revealed that *O. punctata* has some special unicellular salt hairs (trichomes) on the adaxial surface of the leaves (Al-Tamimi *et al.*, 2016; Atwell, Wang and Scafaro, 2014). Sodium and chloride were the dominant ions in the excreted material. The most critical stage in seedling establishment is usually considered as seed germination, which consequently determines the successful crop production. Understanding the responses of plants at these stages is particularly important for elucidating the mechanisms of salt resistance or sensitivity in plants and their survival (Jing and Zhang, 2017; Hasanuzzaman *et al.*, 2009)

Methodology

Experimental design

The experiment was conducted in a Randomized Complete Block Design (RCBD) with two replications in the glass house at the Agriculture Research Institute, Tandojam.

Treatment

Eight treatments were applied with saline water in ppm. T1=control (no salt applied), T2=500 ppm, T3=1000 ppm, T4=2000 ppm, T5=4000 ppm, T6=8000 ppm, T7=16000 ppm and T8=32000 ppm.

Soil Analysis

Soil texture, EC (Electrical Conductivity), pH and OM (Organic Matter) (Ryan *et al.*, 2001).

Observation to be recorded

Shoot length and shoot weight (five plants were harvested at intervals of 15 and 22 days respectively).

Plant Analysis

For quantifying the salinity tolerance potential of wild rice genotype, two high salinity tests were performed by analysing the sodium (Na) and potassium (K) concentration using (Ryan *et al.*, 2001).

Results

In invitro conditions, the experiment was conducted to evaluate the salt tolerance level of species, eight treatments were applied with saline water in ppm. T1=control (no salt applied), T2= 500 ppm, T3= 1000ppm, T4=2000 ppm, T5=4000 ppm, T6=8000 ppm, T7=16000 ppm, T8=32000 ppm in normal solution. The agronomic data was recorded initially after 15 days and then repeated at 22 days after sowing. The positive response of wild rice species towards salt stress was recorded because shoot length of wild rice was goes very well maximum to 8000 ppm.

Discussion

Firstly, the soil was analyzed to check the salinity status, then wild rice a land race checked at different (artificial) salinity levels. The first stage seedlings emerged very densely, with the population maintained at around ten plants per pot. The first five plants were observed, harvested and recorded after 15 days of germination and next five plants at 22 days. To check the soil status after the last harvesting, the soil was analyzed to check to the level of salinity at which the wild rice survived best. The study concluded with unexpected scientific results, and further studies are required to done with the salinity texture as salinity is going to degrade the soils in the world. The situation is not better in the delta required for the different crops.

Conclusions

It is concluded that dramatically the quality of wild rice variety shown from the results, as salinity level increases. Variety highlights the progressive performance in all traits as shoot, length and early growth. The performance of wild rice in salt-stressed conditions makes this variety more attractive for saline conditions. It is suggested to test *O. punctata* for large scale growing for additional value.

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Subsurface irrigation of tomato with saline water using an exudation textile pipeline: an option with risks

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Keywords: subsurface drip irrigation, saline irrigation water, pipelines clogging

Introduction, scope and main objectives

Subsurface drip irrigation (SDI) is an effective alternative for improving the behaviour of crops irrigated with saline water. Frequently, yield and quality improvement are mentioned with SDI associated to a decrease of salts at the root level (Phene *et al.* 1991; Hanson and May, 2004). However, known evaluations use drip emitters but the behaviour of tomato crop with SDI using an exudation textile pipeline (EP) was unknown, which by including three salinity levels of irrigation water becomes the aim of this study.

Methodology

Early results in SDI (Kahlaoui *et al.*, 2011) together with our previous hydraulic evaluations of an EP (2013) were the background for an experiment set in 2019 aiming to compare EP in SDI for tomato crop with surface drip irrigation (DI) using a drip tape (n=5). Irrigation water was 2.5 and 5 dS/m for saline irrigation treatments, set as convenient levels for evaluating tomato based on Ayers and Westcot (1985) and Misle and Kahlaoui (2015). Non-saline water for the control treatment came from a well (0.24 dS/m). EP 16 mm was installed 20 cm depth and each experimental unit of 3 m length was randomized accordingly. Soil density was 1.31 g/cm^3, field capacity 0.33 and permanent wilt point 0.184. Irrigation was carried out according to Allen *et al.* (1998). Leaf area was evaluated at 20, 40, 60, 80, 100 and 120 d after transplant (DAT), measuring leaf width and length for further calculation by an allometric function (Schwarz and Kläring, 2001). Total soluble solids (SS), titratable acidity (TA), diameter and weight were determined for fruits. Total yield and aerial biomass was also measured. Two way anova and Tukey ($p< 0.05$) test when corresponding was used for statistical analysis.

Results

SDI overpassed DI until 60 DAT by 27 percent in leaf area ($p< 0.05$), having no significant differences among salinity treatments. Fruit weight and diameter decreased in response to increasing salinity corresponding to a decrease of 21 percent and 41 percent in yield using DI with 2.5 and 5.0 dS/m, respectively. However, SS, TA, fruit diameter and weight, aerial biomass as well as yield, revealed significant differences at harvest in EP not attributable to salinity effects but to water deficit caused by pipelines clogging with roots. Notably, the more the salinity, the less the pipelines clogged. Even more, root biomass found inside pipelines correlated negatively with aerial biomass, leaf area and yield.

Discussion

Despite our evaluations on EP as DI in 2013 revealed an acceptable Christiansen's uniformity coefficient (0.85 at 0.3 bar) using a hydraulic test unit, a first suspect of clogging was found by that time irrigating tomato with DI. Certainly, pressure can be a factor to consider but in 2019 we used the same 3 m hydraulic constant head employed in 2013, good quality well water and 120 mesh filtration. Surprisingly, roots were able to grow inside the pipeline. Root intrusion has been reported for SDI and different preventive designs have been created (Lamm and Camp, 2007).

Some changes in irrigation pressure and frequency may help but this cannot warrant the absence of root intrusion.

Conclusions

EP has acceptable uniformity for a line without emitters but is exposed to root intrusion, causing clogging of pipelines. Studied parameters confirmed a superiority of SDI over DI until 60 DAT previous to root intrusion. So that the subsequent clogging by roots makes it impossible to support EP for SDI unless further experiments can provide different evidence.

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Concentrated phosphate fertilizers: agrochemical efficiency and environmental safety on saline soils

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Keywords: phosphorus, fertilizers, soil, efficiency, cotton, harvest, macronutrients

Introduction, scope and main objectives

New, concentrated phosphorus fertilizers, such as enriched superphosphate, ammoniated superphosphate and ammophosphate have slow-release properties and are developed specifically for use on saline soils under irrigation conditions. The fertilizers are obtained by innovative technology. The use of prolonged fertilizers optimizes plant nutrition, helps to reduce the loss of macronutrients and increases their efficiency.

Methodology

Using a complex of physical, chemical, microbiological and biochemical studies the following have been assessed: 1) the rate of nutrients release from fertilizer granules; 2) the impact of concentrated fertilizers on the dynamics of macronutrients in the soil, as well as the growth, development and productivity of cotton; 3) the dynamics of microbial activity in the soil, including the number of microorganisms and 4) the activity of enzymes involved in P and N transformation.

At the beginning of the experiment and at the main phases of plant development, the physical and chemical properties were determined by the procedures described by Estefan (2017): concentrations of soil organic matter, total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus and available potassium.

To estimate the number of living microorganisms in soil, the dilution plate method was used. The oligonitrophylic, oligotrophic, ammonifying bacteria, bacillus, actinomycetes and amylolytic microorganisms were identified by (Pansu and Gautheyrou, 2016). Enzyme activity (phosphatase and urease) in the soil was measured with methods using sodium phenolphthalein phosphate and urea as substrates (Bab'eva and Zenova, 1989).

Results

Laboratory and lysimetric experiments on two types of soils (saline and typical Sierozem) showed that new, concentrated phosphorus fertilizers had a positive effect on the development of cotton plants, stimulating the growth of plant organs by 3–19 percent, enhancing the uptake of elements and increasing the aboveground mass and cotton yield. Obviously, the formation of vegetative and reproductive biomass is probably provided mainly due to the use of nutrients, which are included in fertilizers.

An increase of yield by 2.2–12.1 percent was observed on typical Sierozem, while on a saline Sierozem an increase in yield of 6.4 percent was achieved with the addition of ammophosphate. This is simply related to the worst growing conditions under salinity.

In a saline Sierozem, there was an increase in the amount of SOM by 13–15.4 percent, NH_4 by 3.6–43.1 percent, NO_3 by 21–95.8 percent, P tot by 22.7–42 percent and P_2O_5 by 73.6–24 percent in comparison with the initial early spring soil levels.

The new phosphorus fertilizers contributed to an increase in the number of oligotrophic, ammonifying, amylolytic and oligonitrophilic microorganisms, with a sharp increase in the proportion of active destructors - the actinomycetes and bacilli.

The study showed the protective effect of new fertilizers on enzyme activity in saline Sierozem. It was found that the activity of phosphatase was 10–80 percent higher in saline soil with ammophosphate addition, while no significant effect on urease activity was revealed.

Conclusions

Prolonged properties of the new fertilizer are achieved by regulating the solubility of granules, with a slow and gradual release of nutrients into the rhizosphere during the plants' growing season. It should be noted that the nutritional effect of fertilizers is significantly reduced in saline conditions. Nevertheless, the new extended fertilizers can be successfully applied to saline soils, since they have a protective effect in terms of reducing the rate of transformation of available phosphorus compounds, preserving them in the soil for a longer time.

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Saline soil reclamation though cut-soiler drainage technology: Spatio-temporal assessment

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Keywords: Soil salinity, cut-soiler, EM-38, Spatio-temporal mapping

Introduction

Soil salinity is a serious environmental threat adversely affecting the crop yield and soil productivity. Major reclamation of such potentially productive soil is leaching and draining out of excess salt through drainage. Cut- soiler is a machine that cuts and opens V-shape furrow at 40–60 cm soil depth and fills it back with scattered residue lying on soil surface. It improves soil permeability and help to draining out saline water from surface and vadose zone.

Methodology

The cut-soiler was run at 2.5, 5.0 and 7.5 and 10.0 m spacing at 50 cm depth with straw as residue incorporation and being monitored for spatio-temporal changes in soil salinity and improvement in crop yield at Nain experimental farm, CSSRI. Spatio-temporal changes in salinity in upper (0–50 cm) and below (50–90 cm) cutsoiler depths was measured trough EM-38 techniques and modeled through quasi-3-dimensional inversion algorithm and mapped.

Results

Model derived apparent conductivity (EC_a) significantly correlated with field measured EC_e for upper (R^2–0.66) and below (R^2–0.64) cut-soiler depths. Successful operation of cutsoiler over a period of three years 2018 to 2020 revealed that, in upper cutsoiler layer (0–15 cm), non-saline to slightly saline (<4–6 dS/m) area was increased by 4 percent and high to very high (8–16) saline area decreased by 18 percent in 2.5 m spacing cutsoiler as compared to control. The improvement in land area was more prominent in closer the spacing of cutsoiler installation. This improvement of land resulted in increasing crop yield. In three years (2018–2020), 22 and 32 percent increase in average pearl millate and mustard yield was recorded in 2.5m spacing cutsoiler installed plot compared to uninstalled plot.

Discussion

Increase in non-saline area and reduction in high and very high saline area (8–16 dS/m) under different cutsoiler spacing installation mainly be attributed to the draining out more salts through preferential path created by cutsoiler in subsurface layer. This draining out excess salts in addition to natural leaching process improves the land and increase crop yield

Conclusions

The overall results of the study suggest that cut-soiler has significant effect on desalinization process and improving crop yield in waterlogged saline soil

Acknowledgements

ICAR, JIRCAS

Effect of different mulching rate on productivity of winter wheat yield under no-till method in salt-affected regions of Uzbekistan

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Keywords: manure, soil, salinity, no-till method, irrigation, yield

Introduction
Salinity is becoming a major problem in Uzbekistan, which is increasing year after year, and thereby adversely affecting crop yields. There are different options by which the salinity problem can be managed. These include the use of salt-tolerant varieties, cropping system diversification, and adopting Conservation Agriculture (CA) which can also include salt-tolerant varieties and diversified cropping such as cotton-wheat-legume cropping systems. Mulching or crop residue retention is one of the simplest and most beneficial practices. Manure application has been used from ancient times in Uzbekistan as a fertilizer for crop cultivation, being rich in nitrogen and other nutrients which facilitate the growth of plants. The objective of this research was to study the effect of different mulching rates on the productivity of winter wheat yield under a no-till method.

Methods
The experiment was conducted between 2016 and 2018. A salt-tolerant winter wheat variety, Dostlik was sown using a no-till method in the experiment.

Results
One of the main CA practices is the creation of crop residue in the field with stubble stems and chopped straw, which provides the full effect of mulching. Consequently, salts will not be accumulated in the upper layer of the soil due to decreased evaporation. Soil mulching with crop residue and manure decreased the salt content in 0–10 cm soil layer 1.9–3.2 times. Current research evidence from irrigated production in Uzbekistan shows that mulching through crop residue retention is effective in combating salinity.

The increase of manure levels from 10 t/ha to 20 t/ha also brought a significant increase in yield and yield-contributing traits. The coefficient of variation was 10.8. Winter wheat yield under mulching treatments was numerically higher than the control treatment. Wheat yield in treatments with manure application was 0.23–0.97 t/ha higher than in control plots, which was 3.52 t/ha. This is because the evaporative loss of water from mulching plots is lower than that of plots without mulching. With reduced evaporation, the accumulation of salts in the root zone decreases, facilitating the proliferation of roots and in turn greater yields.

Conclusion
We clearly realize that some residue retention will be essential before attempting to adopt CA practices, even though the primary goal may be to simply realize lower production costs which is common with tillage reductions.

Technology of cultivation of super early potatoes in the conditions of slightly saline irrigated light serozom soils of the Kashkadarya region

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Keywords: slightly saline light Serozom soil, potato varieties, soil mulching, plant growth, development

Introduction, scope and main objectives

For growing very early potatoes, planting begins in early spring, as soon as agricultural machinery can be used in the field. For each day that planting is delayed the early harvest reduces by an average of 1 percent (Ostonakulov, 2018; Serderov and Serderova, 2021). Soil mulching offers many advantages- it makes it possible to regulate the temperature and moisture of the soil, without the formation of a crust, the destruction of weeds and improves the activity of beneficial microorganisms in the soil.

Methodology

The experiments were carried out in the Ochiloy Zakhirova farm (slightly saline-chlorine anion 0.018–0.025 percent). The soil was an irrigated light Serozom soil, medium loamy texture, 2–3 m of groundwater depth. The agrochemical characteristics of the topsoil in terms of availability of mobile nitrogen was very low, mobile phosphorus was low, and exchangeable potassium was medium.

In the study, the varieties were compared over four planting dates (15.04–20.04, 30.01–05.02, 15.02–20.02, and 02.03–07.03–control) in 2018, 2019 and 2020.

In each period, four types of soil mulching were studied; without mulch (control), manure, film, and manure plus film.

Results

With planting from 15–20 January, the studied varieties all showed fully-formed shoots on the 31–32nd day after planting in the variant of soil mulching with manure plus film, three to seven days earlier than control. The seedlings appeared with the Saviola cultivar at 25 days, the Silvana cultivar by 21 days, and the Arizona cultivar appeared 23 days after planting. When mulching with manure and film, the seedlings appeared according to varieties two to five days earlier.

In the studied varieties with planting from 30 January to 5 February, in the control variant, 0.55–0.64 m^2 of plant leaf area was formed, and with mulching 0.70–0.93 m^2.

The highest yield (29.7–32.9 t/ha) was obtained at planting dates of 30 January to 5 February with mulching manure (5–8 t/ha) plus film.

Discussion

On slightly saline soils, the study of potato varieties and the development of their individual elements of cultivation technology are discussed in the works of Zuev *et al.* (2005), and Abdurakhimov (2014).

In the slightly saline conditions of irrigated light Serozom soils of the southern region of the republic, we identified the formation of growth, development and yield of potatoes in the context of modern early and mid-early varieties, which the data obtained agreeing with the results of the above authors.

Conclusions

To obtain a high yielding and super-early harvest of potatoes in the slightly saline conditions of irrigated light serozom soils of the Kashkadarya region, it is necessary to cultivate the selected varieties–Gala, Silvana, Saviola, Arizona, Evolution, Bogizogon and Yarokli-2010, planting in the last ten days of January and the first ten days of February with mulching manure plus film. This forms tall plants (74.4–87.0 cm) with powerful tops (375–412 g) and a large leaf surface (0.81–0.93 m^2) which ultimately contribute to obtaining a very early harvest (up to 1 June) with a yield of 28.3–30.9 t/ha.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Site specific varietal selection and application of partially burnt rice husk to improve the productivity of salinity affected rice growing soils in Mahaweli System 'H' majour irrigation scheme in Sri Lanka

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Keywords: partially burnt rice husk, proximal soil sensing, salt-tolerant rice varieties, soil salinity

Introduction, scope and main objectives

Development of saline conditions in rice growing soils has become one of the major constraints that reduce the crop productivity in a number of irrigated areas in the dry zone of Sri Lanka (Perera *et al.*, 2015; Sirisena and Hemachandra, 2007). Nayakkorala (1998) and Perera *et al.* (2015) reported the development of salinity in some of the agricultural lands of the Mahaweli irrigation systems. Hence, this study was conducted to assess the effectiveness of the site-specific varietal selection and application of partially burnt rice husk to the salinity management classes identified based on the proximally sensed soil electrical conductivity to improve the productivity of salinity affected rice growing soils in Mahaweli System 'H' majour irrigation scheme in the dry zone of Sri Lanka.

Methodology

Two sites were selected in Galnewa and Thalawa areas in Mahaweli System 'H' where rice–other field crops cropping system has been practiced for nearly thirty years. The salinity management classes identified based on the proximally sensed electrical conductivity data of the topsoil (0–40 cm depth) in the Galnewa and Thalawa experimental sites in a previous study were used for the experiment (Perera, Vitharana and Nawarathne, 2015). The resultant average electrical conductivity (ECe) values were 0.38 dS/ m, 0.48 dS/ m and 0.60 dS/ m in the identified salinity management class 1, 2 and 3 respectively. Non-salinity tolerant rice variety Bg 300 and salinity tolerant variety Bg 310 were investigated for their growth and yield performances without and with the application of Partially Burnt Rice Husk (PBRH).

Results

The ECe levels in all the salinity management classes at the commencement of the Yala growing season were significantly higher than the ECe levels recorded at the commencement of the Maha growing season indicating a greater salt stress for rice cultivation from the onset of the Yala season. The variety Bg 310 showed 25–45 percent yield increment compared to the yield of the variety Bg 300 in the salinity management classes with comparatively higher electrical conductivity levels in the Yala growing season.

The application of PBRH increased the rice yields and the benefits were more distinct under the salt affected conditions recording around 20 percent more yields from the higher rate of PBRH applied plots compared to the yields obtained from the PBRH unamended plots in the salinity management classes with higher electrical conductivity levels in the Yala growing season.

Discussion

The data obtained from the weather station located near to the experimental site indicated greater net evaporation loss of soil water under lower precipitation received in between the Maha 2015–2016 and the Yala 2016 growing seasons compared to evaporation loss of soil moisture between the

Yala 2015 and the Maha 2015–2016 growing seasons, leading to comparatively higher salinity at the on-set of Yala growing season.

The crop performances explained by the growth parameters were significantly higher in the salt tolerant rice variety Bg 310 compared to those of the non-salt tolerant rice variety Bg 300 in the salinity management class two and three in the Yala 2016 growing season indicating a higher potential of the salt tolerant rice variety to give higher yields in salt affected soils. Sirisena *et al.* (2011) has also reported obtaining significantly higher rice yields from newly developed salt tolerant rice lines compared to those of the salt sensitive varieties in salt affected soils in major irrigated areas.

The results clearly indicated the importance of the application of PBRH on the basis of salinity management classes to enhance the productivity in rice cultivation. Results indicated benefits of application of PBRH for relatively less saline salinity management class one during the drier Yala season within which an increase of soil sanity level was observed. Especially in the drier Yala season, further increase of the application rate of PBRH need to be researched for the salinity management classes two and three.

Conclusions

Site specific varietal selection and application of PBRH to the salinity management classes identified based on the proximally sensed soil electrical conductivity has a considerable potential for further improvement of the rice yields in salinity affected rice growing soils in the dry zone of Sri Lanka. Further, the results of this work showed the need of further increasing of the PBRH rates in the salinity management classes with higher electrical conductivity levels.

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Preliminary surveys of natural plant species tolerant to severe salinity on the Al-Jabbul Lake banks

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Keywords: salt tolerant Plant species, severe salinity, Al-Jabbul Lake, natural plants.

Introduction, scope and main objectives

Salinity is one of the most important environmental stresses that threatens the agricultural production in arid and semi-arid areas, which negatively affects plant biodiversity (Ghazanfar *et al.*, 1995), furthermore, the biological method of saline soils reclamation comes to the fore especially in conditions of water scarcity, and becomes the vital solution for reclaiming of saline soils in arid and semi-arid areas (Kamel, 2001). The aim of this study is to investigate the most important natural tolerant to severe salinity plant species naturally scattered on the banks of the Al-Jabbul Lake to be a potential source for further breeding and growing.

Methodology

Depending on Field survey and reviewing of different references, severe salinity tolerant plant species (> 35 dS/m) were classified, taking in consideration the following factors:

- The taxonomic status of the species, the scientific name according to the genus and families
- Botanical description of these species, leaves, flowers, fruits, and flowering date.
- The use of each of these types.

Results

The survey of the study area lead to find the following severe salinity tolerant plant species in the bank of Al-Jabbul Lake in the north of Syria to the east of city Aleppo:

- *Aloe vera* (L) Burm. F. family *Aloaceae*
- Aeluropus littoralis (Gouan) Pari family *Gramineae*
- *Juncus subulatus*, Forsk family *Juncaceae*
- *Arthrocnemum glaucum,* (Del.) Ung-Sternb family *Chenopodiaceae*
- *Seidlitzia rosmarinus* (Ehr.) Bge family *Chenopodiaceae*
- *Salicornia strobilacea* Pall family *Chenopodiaceae*
- *Gressa cretica* L family *Convolvulaceae*
- *Launaea nudicaulis* (L.) Hook. F Family *Compositae*
- Pulicaria inuloides (Poir.) DC Family *Compositae*
- Fagonia bruguieri DC Family *Zygophyllacee.*

Discussion

There are three characteristics of these plants that make them able to tolerate dissolved salts:

- Juiciness: It means its ability to retain a large amount of water in its stems and leaves, and this phenomenon can be explained by the attempt of these plants to dilute the cellular juice, whose concentration increases due to the absorption of chlorides.
- Secretion of salts: Some halophytic plants secrete salts through saline glands located on their leaves or stems, and within these glands there are a number of active cells work to pump the concentrated saline solution from the plant cells to the outside. Such as *Aeluropus littoralis* (Gouan) Pari, *Juncus subulatus* Forsk, *Gressa cretica* L.
- Elimination of some parts of the plant: a phenomenon of partial death for the continuation of life, and the reason for this phenomenon is the concentration of salts in some parts of the

plant throughout the growing season, when the concentration of salts reaches the critical level, parts of the plant die and fall off, removing large amount of salt. (Bitanuni, 1986).

Conclusions

- The region is rich in distinct species of salt-tolerant plants to varying rates.
- Tolerant species to severe salinity have many uses as nutritional, fodder, medical or industrial, as well as can be used in ornamental gardens.
- The importance of these types comes from the fact that they can be grown on saline lands outside the scope of agricultural investment, to benefit from them and receive an economic return through the multiple benefits of these plant.
- Reduction of soil salinity, as the salt-tolerant plants absorb huge quantity of salts, so their cultivation on saline soils will reclaim and remove the salts from soil profile.

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Exploration of desert halophytes plant for rehabilitation of saline soils through phytoremediation

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Keywords: Halophytes, Salinity, Phytoremediation, chlorophyll, K+, Na+

Introduction, scope and main objectives

Salinity is affecting almost 20 percent of land under cultivation and almost half of land under irrigation across the globe (Cheong and Yun, 2007). It is nearly affecting 15 percent of world's total area. Phytoremediation can be inexpensive and ecologically sound technique for remediation of saline soils (Hasanuzzamn *et a*l., 2014). This study concerns about assessment of salinity stress to shrubs *Capparis decidua* and *Haloxylon salicornicum* in order to suggest them to reclaim saline soils.

Methodology

C. decidua and *H. salicornicum* raised in nursery were shifted to hydroponic system. Before application of treatments plants were irrigated after every three days a week with a half-strength Hoagland solution for three months. Solutions pH was maintained at 5.5 to 7.0. At end of experiment samples were harvested and oven dried at 50 ^{0}C. Each species having four treatments and three replications were subjected to different doses of NaCl salt applications at 0, 70, 140, 210 mM level in a Completely Randomized Design (Kong and Zheng, 2014).

Results

Number of leaves increased for *C. decidua* initially but decreased at T4 (19). Number of leaves for *H. salicornicum* increased to maximum at T4 (27). For *C. decidua* weight mean was maximum at T3 (3.35g) but declined at T4 (2.1g). Weight initially increased and was minimal influenced at T3 (8.33g) but then increased at higher level for *H. salicornicum*. Shoot length increased for *C. decidua*, maximum at T3 (140cm) and then declined. *H. salicornicum* shoot length is not affected by salinity. This shows species is well adapted to highly saline areas. Both species root length is not affected by salinity levels. Shoot fresh weight measured was higher in *H. salicornicum* (13g) as compared to *C. decidua* (2.6 g). Shoot dry weight measured was maximum in *H. salicornicum* at T2 (11.6 g) and remained high for *C. decidua* at T1 (7.4g) Maximum shoot dry weight is shown by *H. salicornicum*. Root dry weight was increased at T4 for *C. decidua* but showed an irregular pattern for *H. salicornicum*. Root fresh weight was higher at T1 for *C. decidua* then continuously declined but showed an irregular pattern for *H. salicornicum*. Na^+ uptake increased in both species maximum at T4 (50459 and 60117ppm) respectively K^+ uptake decreased in both species maximum at T1 (50162 and 56632 ppm) respectively.

Discussion

Ecological sound management of saline soils is a prerequisite towards sustainable development. Biomass production initially increased in *H. salicornicum* and was minimal influenced at higher level. These results suggests *H. salicornicum* more salt tolerant and are similar to the findings of (Naz *et al.*, 2010) which shows species is most dominant in term of percent cover under saline conditions. Salinity stress may cause death of plant, chlorosis and necrotic stains (Mer *et al.*, 2000; Antcliff, Newman and Barrett, 1983) stated that plant species which are able to limit salt accumulation in shoot are more resistant to salinity. Na^+ uptake increased in both species at all treatment levels. While at the same time K^+ uptake was decreased in both species at all treatment levels. *C. decidua* low palatable can grow under normal to moderate salinity stress as compared to *H. salicornicum* and available year around which grows under highly saline environments (Ali, Chaudhry and Farooq, 2009).

Conclusions

C. decidua is suggested for planting in normal to moderately saline soils and *H. salicornicum* for highly saline above 210 mM concentrations of salts. Planting these species would help in successful reclamation efforts.

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Inorganic and Organic Amendments and Irrigation Water Quality affect P Losses in Saline-sodic soil

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Keywords: City waste compost, Saline-sodic soil, P fractions, leachate, sodium absorption ratio

Introduction

Integrated application of gypsum and city waste compost is recommended for reclamation of saline-sodic soils. After application of amendments leaching is advocated to remove the soluble salts which are generated during exchange reactions. Besides neutralization of sodicity, use of amendments has profound influence in P retention because the process of reclamation alters the P retention capacity and thereby increasing risk of P losses. The P losses also differ with application of variable water qualities. Therefore, study of P losses from soils is important for evaluating agronomic efficacy of P as well as environmental point of view.

Methodology

A laboratory study was conducted at CSSRI, Karnal, India with sodic soils having pH_s 10.0, EC_e 12.2 dS/m and exchangeable sodium per cent (ESP) 77 percent and gypsum requirement (GR100) 22.7 Mg/ha. The unamended (control) and amended soil was incubated in 60 percent field capacity with 25, 50 percent recommended doses of gypsum, GR25 and GR50 and integrated treatments 25GR + Mg/ha FYM (GR25F10); 25GR + 10 Mg/ha of Karnal GR25KC10) and Delhi compost (GR25DC10) for 30 days. After completion of incubation, soil was packed in columns with 1.66 kg air-dried soil to a depth of 15 cm. Further, soil was intensively leached up to ten pore volumes separately with different water qualities normal irrigation water (NIW), and saline-SAR water with fixed salinity of 6.0 dS/m with two-level of SAR of 5.0 and 15 $mmol^{1/2}/L^{1/2}$. Soluble and total P was analyzed in individual pore volumes of soil leachates. After completion of leaching soil columns were broken and air dried for analyzing soil P fractions.

Results

Gypsum (Gyp) applied at the rate of 25GR or 50GR had lower dissolved reactive P (DRP) in leachates compared to control. The quantity of P in leachates was greater in the form DRP than particulate P (PP). Addition of gypsum and compost 25GRF10 reduced (81 percent) the P losses in form of DRP upto fifth pore volumes followed by 25GRK10 (76 percent). Overall, cumulative P losses decreased by amending 50GR Gyp (66.8 percent) than control (92.4) ($P < 0.05$). Irrespective of treatments, the cumulative P losses through DRP were greater (109.4 me/l) when leaching with NIW compared to SAR 15 (71.7 me/l) and SAR 5 (64.6 me/l). Organic, Olsen's and water extractable P in soil were greater in 50GR Gyp followed by 25GRK10/D10/F10.

Discussion

The dissolution of gypsum produces Ca^{2+}_{sol} which occurs precipitation of P as CaP. The cumulative DRP concentration in Gyp was lower in the leachate may be formation of CaP. Total P leaching in the treated soil was significantly reduced because increasing exchangeable Ca^{2+} in the soil. Low concentration of electrolytes in NIW promotes deflocculation which may further enhance the P losses.

Conclusions

Amending soil with 50GR gypsum or integrated application of 25GR and 10 Mg/ha of compost followed by leaching with low SAR water to prevent soil P loss during reclamation.

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Effect of saline water with different irrigation methods on soil, yield and water use efficiency of tomato (*Solanum Lycopersicum)* under Tungabhadra Project Command

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Keywords: Surface drip irrigation, Subsurface drip irrigation, Water requirement, Salinity level, Yield, Water use efficiency, HYDRUS-1D

Introduction, scope and main objectives

Utilization of saline water for irrigation is associated with salt accumulation in the soil, which is harmful to plants, and reduces yields. When water resources are limited and the cost of non-saline water becomes prohibitive, crops of moderate to high salt tolerance can be irrigated with saline water especially at later growth stages, provided appropriate irrigation methods and management practices are used. Many farmers in Tungabhadra Project (TBP) command area use saline ground water. No information is available on the effect of use of saline water on soil properties and the threshold limit to use it.

Methodology

A comparative study was carried out at Agricultural Research station, Gangavathi (Karnataka) in 2017–2018 and 2018–2019 to study the effect of three (Furrow, Surface drip and Subsurface drip) irrigation techniques and five different salinity (0.65 dS/m (normal water), 2, 3, 4 and 5 dS/m) irrigation water levels on soil physico-chemical properties, yield and water use efficiency of tomato.

Results

The water saved in surface drip and subsurface drip over furrow irrigation was found to be 41.0 to 45.7 percent and 46.3 to 54.7 percent from 0.65 dS/m to 5 dS/m saline water treatments respectively (Wan *et al*, 2007). In SDI, accumulation of salts was more at the soil surface but it was lesser near and below the buried dripper. In surface drip and subsurface drip irrigation techniques there was 30.9 and 34.0 percent increase in the total yield as compared to furrow technique. There was 3.96, 17.53, 25.13 and 34.63 percent reduction in yield in case of 2, 3, 4 and 5 dS/m respectively as compared to 0.65 dS/m treatment (Malash, Flowers and Ragab, 2008; Chen *et al.*, 2010). It was found that every one dS/m increase in salinity reduced 9–10 percent of yield.

Discussion

The maximum water use efficiency was under subsurface drip irrigation technique because of the lesser water requirement due to application of water at the root zone of tomato during growing season and also higher yields. The HYDRUS-1D model can be used for prediction and simulation studies in water and solute movement.

Conclusion

When there is not enough fresh or good quality water available for irrigation, saline water up to 2 dS/m can be applied as an alternative water source to irrigate the tomato crop in black soils with surface or subsurface drip irrigation techniques to get on par yield without much affect to the soil in TBP command area.

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Effect of irrigation management on soil properties, growth and yield of sugarcane *(Saccharum officinarum)* in waterlogged saline Vertisols under Tungabhadra Project Command area

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Keywords: Evapotranspiration, Saline soils, Subsurface drip irrigation, Sugar Water Use Efficiency, Water Use Efficiency

Introduction, scope and main objectives

In the Tungabhadra project command (TBP) area, subsurface drainage systems are being installed to reclaim waterlogged and salinity area, but due to higher investment cost for individuals per unit area and very poor technical knowledge on installation, adoption of this technology taking a back seat. Some individual farmers do not have the required elevation difference with natural drainage. All the waterlogged and salinity areas of the TBP command cannot be brought under the subsurface drainage system. Instead, soft options like surface or subsurface drip irrigation technology under the waterlogged and salinity area could be a better option. However, surface drip irrigation under saline soils is less effective as the water applied may not effectively leach down salts. To overcome these problems, subsurface drip irrigation (SSDI) is tested in saline soils.

Methodology

A field experiment was conducted at Agricultural Research Station, Gangavathi, Karnataka, India, to know the effect of different irrigation techniques and irrigation levels on soil properties, growth and yield of salt-tolerant sugarcane in saline Vertisols of TBP command. The experiment was laid out in saline soils (4–6 dS/m) with irrigation methods viz., surface drip, subsurface drip, and furrow irrigation as main treatments and with irrigation levels viz., 0.8, 1.0, and 1.2 evapotranspiration (ET) as sub treatments.

Results

Higher moisture was retained and more salts were leached out from the root zone in subsurface drip-irrigated with 1.2 ET level treatments and water table was deeper. Among different irrigation techniques, higher cane yield (131.0 t/ha) was recorded in subsurface drip irrigation and among different irrigation levels, the higher yield was recorded in 1.2 ET level (124.7 t/ha). Similarly, higher water use efficiency (WUE) and sugar water use efficiency of 83.0 kg ha/mm and 1.72 kg/m^3 were recorded in subsurface drip irrigation respectively and more salts were leached out at sugarcane roots in SSDI.

Discussion

Subsurface drip irrigation with 1.2 ET level treatments in saline recorded higher cane yield due higher salt leaching and lowering of water table (Wang *et al.*, 2011) and higher moisture was retained in at deeper depths (Santos *et al.*, 2016).

Conclusions

Improved subsurface drip irrigation technique with 1.2 ET regimes had contributed to better performance of the crop under saline soils. Hence, this practice can be considered as a viable option to improve the crop productivity of sugarcane in the TBP command and could be an option for replacing drainage system.

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Evolution and change of the main properties of difficult-to-reclaim saline soils of the desert zone Uzbekistan during irrigation

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Keywords: soils, gray-brown, evolution, reclaimed, saline, gypsum, desert, humus

Introduction, scope and main objectives

In Uzbekistan, the soils of the desert zone account for almost half of the land fund of the republic. Among them, 24.3 percent or 11.0 million hectares are occupied by gray-brown and gray-brown-meadow soils, the main part of which is mainly used for pastures (Kuziev and Sektimenko, 2009; Kuziev *et al*., 2010). Due to unfavorable soil-reclamation conditions associated with their salinity, gypsum content and remoteness from water sources, their share in irrigated agriculture is small - 140 .0 thousand hectares or 1.3 percent of the total area. Despite this, gray-brown soils are of particular interest from the point of view of their use as pasture livestock, and when searching for water sources, where possible, and small-scale irrigated agriculture. Gray-brown soils are irrigated mainly on the Malikchul plain (Kushakov, 2007), the Bukhara oasis (Artikova, 2019), the Tashsaka plateau (Madrimov, 2019; Gafurova *et al*., 2019).

Methodology

The research included field and laboratory work. Field work was carried out by a comparative geographical method with the laying of sections on hypsometric levels. Laboratory work included the determination of the mechanical composition of soils, humus, easily soluble salts, gypsum, batteries (Machigin *et al*., 1963; Sokolov, 1975), of mobile oxides and a half (Arinushkina, 1970).

Results

Prolonged irrigation of gray-brown soils on the plateau with fresh water leads to the redistribution of water-soluble salts in the direction of their indentation into the underlying soil layers. Strongly and very strongly saline gray-brown soils pass into the category of unsalted and slightly saline, chloride-calcium-sodium salinity passes to chloride-sulfate and sulfate, magnesium-calcium, the alkalinity of the aqueous solution decreases to 0.06 percent, the content of organic matter increases from 0.76 percent to 1.80 percent. Irrigation of soils with weakly and medium mineralized waters leads to an increase in the degree of salinity in the upper horizons, the humus content remains unchanged, while there is a decrease in the total alkalinity and leaching of gypsum deposits with the same content of humus and nutrients. In the irrigated soils of the Tashsaka plateau, humus increases from 0.35 percent to 0.74 percent.

Discussion

Irrigation of gray-brown soils with fresh water leads to positive results, namely, to leaching from easily soluble salts and gypsum, an increase in the content of organic matter and changes in its qualitative composition towards the transition of the fulvate type to the fulvate-humate type, the exposure of the biologically active soil layer increases the effective soil fertility.

Conclusion

The results of the research revealed the positive influence irrigation in the use of saline gray-brown soils in compliance with agrotechnical and reclamation measures.

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Soil salinity control in an era of risks and opportunities: Insights from physics-based numerical simulations of flow and transport

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Keywords: Treated Waste Water, Desalinized Water, Field scale water flow and solute transport, Numerical simulations, crop production, groundwater quality

Introduction, scope and main objectives

Declining water resources impose irrigation with low-quality water (LQW) which may have negative effects on crop, soil (Bernstein, 1975), and, consequently, on water and solute movement through the soil, and, eventually, on groundwater quality (Russo *et al.*, 2009). The problem is expected to worsen due to global warming. It is clear, therefore, that soil salinity management will remain the core challenge for the future irrigation, requiring improved irrigation-management schemes with emphasis on minimizing damage to agricultural productivity and environment quality (Assouline *et al.*, 2015).

The traditional leaching requirement (LR) concept for salinity control is based on a simplified, mass balance approach which disregards the complex plant-soil-water-salt interactions (van Schilfgaarde *et al.*, 1974; Ayers and Westcot, 1985). It promotes salt removal from the soil by applying excess amounts of irrigation water.

Due to technological innovations, desalinated water (DSW) obtained by a reverse-osmosis technique (Tal, 2006; Elimelech and Phillip, 2011), may be considered as a competitive source of high quality water (HQW) for irrigation (Ben-Gal, Yermiyahu and Cohen, 2009; Silber *et al.*, 2015). This allows a different approach for soil salinity control, namely, salt removal from the irrigation water prior to its application to the soil. Cost, lack of nutrients, and low salinity, however, may restrict the use of DSW for irrigation. Consequently, the efficient use of DSW for irrigation and salinity control, should cope with the aforementioned limitations, relying on a data-driven irrigation management scheme (Russo *et al.*, 2015).

The objectives of this presentation are: (i) to assess consequences of soil salinity control based on the traditional LR concept, on crop yield and groundwater quality, and (ii) to present and analyze advanced data-driven, irrigation management scheme for salinity control.

Methodology

To pursue the aforementioned goals, flow and transport in a realistic soil-water-plant-atmosphere system are simulated using a physics-based 3-D flow and transport model (Russo *et al.*, 2015), considering soil-water-plant-salt interactions along with realistic features of the flow system (*i.e.*, temporal and/or spatial variations of soil, plant, irrigation weather and water table depth).

Results

Regarding Objective (i). The results of the simulations suggest that in contrast to predictions based on the LR concept, when LQW is used, the damage to the crops yield is unavoidable, and salt load in the groundwater may increase substantially. Furthermore, the results of the analysis suggest that from both agricultural, and, particularly, environmental perspectives, irrigation with high-quality water (HQW) is desirable.

Regarding Objective (ii). A data-driven protocol for soil salinity control (ADW), based on alternating irrigation water quality between TWW and DSW (obtained by desalinization of TWW), guided by the soil solution salinity at the centroid of the soil volume active in water uptake is presented and analyzed. The protocol aims at minimizing the use of the HQW (DSW) while maintaining desired levels of crop productivity and groundwater quality. The performance of the ADW scheme is determined by a user-controlled, critical root-zone concentration, Ccr. Results of the analyses suggest that the ADW scheme may lead to a substantial increase in crop yield, and, particularly, to a substantial decrease in the salinity load in the groundwater.

Discussion

The results of the simulations are explained by the non-linear relationships between water uptake by plant roots and the flow-controlled attributes (i.e., solute concentrations, water content), which, in turn, mutually depend on the soil hydraulic properties, and also depend on the boundary and initial conditions imposed on the flow system. An increase in soil salinity in the root zone causes a reduction in water uptake by the plant roots (i.e., a reduction in crop yield), resulting in an increase in soil water content and soil hydraulic conductivity within the root zone, and, consequently, in an increase in the solute mass-flux below the root zone.

Conclusions

When LQW is used for irrigation, traditional salinity control methods cannot prevent the reduction in crop yield, and may increase the salt load in the groundwater substantially. The data-driven ADW approach for soil salinity which alternates irrigation water quality between LQW and HQW, based on a critical root-zone concentration, C_{cr}, may lead to a substantial increase in crop yield, and, in particular, to a substantial decrease in the salt load in the groundwater, while reducing the use of the expensive HQW. Optimal selection of C_{cr}, which will minimize the expensive DSW, without compromising crop production and groundwater quality, should be performed in an economical framework.

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Salinity amelioration in salt affected agriculture soils of semi-arid tropics through traditional ecological knowledge (TEK)

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Keywords: salinity, soil, indigenous, semi-arid tropics, amendments, fertility, agriculture

Introduction, scope and main objectives

Agro-ecosystem management strategies based on traditional ecological knowledge (TEK) are gaining importance due to their better adaptability and sustainability. TEK is the knowledge database and adapted practices of indigenous and local communities around the world (CBD, 2021). World over, especially in India, there is enormous wealth of TEK but it is being lost and is surviving only in bits and pieces. The present work deals with the relevance of these TEK based systems in dealing with the issues of salinity for better soil management and achieving overall goal for agricultural sustainability.

Methodology

Spread across four years, the pre-, mid- and post-harvest phases of crop in six cropping seasons were compared in ten fields/system of TEK (A1) and chemical intensive-integrated (A2) systems of a geo-ecologically unique terrain of Western India-Kachchh that is a typical representative of allied arid and semi-arid tropics that are prone to various natural threats and stresses like drought, salinity, incessant rainfall pattern etc. in terms of agriculture management (Sharma and Thivakaran, 2020). The TEK agrisystems used organic manures of different types. Farmyard compost (FYC) was applied in quantity of 4 ton (Mg) /hectare as a basal dose before sowing and modified 'Jivamrit S' (Palekar, 2006), a fermented concoction consisting of cow urine, cow dung, jaggery, gram flour and soil. It was applied with watering twice, at seven days interval from sowing. Using standard soil sampling protocols (EPA, 1992), sample collection was carried out from the rhizosphere of the crop up to the depth of 12–15 cm.

Results

Soil electroconductivity (EC) is a measure of the salinity of soil i.e. the amount of salts in soil is an important soil health indicator. The range of EC for the six cropping seasons for amendment A1 and A2 was from 0.15 dS/m to 0.99 dS/m, with SE = ±0.01 dS/m and SD = ±0.18 dS/m. The mean value for EC for the amendments was 0.62 ± 0.01 dS/m. However, A1 had a lower value (0.55 dS/m; SE = ±0.01 dS/m) compared to A2 (0.69 dS/m; SE = ±0.01 dS/m). The post-harvest phase had a higher EC value (0.74 ± 0.01 dS/m) than both the pre-sowing (0.58 ± 0.01 dS/m) and mid-phases (0.53 ± 0.01 dS/m) across all the amendments and seasons. The highest EC value amongst the six seasons was observed in season 1 (0.69 ± 0.02 dS/m) and lowest in season 5 (0.56 ± 0.02 dS/m).

Discussion

The electrical conductivity of soil affects crop suitability, agriculture yield, plant nutrient availability, and the soil microorganisms' activity. It is affected by irrigation, land use, and the application of fertilizer and compost. In the present study it was found that the effect of season, phase, and the amendments on the electrical conductivity of the soil was very highly significant ($p < 0.0001$). Interaction studies showed that the season by phase interaction was significant. However, the season by amendment and phase by amendment effect did not yield significant F values. This shows that EC of the soil is definitely affected by the prevalent management practices adopted by the farmers, irrespective of the seasonal conditions and crop phase.

Conclusions

In the present scenario—where chemical fertilizers had already shown detrimental effects in the form of long-term soil fertility depletion, health concerns occurring due to chemical inputs to both the growers and consumers, environmental deterioration—ecologically sustainable agri-management systems are not a choice, but a necessity. This is a first of its kind study to assess the certain important physico-chemical properties in traditional versus chemical-based agri-management systems in natural fields of semi-arid tropics. Studies that incorporate yield data would be complimentary to this and are underway. The arid and semi-arid tropics are highly prone to stressors like drought, highly erratic rainfall patterns, and salinity, and the present study advocates the supremacy of TEK-based agri-management systems in soil salinity amelioration for maintaining soil fertility in the long run (Sharma, Thivakaran and Thakkar., 2021).

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Sustainable rehabilitation, bridging yield gaps and increasing farmers' income in salt affected rice–wheat agroecosystems: A farmers' participatory assessment

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Key words: Participatory research; salt–affected soils; soil and crop management practices; plant physiological and growth parameters; economic assessments; rice–wheat system

Introduction, scope and main objectives

Continuous use of bicarbonate-dominated residual alkalinity in groundwater (RSC_{iw}) results in build-up of soil sodicity and negatively impacts rice-wheat system (RWS) productivity (Minhas *et al.*, 2019). Therefore, it is imperative to develop a climate-resilient integrated soil-crop management system to harness the potential of salt-affected soils.

Methodology

Different sets of field experiments on adaptation (crop management) and mitigation (soil reclamation) strategies were laid out in participatory mode (2016–2020) for sustainable rice-wheat production in sodicity-affected Ghaghar Basin of Haryana, India.

Results

Gypsum and pressmud amended sodic soils [GR_{25}+PM_5; soil pH and RSC_{iw}–based 25 percent gypsum requirement + pressmud 5 t/ha] accelerated the reclamation process, improved plants tolerance and enhanced RWS performance by 26 percent compared to unamended control. Compared to highly adapted varieties (PB1121 in rice and HD2967 in wheat), better tolerance mechanism and lesser yield reduction in salt tolerant rice (CSR30 Basmati) and wheat (KRL210) varieties imparted significant yield and economic gains, and also broaden the farmers' choice to select appropriate varieties. Curve Expert model revealed genotypic variation in N requirements attaining economic N optima at 90 kg in CSR30 Basmati, 140 kg in PB1121, 173 kg in KRL210 and 188 kg/ha in HD 2967. Transplanting rice using 2 seedlings/hill at 20×15 cm spacing, managing resistant *Phalaris* minor through sequential herbicides and foliar K–nutrition in wheat sustainably enhanced yields and profit margins. Technology package involving GR_{25}+PM_5–mediated land reclamation, tolerant varieties and crop–specific agronomic manipulations in RWS displayed appreciable reductions in soil sodification, improved physiological and agronomic efficiency, and enhanced system yields, profit margins and benefit:cost ratio (8.29 t/ha, USD 2103 per ha and 3.21) in comparison to existing farmers' practices (6.63 t/ha, USD 1503 per ha and 2.60), respectively.

Discussion

Adequate Ca^{2+} availability, displacement of Na^+ ions, and mobilization of Ca^+ ions from native $CaCO_3$ in GR_{25}+PM_5-mediated land reclamation led to improved soil conditions, morpho-physiological adaptability, and yield realization under sodic conditions (Minhas *et al.*, 2019; Sheoran *et al.*, 2021b). Additional N helped in improving nutrient availability and salt dilution (Esmaili *et al.*, 2008; Singh *et al.*, 2010; Sheoran *et al.*, 2021a) while optimized plant stand and balanced nutrition (N and K) might have contributed towards regulating the photosynthetic efficiency, osmolytes accumulation, scavenging ROS-induced damage; thereby, alleviating the negative effects of salt stress (Sikder *et al.*, 2020; Singh *et al.*, 2013). Sequential use of herbicides managed herbicide–resistant *P. minor* more efficiently and triggered interspecific crop-weed competition for limited resources (Yadav *et al*, 2016).

Conclusions

This study highlights the need of devising ecosystem-based approach involving combinations of genetic tolerance with affordable soil, crop and nutrient management practices in alleviating the sodicity stress, bridging yield gaps with optimal resource use, socio-economic development and eventually achieving the UN-SDGs of land degradation neutrality, food security and environmental protection. Sustainable use of sugarcane pressmud compensating 25 percent gypsum requirement provided an affordable alternative for reclaiming sodic soils. Yield enhancement with added N beyond the existing recommendations suggests upward revision and corrective N applications to compensate sodicity stress.

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State of the art of difficult-to-reclaim soils of the Jizzakh steppe

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Keywords: saline soils, water-physical properties, soil solution, reclamation, water-soluble salts, saline soil, salinity degree

Introduction, scope and main objectives

The study of the current ecological and reclamation state, the level of fertility and the development of agrotechnical and reclamation measures for the protection and rational use of saline lands is an urgent task today.

Methodology

In the studied area, four key areas were selected, covering the most common soils taking into account all the diversity of the lithological structure, geomorphological and hydrogeological conditions and soil cover (the age of irrigation and cultivation, the degree of salinity and gypsum content of soils). Field studies and laboratory analyses were conducted according to generally accepted methods.

Results

According to the position of the salt horizons on the profile, their thickness and degree of salinity, the soils present the complexes from deeply saline soils to saline soils (Abdullaev, Mazirov and Raxmatov, 2007). Deeply saline soils variations are practically not saline to a depth of 140–150 cm and the content of water-soluble salts in the soil solution is less than 0.3 percent. According to a recent report (Saidjon, Munojat and Nigora, 2020), salt in a small concentration in the range of 0.300–0.310 percent is observed from a depth of approximately 100 cm and corresponds to a low degree of salinity. Salt reserves in the second layer are 36 t/ha, of which 21 t/ha are in the upper 1 m layer.

In saline variations to a depth of 50–70 cm, soils are slightly saline (0.425–0.676 percent), starting from this depth (70 cm) the salt content is 1.07–1.12 percent and is characterized by a fairly uniform distribution to the depth of groundwater. Salt reserves are quite high–from 240–250 to 300–320 t/ha.

Saline soils are highly saline from the surface. The content of water-soluble salts in the arable horizon is 1.673 percent. From a depth of 30–70 cm, a decrease in salts to 1.1–1.2 percent is observed, and from a depth of 70 cm, a uniform moderate and strong salinity within 1.76–1.78 percent is observed. The total reserves of water-soluble salts in the 0–2 m soil layer range from 36–50 t/ha to 420–510 t/ha. The process of salt accumulation on the soil profile continues to this day.

Discussion

The current state of the difficult-to-reclaim soils of the Jizzakh steppe was studied. The change in the basic properties of irrigated sierozem-meadow soils under the influence of irrigation in a long-term cycle was revealed (Abdushukurova, Ruxiddinova and Sidikov, 2016). Recommendations for desalinization of saline soils were developed.

Conclusions

The following rates are recommended for desalinization: on slightly saline lands 3–5 thousand m^3/ha, on moderately saline lands– is 5–7 thousand m^3/ha and on highly saline lands– is 10–12 m^3/ha. It is advisable to set the frequency of desalinization depending on the degree of salinity, salt reserves in the 0–1 m layer of soil and their mechanical composition.

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Plant and soil responses to the combined application of organic amendments and inorganic fertilizers in degraded sodic soils of Indo-Gangetic plains

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Keywords: crop productivity, Indo-Gangetic plains, inorganic amendment, organic amendments, salt tolerant varieties, soil fertility, sodic soils

Introduction, scope and main objectives

About 930 million to 1.2 billion ha of soils globally are salt-affected and are a major part of land degradation (Qadir *et al.*, 2014; Ahmad *et al.*, 2016). Salinization of arable land will result in a 50 percent land loss by 2050 if remedial actions are not taken (FAO, 2016). The major portion (2.7 million ha) of salt-affected soils in India (6.74 million ha) is in the Indo-Gangetic plain zone (Mandal *et al.*, 2009). Amelioration of these soils through inorganic amendments like gypsum and phosphogypsum is a costly affair and fails to improve the physical and biological properties of salt-affected soils (Hamza and Anderson, 2003). Thus, the present study was conducted to monitor the combined effect of organic sources of amendments and inorganic fertilizers on the bio-physical and chemical properties of soil and the productivity of rice and wheat crops, in order to to minimize the dependency on inorganic fertilizers.

Methodology

A three times replicated field experiment designed with 13 treatments using four sources of organic amendments; municipal solid waste compost (MSWC), vermicompost (VC), farm yard manure (FYM) and pressmud (PM) with uniform quantity (10 t/ha) and three levels of nutrients. These were applied through inorganic fertilizers; 50 percent recommended dose of N (RDN), 75 percent RDN and 100 percent RDN and one control, conducted with a rice-wheat cropping system in a randomized block design. Grain yields of both the crops was recorded at maturity. In order to monitor changes in soil bio-physical and chemical properties, soil samples were collected after three years of study.

Results

The application of VC at 10 t/ha^{-1} plus 75 percent RDN decreased soil bulk density, pH, EC, ESP and Na content by 2 percent, 4.2 percent, 26.5 percent, 42.8 percent, and 56.6 percent respectively and increased soil organic carbon by 34.6 percent over control. Available N, P, K, Ca, and Mg increased by 20.5 percent, 33 percent, 36.4 percent, and 44 percent respectively, over control. Soil MBC, MBN and MBP improved significantly due to the combined use of organic amendments and inorganic fertilizers. Decreases in soil sodicity and increasing soil fertility showed significant increase in grain yields of rice and wheat.

Discussion

A reduction in the soil's physical and chemical properties and increasing SOC and available N, P, K, Ca and Mg over the initial and control might be due to an increase in root and shoot biomass, conversion of micropores into macropores and decomposition of organic residues by further microbial activities and higher production of CO_2 and organic acids followed by solublization of $CaCO_3$ and removal of excess Na^+ from the exchange complex sites (Wang *et al.*, 2014; Arora *et al.*, 2016; Singh *et al.*, 2018). Grain yields of rice and wheat with application of 10 t/ha VC with 75 percent of RDN through inorganic fertilizer was significantly higher over MSWC, FYM, and PM but on par with control.

Conclusions

The combined use of organic amendments with a reduced dose of nitrogen though inorganic fertilizers improves soil physico-chemical and microbial properties, soil fertility, and increases the yield of rice and wheat in sodic soils. Application of vermicompost at 10 t/ha saved 25 percent N without significant reduction in grain yield. Therefore, application of VC with 75 percent of RDN can be promoted to improve soil fertility and sustaining productivity of sodic soils.

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Impact of Saline Water in Groundnut-Wheat Cropping System in Hyper Arid-Region of Rajasthan

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Keywords: Drip irrigation, saline water, groundnut-wheat cropping, economics

Introduction
Rainfall variability has accentuated the reduction in cultivable areas due to the salinization of the lowlands in the ricegrowing valleys in Casamance. Our study is a part of the fight against weakness and poverty and the achievement of food selfsufficiency in Senegal. The aim is to determine the effects of two composts formulas (F1 and F2), phosphogypsum and mineral fertilization on the chemical and biochemical parameters of the soil and on the agromorphological parameters and the yield of rice (War 77) in salted sulphate-acid rice fields.

Methodology
A trial was performed using a Fisher block device with four replicates. A single factor was studied, organomineral fertility with five modalities. This is a control without input (T0), a recommended dose of mineral fertilization (FM) (200kg / ha 15N-15P-15K + 150 kg/ha Urea 46% N), a recommended dose of phosphogypsum (1t/ha), a dose of 7t/ha of compost of formula one based on rice straw and crushed oyster shell in powder (F1) and a dose of 7t/ha of compost of formula two based on Andropogon gayanus Khunt (F2) phosphogypsum and urea straw.

Results
The results showed that the salinity was more reduced by phosphogypsum (42.37 permille) and F1 (48.42 permille) in the 0–20 horizon and by FM (42.81 permille) and F1 (52.50 permille) in 20–40. However, the supplementation significantly influenced the pH (Pr = 0.0001), and the activities of β-glucosidase (Pr = 0.0001) and of acid phosphatase (Pr = 0.0023). These chemical and biochemical parameters were further improved by the addition of compost, in particular formula F1 with one of the pH values = 4.9 in the 0–20 horizon and 4.03 in the 20–40 horizon; β-glucosidase = 114.13 μg p-Np / gsol sec / h; phosphatase = 76.42 μg p-Np/gsol sec/h in 0–20 and for F2 pH = 4.63 in 0–20 and 4 in 20–40; β-glucosidase = 128.58 μg p-Np/gsol sec/h in 0–20; phosphatase = 38.61 μg p-Np/gsol sec/h in 20–40). In fact, the supply of phosphogypsum does not meet the nutrient deficiencies for the plant compared to composts. From an agronomic point of view, the rate of plant mortality is higher in the control (21.7 percent) than in the treatments with the addition of composts (F1 = 10.28 percent; F2 = 19.69) and mineral fertilizers. (17.67 percent). The lowest rate is obtained with phosphogypsum (3.02 percent). The rate of increase in grain yield is 162.14 percent for F1 compared to control (T0) followed by FM (124.1 percent) compared to T0 and the lowest rate is recorded at the level of the treatment with phosphogypsum (46 percent) and F2 (24. 7 percent).

Discussion
Organic amendments from compost increase pH, density and microbial activity. This promotes good behavior of the rice plants and better yields. These results show that the amendment in compost (F1) enriched with shells rich in Ca^{2}+ not only improves the chemical parameters and the microbiological activities in acid sulphate soils, but also the rice grain yields. This is not the case with phosphogypsum which acts only on the leaching of salt.

Conclusions
The addition of organic amendments based on improved compost formulas could be an alternative to the use of phosphogypsum (polluted with heavy minerals) for the valorization of degraded lands, in particular by salinity in Senegal.

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Integrated use organic and inorganic amendments for management of calcareous sodic soils in eastern India

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Keywords: Gypsum, Calcareous sodic soil, Rice, Wheat, Sulphitation-Pressmud, Dhaincha

Introduction, scope and main objectives

In Bihar, a state of India, out of total 92.83 lakh hectares, about 4.0 lakh ha arable area falls under salt-affected soils (Singh *et al.*, 2011, Sharma *et al.*, 2011). The nature of some of sodic soils is calcareous in nature and calcium is present as insoluble calcium carbonate thus pyrite (FeS_2) is good source for its reclamation (Chaudhary, 1980) but due to non/less availability of pyrite, response of the other alternate amendment, natural gypsum ($CaSO_4 2H_2O$), along with locally available sulphitation pressmud was evaluated under rice-wheat cropping system in farmer's field.

Methodology

A field experiment was conducted in calcareous sodic soils in farmers' fields of Bihar (eastern India). The different treatments T1–Control, T2–50 percent of GR (gypsum requirement), T3–Sulphitation Press Mud (SPM) at 10 Mg/ha, T4–50 percent of GR + PM at 10 Mg/ha , T5–50 percent of GR + Dhaincha and T6–50 percent of GR + PM at 10 Mg/ha + Dhaincha were applied in randomized block design. After application, amendments were mixed in surface soil and fields were irrigated for leaching the salts followed by dhaincha cultivation. In all treatments, recommended dose of fertilizers were applied as per the crop requirement. The salt-tolerant rice (Usar Dhan-3) was selected as the first crop to grow after reclamation of soils. The wheat crop (HD 2824) was sown after harvest of rice.

Results

Significant increase in the grain and straw yield of rice and wheat was recorded in all the treatments over control (no amendment). The mean grain yield of rice increased from 18.7–37.9 q/ha under control and treatments received Gypsum at 4 t/ha + Pressmud ar 10 t/ha + *Dhaincha,* respectively. The mean grain yield of wheat, varied from 19.2 to 45.2 q/ha. The increase in grain yield treated with amendments was significantly higher under all treatments over control. The application of different treatment increased the yield as well as improves the economic condition of farmers. The benefit: cost (B:C) ratio after two cropping cycle was recorded highest in treatment T_6 (1.29) followed by T_5 (1.20), T_4 (0.87), T_3 (0.84), T_2 (0.70) and T_1 (0.40) and comparative cost of amendments and other inputs were highest in T_6 followed by T_4, T_5, T_2 and T_3. Application of different amendments also improves the physico-chemical properties of soils.

Discussion

Application of the chemical amendments i.e. gypsum gave a more pronounced result in increasing grain and straw yield of both rice and wheat as well as soil properties in presence of organic manures viz. pressmud and Dhaincha because organic amendments enhanced the chemical reactions. During chemical reaction, the exchangeable Na^+ ions are replaced by Ca^{2+} from the exchange sites of the soil clay and thus improved soil aggregation, structure, water infiltration and nutrient availability (Brady and Weil, 2001).

Conclusions

The present study indicates that the calcareous soils could be managed with the alternate source of amendment i.e. gypsum which is also economical for the farmers. The integrated application of gypsum (at 4 Mg/ha) along with SPM (at 10 Mg/ha) and Dhaincha was found the best management practice for reclamation of calcareous sodic soil in Bihar (eastern India).

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Salt-affected soil management utilizing coated sand materials - "Breathable Sand"

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Keywords: Breathable Sand; Water Conservation; Saline/Sodic Soil; Coated Sand

Introduction, scope, and main objectives

Worldwide, over 1100 million hectares of soils are affected by salinity and sodicity, including saline, sodic, and saline-sodic affected lands (FAO, 2008). Studies have shown that coated sand can significantly reduce water consumption and suppress evaporation (Ogawa, 1996; Shokri, 2008; Mishra, 2018). These features can alleviate the negative impacts of salt impacts by preventing salt from reaching the root zone, and by reducing salt accumulation due to evaporation; however, case examples are sporadic.

An air-permeable watertight sand material (hereinafter "Breathable Sand") was invented by Rechsand Science & Technology Group (hereinafter "Rechsand") (Rechsand, 2021). The objectives are to 1) Introduce Breathable Sand. 2) Study performance as a liner. 3) Study performance as a cover to reduce evaporation.4) Discuss a salt-affected soil management case.

Methodology

<u>Introduction to Breathable Sand</u>

Proprietary coating and surface modification processes are used to form the new coated sand material. The finished Breathable Sand demonstrates good air permeability due to its porous nature, while can withstand water pressure without being wet due to its water repellency properties.

<u>Use Breathable Sand as a liner – agricultural applications</u>

Rice field in Yangqingmiao, Zhejiang Province is used as an example to evaluate the effects of utilizing Breathable Sand as a liner.

<u>Salt-affected soil management – case study</u>

A salt-affected soil management project in Dengkou, Inner Mongolia of China is introduced.

<u>Use Breathable Sand as an evaporation suppression layer – lab experiment</u>

Bench-scale tests have been conducted to evaluate Breathable Sand performance in suppressing evaporation.

Results

<u>Breathable sand properties</u>

The water-resistance of Breathable Sand is about 10.2 meters. The air-permeability of Breathable Sand is 1.23 cm/s at 0.05 Mpa.

<u>Breathable sand in agricultural applications</u>

Water use showed that 29 percent water saving was achieved with Breathable Sand in hybrid late rice fields. Roots were stronger. Average leaf count, grain weight, matured grain per plant, grain per ear, and grain maturity rates were 5.5 percent, 0.6 percent, 4.8 percent, 1.3 percent, 3.3 percent higher than those without liner, respectively.

Breathable Sand applications – salt-affected soil management results

Breathable Sand has been used as a liner in a salt-affected field in Dengkou, Inner Mongolia since 2017. Good vegetation establishment and plant growth were observed in fields. After four years of the initial application, no signs of plant depression nor salt intrusion was observed.

Breathable Sand as evaporation suppress layer - laboratory experiment results

A thin layer (1–5cm) of Breathable Sand can significantly reduce evaporation by 80–90 percent.

Discussion

Rechsand has also invented another product called Geosynthetic Breathable Sand Liner.

Conclusions

A coated sand-based material, called Breathable Sand, was invented. The material is watertight, while air-permeable. The product has been widely used in China including a salt-affected land management projects. Breathable Sand can be installed under the plant root zone to reduce water infiltration, and salt intrusion if excessive salt in subsoil presents. Field tests showed that 31 percent of water-saving and improved rice quantity and quality. Breathable Sand can also be used near the surface to suppress evaporation by up to 90 percent, which reduces salt deposition.

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Utilization of Flue gas desulfurization (FGD) Gypsum in Reclamation of Sodic soil

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Keywords: FGD Gypsum, sodicity, leachate, reclamation, sodium absorption ratio

Introduction

Flue gas desulfurization gypsum (FGDG) is widely available byproduct of forced-oxidation wet scrubbers that are used to reduce sulfur emissions (SO_X) from coal-fired power plants using spray of lime stone slurry. Applications of FGDG in sodic soils supply Ca^{2+} which neutralize soluble alkalinity (CO_3^{2-} and HCO_3^-) and replace exchangeable Na^+. Subsequent leaching of Na^+ in presence of abundant SO_4^{2-} ions reclaim the sodicity of soil. Therefore, reclamation of soil sodicity is accompanied with lower soil pH and improved soil physico-chemical properties suitable for crop production.

Methodology

An on farm sodicity reclamation experiment was initiated at ICAR-CSSRI, Karnal, India for evaluating the reclamation efficiency of FGDG produced by Thermal Power Plant of India in the lysimeters set up with sodic soils collected from adjoining area of Karnal, India, having $pH_{1:2}$ 10.1, $EC_{1:2}$ 0.70 dS/m and gypsum requirement of 16.7 Mg/ha. The FGDG were applied on the equivalent basis of 100 (replacing of cent per cent of Na^+ from soil exchange phases by Ca^{2+}), 75 and 50 GR and standard recommended reclamation dose of mineral gypsum 50GR and unamended control. Leaching was started after 30 days of FGDG application by transplanting sodicity-tolerant rice variety (cv. CSR-56). Leachate collecting units were installed at depth of 15 cm to monitor change in pH and EC of the leachates at regular intervals. Rice yield and soil saturation extract pH and EC were monitored after the crop harvest.

Results

A decrease in the pH of the leachates was observed up to thirty-five days after transplanting (7.50–7.90) with subsequent increase towards alkaline range (8.00–8.60) for all soil treatments. There was a significant increase in EC of leachates at 40 days after transplanting of rice; thereafter it declined. The sodium absorption ratio (SAR) of the leachate attained peak at 21 days after transplanting of rice thereafter a gradual decrement was observed. The pHs declined significantly compared to control and fallow treatments at 0–15 cm depth after the rice crop. 100 FGDG applications showed lowest pHs value followed by 75 FGDG, 50 FGDG and 50GR. A higher value of EC_e (5.84 dS/m) was observed in 100 FGDG treatment and was significantly higher than other doses of FGDG and mined gypsum at 0–15 cm soil depth. Control and fallow lysimeters had EC_e of 2.01 and 2.20 dS/m. The higher paddy grain yield was recorded in FGDG-100 GR, FGDG-75 GR, FGDG-50 GR (0.43, 0.41 and 0.40 kg/m^2) compared to mined gypsum 50GR (0.33 kg/m^2) and unamended control (0.23 kg/m^2).

Discussion

Washing of inherent salts increased leaching of salts in the initial leachates. Subsequent increase in EC of leachates was mainly because of the release of the FGDG and Na-soil reaction product. Release of more Na^+ in leachate increased the SAR and leachate pH. Application of gypsum and FGDG supply soluble Ca^{2+} with progress of reclamation and exhibited lower values of SAR in effluent. All doses of FGDG treatment reported a decrement in soil pH and increase in the grain yield.

Conclusions

Decline in pH of the sodic soil and improved grain yield showed the potential of FGDG in the reclamation of sodic soils and its input towards the global food security. The treatment of barren saline-sodic soils with FGD gypsum would be of considerable benefit to both agricultural development and the improvement of ecosystems services.

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Assessment of finger millet cultivars/landraces for performance, stability, and interrelationships among traits under contrasting irrigation water-salinity levels in Dubai

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Keywords: irrigation water, salinity, finger millet, marginal environments, correlations, path analysis, stability

Introduction, scope, and main objectives

Soil and water salinity are major contributors to decline in productivity of agricultural lands, thereby, limiting food and fodder production as demonstrated by Khan *et al.* (2006). The International Center for Biosaline Agriculture (ICBA) is presently exploring nutrient-dense and stress-tolerant under-utilized crops for dietary diversification in marginal environments. The objectives of this study were to identify finger millet cultivars with high grain and/or fodder yield(s), determine the stability of the cultivars and investigate interrelationships among traits under varying salinity levels.

Methodology

One hundred entries comprising 75 test entries (unreplicated) and 5check entries which were replicated in each of five blocks using augmented randomized complete block design were tested under 0 (control), 6 and 10 dS/m irrigation water salinity levels at ICBA research field in 2021. Each experimental unit was 1 m^2 with inter- and intra-row spacings of 0.25 m. Fertilization was done using NPK and urea. Weeds were controlled manually, while pesticide was used to control insects. Data were collected on days to maturity (DM), plant height (PHT), plant aspect (PASP), panicle weight (PWT), fresh fodder yield (FFYLD), dry fodder yield (DFYLD) and grain yield (GYLD). Measured traits were subjected to analysis of variance (ANOVA), correlation, path and stability analyses using appropriate statistical softwares (SPSS Inc, 2007; SAS Institute, 2011; IRRI, 2014).

Results

Cultivar IE 2457, IE 3391, IE 4028, IE 7320, IE3392, IE 6337, IE 2619, IE 4646, IE 4797, and IE 6240 were the top performers based on rank summation index (RSI) that incorporated high PWT, FFYLD, DFYLD and GYLD (Mulamba and Mock,1978). Stability analysis revealed IE 3392 as highest yielding and most stable across all salinity levels, whereas IE 6337 showed specific adaptation to 0 dS/m and IE7079 to both 6 and 10 dS/m salinity levels. Path analysis revealed PASP and PWT as the traits accounting for 86.6 percent of the variation in GYLD while DM, PWT, and FFYLD were the traits identified as contributing 81.5 percent to the differences in DFYLD.

Discussion

The identified top performers for grain and fodder yields suggested the availability of cultivars for addressing the food and fodder deficit in the region.

Cultivar IE 3392, with high grain yield and stability across all research environments could be cultivated under fresh and saline water irrigations environments. Similar findings were reported by Kandel *et al.* (2020). Cultivar IE6337 with specific adaptation to 0 dS/m should be explored under freshwater irrigation while IE7079 with adaptation to 6 and 10 dS/m salinity levels should be promoted for production under saline water irrigation environments.
The PASP and PWT were the two important secondary traits for improvement of GYLD while DM, PWT, and FFYLD were found important for DFYLD improvement.

Conclusions

The promising cultivars could contribute to the food and fodder requirements in salt-affected areas. Cultivar IE 3392 should be promoted for wide cultivation across environments. However, IE 6337 should be explored for fresh irrigation water production while IE7079 should be promoted for production under saline water irrigation environments. The PASP, PWT, DM, and FFYLD could serve as secondary traits for indirect or index selection for grain and/or fodder yield(s) improvement.

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Effect of planting windows and irrigation schedules on yield of dibbled wal (Field bean) under zero tillage in coastal saline soils of Konkan region of Maharashtra.

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Keywords: Wal, Irrigation water, Salinity, Planting windows

Introduction, scope and main objectives

Basically, Indian bean is a multipurpose crop which is being primarily grown for its green pod. However, it is consumed as vegetable as well pulse. Demand is excellent in local markets. Coastal saline soils of Konkan region of Maharashtra are locally called as *khar* or *khajan* soils. Even when encroachment of saline creek water is checked by putting an embankment, the brackish water from shallow water table rises through the capillaries due to evaporation, enriching the upper crust of the soil with salts and thus the salinity problem persists. Coastal saline soils are mostly monocropped. Rice is grown during the *Kharif* season. The choice of crops to be grown in salt affected soils is very important to obtain acceptable yields. This also decides cropping systems as well as favourable diversification to meet the other requirements of farm families. The dibling of wal (field bean) vegetable during *rabi* season after immediately harvest of crop with only source of groundwater and rain harvested in ponds which is used for irrigation during *rabi* season of coastal salt affected area. In this view, it is proposed to monitor the seed yield capacity of wal under different irrigation levels and planting windows i.e. at the different date of sowing.

Methodology

The study was conducted at experimental farm of Khar Land Research Station, Panvel Dist-Raigad (Maharashtra). The experimental soil was clay loam in texture, neutral in reaction, medium in available phosphorus and very high in potassium during *rabi* 2019–2020 with three levels of irrigations viz., no irrigation (I_0), one irrigation (I_1–At flowering) and two irrigation (I_2–At flowering and pod formation) and three levels of planting windows i.e. immediately planted after harvest of Rice (P_1), 10 days After harvest of Rice (P_2) and 20 days after harvest of Rice (P_3) with four replications by dibbling of wal crop. Seed yield data of wal determined quintal per hectare and statistically analyzed by following the procedure given by Panse and Sukhatme (1995).

Results

The data pertaining to seed yield of wal as affected by the treatment combinations of Irrigation levels and Planting window, it revealed that, among various treatments of irrigations, the treatment receiving application irrigation water for the two times i.e. at the time of flowering and at the time of pod formation (I_2) recorded statistically significant and higher yield of 17.63 quintal/ha over one irrigation at flowering I_1(8.10 quintal/ha) and no irrigation I_0 (06.00 quintal/ha). Critical look on the data further revealed that the planting windows for the wal crop seed produced statistically higher yield (13.19 quintal/ha) over the treatments of planting after immediate after harvest of rice P_1 over P_2(10.08 quintal/ha) and P_3(8.46 quintal/ha). Interaction effect of I_2P_1 (two irrigations at the time of flowering and at the time of pod formation with planting immediate after harvest of rice) produced statistically significant and higher yield of (21.14 quintal/ha) over remaining interactions.

Discussion

It is evident that two irrigations caused a significant increase in yield of wal. Interactions of two irrigations (I_2) with sowing of wal immediately after harvest of rice (I_2P_1) also caused a significant improvement in yield of wal.

Conclusion

Even though two irrigations at flowering stage and at pod formation stage the sowing immediate after harvest of rice gave maximum yield, in the view of diversified climate of Konkan region of Maharashtra and in spite of high annual rainfall, scarcity of water is normal phenomenon during post monsoon period (Gajbhiye *et al.*, 2017)

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Sandalwood (*Santalum album* L.): a possible high-value tree species for the saline soils

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Keywords: Sandalwood, Salinity, Growth, Haustoria

Introduction, scope and main objectives

Sandalwood (*Santalum album* L.) is an evergreen semi-root-parasitic tree, which makes association with the host plants through "haustoria" to meet its nutrient and water requirements. However, only scarce information is available on performance of sandalwood with host species in the saline environment. Therefore, we hypothesized that salt tolerance of Sandalwood may vary with type as well as compatibility with the host species. The overall objective of present study was to provide an insight into the salt tolerance of Sandalwood, with a future aim to develop cultivation and management practises for species in the salt affected soils.

Methodology

The present experiment was carried out at ICAR-CSSRI for six months during 2020–2021, to observe the effects of saline irrigation level (ECiw 9), including control and different host plant species (*Acacia ampliceps, Azadirachta indica, Citrus aurantium, Casuarina equisetifolia, Dalbergia sissoo, Leucaena leucocephala, Melia dubia, Phyllanthus emblica, Punica granatum, Syzygium cumini*) on the growth potential and physiology of sandalwood.

Results

Results showed that the maximum ($p<0.05$) height (106.0 cm) and collar diameter (12.97 mm) growth of sandalwood were observed with *Melia dubia* and *Dalbergia sissoo*, respectively, under controlled conditions. Under saline conditions (ECiw 9), the maximum ($p<0.05$) height (112 cm) and collar diameter (8.89 mm) growth of sandalwood were recorded with *Dalbergia sissoo* and *Melia dubia*, respectively. Similar trends were observed for other growth parameters, such as number of leaves and branches and total plant biomass. Results revealed that salinity stress reduced K^+/Na^+ ratio in the leaves of Sandalwood, and its higher value (0.98) was observed with *Dalbergia sissoo*, while lower value (0.24) was recorded with *Citrus aurantium*. The number of haustoria in roots on an average declined by more than 50 percent under saline conditions, compared to control.

Discussion

Results of the present study indicated that imposed salinity levels had only a slight effect on the sandalwood growth; however, its growth pattern mainly varies with the type of host species. The performance of a host plant is the single most important criteria for satisfactory growth performance of sandalwood under saline conditions. The results showed that salinity resulted in the moderate decrease in leaf K^+/Na^+ ratio and number of root-induced haustoria, while salinity had very little effect on the plant growth; indicating the existence of salinity tolerance mechanism in the Sandalwood.

Conclusions

Our findings showed that sandalwood growth varied with the host species both under control and saline conditions, and it exhibited good growth potential under the saline conditions. Therefore, based on results obtained so far, sandalwood has shown good prospects of successful cultivation with suitable compatible host plant in the saline conditions.

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Measures of salt-affected soils rehabilitation and sustainable management of their fertility in Ukraine

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Keywords: ameliorants, ameliorative deep ploughing, phytomelioration, rehabilitation, salt-affected soils, soil salinity

Introduction, scope and main objectives

Soil salinity influences the soil quality, ecosystem services, soil health, productivity and food security (Abrol, Yadav and Massoud, 1988; Novikova, 1984). Around seven percent of soils in Ukraine are salt-affected, a relatively small amount, constituting an area of 1.92 million hectares. Of that, 1.71 million hectares are used in agriculture. There are about 350 000 hectares of salt-affected soils on irrigated lands (Baliuk, Zakharova and Vorontyntseva, 2020). About 70 000–100 000 hectares are secondary salt-affected soils.

The objectives of the work are to define the complex of methods needed for the prevention and rehabilitation of natural and secondary salt-affected soils and sustainable management of their fertility when diagnosed.

Methodology

Research was carried out in the Steppe zone of Ukraine on natural and secondary salt-affected soils. Measures were applied both in the field experiments and on croplands.

The effectiveness of a complex of agrotechnical, agroameliorative and phytoamelioration measures were studied on ordinary Chernozems and dark Kastanozem soils (weakly and moderately salt-affected). It included salt-affected soil leaching to remove salts using clean water with an increase in the irrigation rate by 50 percent. Ameliorative deep ploughing was carried out to the depth of 75 cm and 100 t/ha of rotted manure was introduced into a 0–25 cm plow horizon.

Phosphogypsum and calcium sulfate production wastes were added to the soil as calcium ameliorants at 3–7 t/ha. They were used both dry and in suspension. In field experiments, the phytomelioration and resistance of crops to salinity were studied.

Results

Washing irrigation on slightly salt-affected soils contributed to its desalination. The soil water-salt regime was improved (Baliuk, Romashchenko and Stachuk, ed., 2009). The crops' productivity increased by 20–25 percent.

The introduction of ameliorants into the soil when being irrigated with saline water had a positive effect on the physicochemical properties, with the degree of soil salinity decreasing from medium to weak. The composition of absorbed cations was improved, while the content of absorbed sodium and potassium decreased from 7.0 percent to 4.1–5.5 percent out of the total absorbed cations (Vorotyntseva, 2017).

The carbonate content in the 0–50 cm layer increased to 2.6–3.1 percent. The yield gain was 15–45 percent. Ameliorative deep ploughing had a long-term positive effect on the agrophysical and physic-chemical properties of the medium alkalinization ordinary chernozem. The calcium content increased by 8.3–8.7 percent.

The cultivation of salt-resistant crops contributed to the gradual desalinization.

Discussion

The effective use of salt-affected soils is based on taking their properties into account (degree and chemistry of salinity and salt balance), the level and salinity of groundwater and the climatic conditions (Vargas, 2018; Baliuk, Drozd and Zakharova, 2015). Amelioration should be considered in a single system of interrelated methods of soil fertility management (Singh, 2021). An innovative concept of amelioration has been developed in Ukraine. First, chemical amelioration is carried out on moderately and highly salt-affected soils. The effectiveness of the action and after-action of the ameliorants was traced for between five and seven years. On the alkali soils, ameliorative deep ploughing had a positive effect on soil properties over fifty years (Novikova, 2009; Drozd, 2015).

Conclusions

The differentiated complex of rehabilitation and sustainable management of salt-affected soils' fertility based on their genesis has been developed in Ukraine. The use of these measures helps to improve the physical, physico-chemical properties of salt-affected soils and increase crop yields.

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO.

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Double-Desalinization approach: a promising solution to improve the salt-affected soils in semiarid and arid regions

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Keywords: salt-affected soils, semiarid and arid regions, double-desalinization approach (DSA), soil and water resource management, high efficient utilization, green energy exploitation, sustainable development

Introduction, scope and main objectives

Salt-affected soils are one of the most degraded land worldwide, and its distribution is relatively more extensive in the arid and semi-arid regions compared to the humid regions, mainly because of the accumulation of water with salts and over-evaporation of the soil surface. Salt-affected soils induced by irrigation in semiarid and arid areas can appear very easily along rivers and around lakes. A great amount of water is necessary to flush the surface salts away and to irrigate the land for plant growth.

The objectives of this solution are to (1) improve the soil productivity via reduction of soil salts, (2) to reduce the pollution of drainage off-site, such as downstream and the destination of lakes or wetlands, and (3) to save more water and reuse it in the semiarid and arid regions.

Methodology

The countermeasures of soil salinization are discussed based on the regional comprehensive resources, especially soil and water resources and management to develop the strategy and its relating principles and technologies to measure the soil salinization in arid areas for the sustainable development of agriculture and environment. A new integrated strategy is put forward considering the detailed review of references on measurements of salt-affected soils worldwide, the shortcomings and the field investigation in arid areas suffering from soil salinization in the northwest of China and other regions with the same condition.

Double-Desalinization Approach (DDA) is a way to reduce the soil salts with two steps. The first step is to reduce the soil salts with fresh or low salinity water to a certain depth that could plant crops for one year or more, and act as a healthy soil without salinization stress. The less water method is necessary in the washing process, such as plastic mulching, dry salts collection first, low salinity water first, etc. The drainage could be saved in a pond or tanks for the further treatment.

The second step is desalination of the high concentration drainage created from the patches of salt-affected soils treated by the first step. As solar and wind energy is plentiful in the semiarid and arid region, this should be used in the desalination process and the water generated could be reused for salt washing or irrigation, and the dry salts could be saved or sold according to the values of salts. The salts would thus be out of the water and soil system after this stage.

Results

Having a two-step strategy of separating the salts from soil first and then desalinating the salted irrigation drainage will improve the efficiency of soil salinization measures. As a soil desalination measure, it could be described as a "Double-Desalinization approach (DDA)". The strategy of DDA includes the conservation of regional water resources, leaching of soil salts with less water, desalination of the concentrated drainage water from the salt-affected soil, and a more efficient use of agricultural land and associated water resources.

Conservation of regional water resources is the premise of water resource management and ecological protection in arid areas. Leaching of soil salts with less water is the basis of reducing the cost of salt leaching time and water resources. Desalination of concentrated drainage is the key technology in separating the salts and water for the further re-use of salt and fresh water. More efficient land and water use is the core economic principle of agricultural development in arid areas.

Discussion

The new strategy of DDA as a soil salinization measure could increase the efficiency of desalination of soil and water in the semiarid and arid areas and improve the use of both. The risks relating to regional natural resources, environment and ecology of this strategy are relatively lower than traditional methods, and the improved soil and land could be used for a longer time.

The strategy could maintain and improve the regional economic development and the ecological services of the ecosystem in China, but could also be extended for use in countries and regions with soil salinization along the Belt and Road Initiative of China, contributing wisdom and strength from China in achieving the sustainable development goal (SDGs) 2030 of the United Nations.

Conclusions

The "Double-Desalinization approach (DDA)" could reduce soil salts, helping to improve soil and crop productivity. It could also protect the water environment from field to rivers and lakes or wetland in the semiarid and arid regions via reduction of soil salts, by reducing the pollution of drainage off-site, such as downstream and the destination of lakes or wetlands, as well as saving more water and reusing it in the semiarid and arid regions.

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Standardizing optimum lateral spacing of cut-soiler constructed preferential shallow sub-surface drainage (PSSD) for dryland salinity management

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Keywords: cut-soiler, PSSD, salinity, pearl millet [Pennisetum glaucum (L.)], mustard [Brassica juncea (L.)]

Introduction, scope and main objectives

Salinity reduces the yield of agricultural crops in many arid and semi-arid areas of the world. In India, the extent of salt-affected soils is 6.7 million ha (Mandal, Sharma and Singh, 2009), and 32–84 percent of the groundwater resources are of poor quality. This study was undertaken to standardize the optimum lateral spacing of cut-soiler constructed rice residue/straw-filled preferential shallow sub-surface drainage (PSSD) for effective salt removal in the drylands of India.

Methodology

A field experiment was conducted between 2019 and 2020 at ICAR-CSSRI, Nain Experimental Farm (29°19'7.09" N; 76°48'0.0" E), Haryana, India. The cut-soiler PSSD lines were constructed in 15 plots (30*30 M^2) at a lateral spacing of 2.5 m, 5 m, 7.5 m and 10 m with the desired rice residue load (6.0 t/ha) on the soil surface. The seasonal changes in soil salinity in different cut-soiler lateral spacing and the subsequent effect on yield of pearl millet-mustard cropping system was determined.

Results

After two years of cut-soiler operation, the highest reduction in ECe (up to 46.7 percent) was recorded in the closest lateral spacing of cut-soiler drains, at 2.5 m, as compared to initial ECe values in May 2018. The lateral spacing of 5 m, 7.5 m and 10 m reduced ECc by 26 percent, 23.9 percent and 14.6 percent salinity (ECe), respectively over their corresponding initial ECe values. This reduction in soil salinity in 2.5 m lateral spacing was 42.2 percent lower than the control (no cut-soiler). There was a 55.88 percent, 21.87 percent, 15.73 percent and 13.79 percent increase in mustard yield in the 2.5 m, 5 m, 7.5 m and 10m lateral PSSD spacing, respectively. The corresponding increase in pearl millet yield in 2.5 m, 5 m, 7.5 m and 10 m lateral PSSD spacing were 50.82 percent, 35.97 percent, 27.04 percent and 23.27 percent higher than the control.

Discussion

This study found a higher reduction in soil salinity in the closest 2.5m lateral spacing, but also significant reductions in soil salinity in all the lateral spacings. Therefore, closer spacing is more effective in salinity removal along with increased mustard-pearl millet yield. Okuda *et al.* (2018) reported the reduction in salinity through shallow subsurface drainage used in combination with a cut-drain. The shallow subsurface drainage significantly supplemented salt removal by rain from the field through preferential flow. The grain yield of a mustard-pearl millet cropping system was also reported to increase with the reduction in salt stress under the dryland salinity due to the beneficial effects of reduced salinity on the physical conditions of soil (Meena *et al.*, 2018; Gopinath *et al.*, 2008).

Conclusions

The narrowest lateral spacing of cut-soiler constructed PSSD was found to reduce soil salinity by up to 46.7 percent, over no cut-soiler plots. The reduced salinity resulted in a significant increase in yield of both mustard and pearl millet crops. Therefore, closer spacing (2.5 m or less) was found promising for salinity management and sustainable agricultural production in highly salt-affected fields

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Mitigation of salinity effect through seed priming with microbial inoculants

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Keywords: soil salinization, microbial inoculants, dehydrogenase, acid and alkaline phosphatise, cowpea yield

Introduction, scope and main objectives

Soil salinization is one of the most serious land degradation (Science Direct, 2021) problems, which has been increasing due to drought combined with poor irrigation practices. In India, about 8.1 million hectares are salinized (Triphati *et al.*, 2007).Salinity results in poor plant growth and low soil microbial activity due to osmotic stress and toxic ions. Soil micro-organisms play a pivotal role in soils through the mineralization of organic matter into plant available nutrients. Therefore it is important to maintain a high microbial activity in soils for better crop production as well as in order to sustain soil health. The field experiment was conducted to evaluate the response of two liquid microbial inoculants with vegetable cowpea (cowpea-236) under saline irrigation (EC–4.30 dS/m).

Methodology

The field experiment was conducted during *Kharif* 2019 and 2020 at the Regional Research Station, Bathinda, Punjab, which is situated in the Trans-Gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plains at 30°09"36' N latitude, 74°55"28' E longitude and at an altitude of 211 m above sea level. The experiment was laid out with two liquid microbial inoculants under two levels of nitrogen and saline irrigation (EC–4.30 dS/m) with vegetable cowpea (cowpea-236) as a test crop. The different treatments were as follows.

T_1:100 percent RDN, T_2: 100 percent RDN + *Burkholderia seminalis*, T_3: 100 percent RDN + *Bradyrhizobium*, T_4: 100 percent RDN+ *Burkholderia seminalis + Bradyrhizobium*,T5:75 percent RDN, T_6: 75 percent RDN + *Burkholderia seminalis*, T_7: 75 percent RDN + *Bradyrhizobium*, T_8: 75 percent RDN + *Burkholderia seminalis + Bradyrhizobium.*

The seed was inoculated with liquid microbial inoculants (2 x 10^6 colony forming units (CFU)/g inoculum culture) of *Burkholderia seminalis, Burkholderia* sp. and *Bradyrhizobium* sp. at 250 ml/ha. All the soil parameters including enzyme activity were analysed as per standard methods, as described by Tarafdar and Yadav (2013).

Results

The results showed an increase in dehydrogenase as well as acid and alkaline phosphatase activity up to 60 days after germination and a decreasing trend was reported with the further plant growth period. Similarly, an overall 7.7 percent, 3.7 percent and 4.0 percent increase in activity was observed in dehydrogenase, acid and alkaline phosphatase, respectively, as well as a decrease in soil pH. Available N, P, K and micronutrient availability was recorded due to microbial inoculation, irrespective of fertilizer application. However, a slight increase in soil electrical conductivity and organic carbon was observed. Similarly, an increase in plant height (3 percent) and green vegetable cowpea yield (24.8 percent) was recorded with seed priming, irrespective of inoculum sp. and fertilizer application.

Discussion

Dehydrogenase, acid and alkaline phosphatase activity was increased up to 60 DAS and further decreases may be due to the maximum rate of root exudates secretion. Plants and microorganisms can release enzymes, therefore underground microbial build up due to root exudates resulted in higher enzyme activity. The microbial inoculants decreased the available soil macro and micronutrients due to increased plant biomass and uptake of higher amount of nutrients. A positive influence of inoculation on plant height and vegetable cowpea yield was recorded. Microbial activity resulted in quantitative and qualitative alterations to the composition of root exudates due to the degradation of exudates compounds and the release of microbial metabolites (Neumann and Romheld, 2000). Higher enzyme activity in soils indicated the potential of soil to affect the biochemical transformations necessary for the maintenance of soil fertility (Rao, Bala and Tarafdar, 1990).

Conclusions

The present results clearly show the positive influence of microbes to mitigate the salinity effect and increased the cowpea yield apparently as a result of the increased soil enzymes activity and transformation of nutrients in plants.

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Management of Soil Salinity and Improvement of Nutrient Use Efficiency of Salt-Affected Farmland

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Keywords: Salt affected soils, salinity management, nutrient loss control, nutrient use efficiency enhancement, straw mulching and interlayer, nutrient management, modifier application

Introduction, scope and main objectives

Salt-affected land spreads in China with many types, large area and various degree, which has seriously affected land productivity, ecosystem stability and environmental quality (Yang, 2008). On the other hand, nutrient loss is often observed in saline farmland, which seriously reduces the nutrient utilization efficiency of salt-affected farmland (Liu *et al*., 2021; Sun *et al*., 2020). The objectives of present study are to study the ways and methodologies for better managing soil salinity and controlling the nutrient loss of salt-affected farmland, so as to effectively reduce saline-alkali obstacles, improve soil quality, improve nutrient utilization efficiency and improve land productivity.

Methodology

Two years of plot experiments were carried out for the study in a salt-affected farmland of Tiaozini in Dongtai City, Jiangsu Province, China. The soil is typical coastal saline soil. Three groups of experiments were carried out, including six treatments of combined application of organic and inorganic fertilizer, six treatments of application of different modifiers, and six treatments of combination of mulching and straw interlayer.

Results

The application of organic fertilizer can effectively reduce the soil saline alkali obstacles by improving the soil structure, organic matter content and water holding capacity, so as to improve the farmland fertility level. However, higher application ratio of organic fertilizer may not ensure sufficient nitrogen supply. OM one-fourth treatment has the best effect, which can take into account for soil salinity management and efficient utilization of nitrogen nutrients. Mulching and straw interlayer approaches had good effects on salt reduction and yield increase. The nitrogen use efficiency of film mulching + straw ditch burying treatment was the highest, which mainly promoted crop yield, increased biomass and finally improved nitrogen nutrient use efficiency by reducing salinity, improving soil structure and increasing soil water content. Different modifiers have various effects on reducing salinity, alkalinity and increasing organic matter content. In general, biochar treatment can effectively reduce soil salinity, improve soil organic matter content and improve soil structure, so as to promote crop growth and improve nitrogen nutrient utilization efficiency, which has a better effect of salt removal and yield increase.

Discussion

Organic fertilizer application is conducive to the leaching of soil salt, reduce the capillary pores of surface soil and reduce the salt accumulation caused by water evaporation. Combined application of organic and inorganic fertilizer can improve the utilization rate of nitrogen fertilizer by continuously and stably release and supply of nutrients (Zhu *et al*., 2019). The combination of film mulching and straw interlayer (FM + SB) has the advantages of both salt suppression and salt removal effect. Thus, the nitrogen uptake and nitrogen use efficiency of aboveground crops were improved. Compared with other modifiers, biochar has the most significant effect on reducing salt through two channels: nutrient adsorption and improving soil structure (Zhu *et al.*, 2020).

Conclusions

Measures of combined application of organic and inorganic fertilizer, application of different modifiers, and combination of mulching and straw interlayer are all beneficial to soil salinity management and improvement of nutrient utilization efficiency of salt-affected farmland. OM one-fourth treatment, film mulching and straw interlayer (FM + SB), biochar application have better performance.

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Theme 3. Agenda for action to prevent and rehabilitate salt-affected soils, protect natural saline and sodic soils, and scale-up sustainable soil management practices

Reclamation condition of sandy desert soils on the dried bottom of the Aral Sea

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Keywords: Aral Sea, soil cover, elementary soil processes sandy desert soils, mechanical composition, soil properties, salt accumulation, salinity type, absorption capacity

Introduction, scope and main objectives

Today, climate change is a phenomenon recognized by the entire world community as an undeniable fact. The main reasons for these changes are anomalous events occurring in nature and increasing anthropogenic pressure. The negative changes taking place in the world as a result of global climate change have affected many countries. Especially in areas where water resources are scarce, desertification processes, which are the product of climate change, are developing rapidly. Central Asia, especially Uzbekistan, is not out of these problems due to its geographical location, climate and complexity of relief (Kuziev and Gafurova, 2015; Kuziev and Abdurakhmonov, 2017).

The aim of the study is to assess the reclamation state of dry seabed soils by determining the properties of sandy desert soils in the dried part of the Aral Sea under the influence of anomalous natural and anthropogenic pressure (Abdurakhmonov *et al.*, 2019).

Methodology

The research was carried out on the basis of generally accepted methods of soil science in the field, laboratory, cameral conditions, including the use of comparative-geographical, genetic, historical-comparative methods of soil in the field. In order to study soil properties in the laboratory, ten soil cuts were made in the scattered sandy desert soils of the dried part of the Aral Sea, and 45 soil samples were taken by genetic layers.

Results

The sandy desert soils of the dried bottom of the Aral Sea are distributed in the Adjibay-Oqqala-Uzunqair massifs, where the groundwater is at a depth of 5 meters. According to the mechanical composition, it consists mainly of sand and sandy loam, as well as sand in some layers of the soil profile, the amount of physical clay (<0.01 mm) particles in light sands is 23.6–29.0 percent, in sands 10.2–19.5 percent and in sands 4.9–9.1 percent. Sandy soils have high water permeability and small water capacity properties.

Up to 1 percent of salt accumulation was also observed in the upper part of the sandy soils on the dried bottom of the Aral Sea. In this case, salt accumulation occurs mainly due to biogenic changes. Clay and semi-clay layers contain large amounts of water-soluble (0.7–2 percent) salts. The maximum amount of salt is usually located at a depth of 4.0–4.5 m, ie in the zone of influence of mineralized groundwater. The upper layers of the sandy desert soils of the dried bottom of the Aral Sea are weak and moderate, very strongly saline in some sections, and the salinity type is mainly sulfate. The amount of dry residue in the genetic layers of these soils was found to be up to 0.950 percent in low salinity, up to 1.940 percent in moderately saline layers, up to 2.015 percent in strongly saline layers, and up to 3.410 percent in very strong salinity. The salinity form of sandy and low-sand horizons is sulphate and chloride-sulphate according to anions, and sulphate-chloride in silt and low silt layers is sodium according to cations.

The absorption capacity of sandy desert soils varies depending on the mechanical composition and the amount of humus. The absorption capacity of these soils is 9.33–15.15 mg-eq, the proportion of absorbed calcium is 29.9–47.4 percent, magnesium 41.5–48.5 percent, potassium 1.6–2.7 percent, sodium 8.1–23.8 percent, and moderate to severe salinity was found.

Discussion

In the dry part of the Aral Sea, full-profile soils are not well developed, where primitive, underdeveloped sandy-desert and hydromorphic soils can be distinguished. Humus in soil soils is very low in nutrients, and now from these elementary soil processes, primarily the process of salt accumulation, as well as light mechanical soil-soil erosion (deflation) processes play a key role (Abdurakhmonov and Kuziev, 2017).

As a result of studying the properties and characteristics of the main soils distributed in these areas, it was found that they are poorly supplied with humus and nutrients, water-physical, physicochemical properties are not optimal. They are now used as low-yielding pastures, which in turn exacerbates soil degradation (Kuziev and Abdurakhmonov, 2008; Kuziev and Sektimenko, 2009).

Conclusions

These data serves as a basis for determining measures to prevent or mitigate the negative processes caused by global climate change and the drying up of the Aral Sea, phytomelioration to improve the ecological and reclamation of soils, as well as a creating medium-scale soil maps and soil-geographical zoning of the Aral Sea and the dried bottom of Aral Sea the.

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Fresh Manure as a Risk of Soil Salinization at High Rates of Application

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Keywords: Sodium; fresh manure, organic matter, metagenomic analysis, annamox microorganism

Introduction, scope and main objectives

Salinization as an initial degradation soil step causes soil structural damage, normally by dissolution of organic and mineral colloids, humic substances and clay materials respectively (Sparks, 2003). At the beginning of the process, sodium and/or chloride start to accumulate, firstly displacing Ca, Mg, Fe and Al, and then sulphates and phosphates respectively. Salinization and soil structure degradation are initiated almost simultaneously. In the Mediterranean area, the use of high saline water is one of the reasons salinization takes place, but this might not be the only cause. A very useful treatment to reduce salinization in soils is Organic Matter (OM) application. OM is great for structural restoration, affecting soils by improving water retention and contributing with colloids to soil structure (Wichern *et al.*, 2020). In summary, OM has a corrective effect in saline soils in order to adequate them for a more favourable plant development (Bot, Benites and Land and Water Division, 2005; Ding *et al.*, 2020).

However, not any OM works this way. OM application could actually salinize soils. In Spain, under high rates of fresh manure applications, some soil chemical analyses revealed a high increase in available sodium and in micronutrients such as Fe, Cu and Zn. Also, metagenomic analysis of these soils showed an increase on anammox taxa at the expense of a decrease on copiotrophic taxa.

Methodology

Chemical soil analyses were conducted following Spanish official methods of soil analysis (M.A.P.A. 1986). In the metagenomic studies, 16S Genomic libraries were prepared following the official Illumina 16S Prep guide and results were then analysed using Qiime2 (Bolyen *et al.*, 2019).

Results

Chemical analysis of 505 agricultural soils surprisingly revealed that Available Sodium was positively correlated (0.213; $p<0.05$) with OM content. In a deeper way, in 25 soils under high rates of fresh manure applications an increase of more than 100 percent in micronutrients such as Fe, Cu and Zn was observed. In addition, metagenomic analyses of these 25 soils showed an increase on Planctomycetes and Verrucomicrobia taxa at the expense of a decrease on Actinobacteria, Proteobacteria, or Bacteriodetes taxa. Moreover, mineral nitrogen levels were very low for these 25 soils with an average of 33.0 ppm (the normal content for agricultural soil is 100 ppm).

Discussion

Results have shown high rates of fresh manure applications in order to improve OM content can have a negative effect in soils under some managements. This could involve the consumption of mineral nitrogen by anammox microorganisms (*Planctomycetes* and *Verrucomicrobia*) (Lee *et al.*, 2009; van Niftrik and Jetten, 2012). Furthermore, an increase of available sodium is reported as a result of materials containing high salt levels excreted by livestock. Finally, manure coming from livestock fed with different complements may have modified soil micronutrient concentrations. In summary, a theoretical good practice such as OM application on soil may in some cases actually be the cause of a long-term loss of fertility and the beginning of soil salinization.

Conclusions

Other than high salinity caused by irrigation, our hypothesis could indicate that fresh OM application at high rates could bring about a sodium level rise in soils and a loss of soil fertility. Composting and co-composting with vegetable residues and Ca as Na remover, could be the most adequate process to transform fresh manure previously to be applied as OM amendments to soil, Therefore, more studies are necessary to clarify the potential risk of this OM management.

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Salts in the Terrestrial Environment of Kuwait and Proposed Management

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Keywords: Salinity, Abdali, Wafra, management, sabkha, osmotic pressure, Kuwait

Introduction, scope and main objectives

Salts are essential for human and plants life. However, when they are increased above the tolerance level "threshold" they become toxic and increase plants osmotic pressure resulting into decline in crop yield. Keeping the salts, level in the root-zone below threshold level is therefore vital. In Kuwait salinity is showing significant effects on farms (Al Menaie *et al.*, 2018) and impacting agricultural productivity (Omar *et al.*, 1998). Therefore, salinity assessment and periodic monitoring in irrigated agriculture farms is essential. In this context, we developed a salinity national action plan for implementation over three years period. Following are the objectives; i) Assess farmland groundwater and root-zone salinities of selected farms, and using the results develop GIS database to publish soil and groundwater salinity maps and evaluate impacts, risks and challenges to local crop production and develop national salinity management strategy for food security.

Methodology

Based on soil survey of Kuwait (KISR, 1999) Kuwait landscape is affected by different levels of soil salinities covering 38.54 percent area. Using soil survey data and GIS, national soil salinity is under consideration by FAO-GSP as a part of chapter in the book. Agricultural farms were not part of this national soil survey. To fill this gap, we proposed salinity survey of agricultural farms. Over 200 farms selected through a simple random sample method (Yamane, 1967) will be investigated for salinity assessment (groundwater/crops root zone) in the field (soil:water 1:2.5 w/v) and in the lab for ECe. A correlation will be developed between EC 1:2.5 & ECe to transfer field salinity to lab salinity to publish soil and groundwater salinity maps and to develop national salinity management strategy and associated GIS based database.

Results

The soil survey of Kuwait (Omar and Shahid 2013; KISR, 1999) revealed the native sandy soils are non-saline ECe < 2 dS/m (54.8 percent), very slightly saline (2–4 dS/m 27.5 percent), slightly saline (4–10 dS/m 0.78 percent), moderately saline (10–25 dS/m 3.26 percent) and strongly saline >60 dS/m 7 percent). Overall 38.54 percent terrestrial desert landscape is affected by salinity. This survey did not include agriculture farms, which we proposed to investigate in near future to develop national salinity management strategy for food security.

Discussion

The non-saline soils of Kuwait belong to two soil great groups haplocalcids, torripsamments covering an area of 54.8 percent (ECe<2 dS/m) due clean sandy soil and low calcium carbonates solubility. The calcigypsids, petrogypsids and petrocalcids cumulatively cover 27.5 percent area (ECe 2–4 dS/m) due mainly to dissolution of gypsum in the profile (salinity is due to salts more soluble than gypsum, therefore part of the landscape with gypsum may be considered non-saline). The strong salinity is confined to coastal areas classified as aquisalids/haplosalids (Soil Survey Staff, 2014) developed over years due to sea water intrusion and subsequent evaporation. In addition, the groundwater used to irrigate farms are brackish/saline and causing severe damage to soils and farms productivity. This is a real challenge to national food security and will be addressed in the proposed national salinity action plan.

Conclusions

The native soils of Kuwait are non-saline, the coastal area is strongly saline. Secondary salinization has been observed in the agricultural farms in Kuwait, which needs full attention in future. Considering salinity ailment to agriculture, a national salinity management plan has been proposed to be implemented over the next three years.

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We wish to acknowledge the permission granted by KISR and PAAFR management to use the results from soil survey of Kuwait project to publish national salinity map. The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of KISR or PAAFR.

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Managing soil salinity in irrigated drylands of Aral Sea basin: An assessment through the lens of sustainability indicators

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Keywords: conservation agriculture; cover crop; furrow irrigation; bed planting; residue retention; skip-furrow irrigation

Introduction, scope and main objectives

Declining water availability and poor land and water management are leading to increasing soil salinity, land degradation, desertification, and threatening the overall sustainability of the crop production system in salt-affected irrigated drylands. Assessment of agricultural innovations that helps to improve sustainability while minimizing the land and environmental degradation is urgently needed. The objective of this study was to determine the potential of Conservation Agriculture (CA)-based practices, crop choice, water-saving irrigation, and nitrogen (N) fertilizer rates for improving the sustainability of rice (RWS) and cotton-based (CSW) systems in salt-affected irrigated drylands.

Methodology

Methodologies included mixed approaches of two years of field experiments, soil salinity and groundwater simulation using simulation model (LeachMod), and multi-criteria trade-off analysis for the holistic assessment of RWS and CWS in irrigated drylands. Thirteen sustainability indicators were computed and compared to assess the sustainability of those crops and the potential of alternative CA-based practices for improving sustainability.

Results

RWS had a higher yield (+24 percent), net profit (+81 percent), and soil organic carbon (SOC) (+29 percent) in trade-off with lower water productivity (WP) (-147 percent), nitrogen use efficiency (NUE) (-70 percent), energy use efficiency (EUE) (-46 percent) with higher greenhouse gas emission intensity (GHGI) (+220 percent) than CWS. The CA-based practices in CWS improved sustainability indicators with higher yield (+19 percent), net profit (+20 percent), WP (+26 percent), SOC (+456 percent), and EUE (36 percent) with decreased soil salinity (-7 percent) and GHGI (-14 percent) than in conventional system. Improved N rate turned out to be beneficial for improving sustainability in CWS. Subsurface drainage loss was highest (92 percent) in wet-direct seeded rice with flood irrigation and 65 percent from dry-direct seeded rice using alternate wet and dry irrigation, while no water loss from wheat, cotton, and maize fields. RWS raised groundwater depth by 25 percent compared to the CWS. Salinity levels at groundwater and top-soil profile were higher in CWS than in RWS. Despite benefits on economic indicators, considering lower environmental indicators flood irrigated rice might not be the appropriate choice for salt-affected irrigated drylands.

Discussion

Our results showed that soil salinity can be managed through the adoption of CA-based practices, especially by residue retention. Permanent soil cover helps to minimize the increasing soil salinity level by reducing evaporation loss of water from the soil surface and minimize human-induced secondary salinization. Higher soil salinity in CWS than in RWS in this study suggests that soil salinity decreases with the increased amount of water application (mainly with high water demanding rice cultivation), however, the availability of a large amount of freshwater to cultivate and irrigate rice is not available in most of the drylands. In such drylands, secondary salinization can be minimized by (i) alternate-wet and dry (AWD) irrigation with a further reduced volume of irrigation water using crop-demand based surface or subsurface, micro/drip, mulched drip, sprinkler irrigation if RWS has to be adopted; (ii) adopt alternative crop other than rice, potentially cotton which requires low irrigation water and tolerates salinity; (iii) cropping system with salt-tolerant crop species; (iv) shallow-depth or efficient drainage schemes in such drylands; (v) improved sub-surface drainage system coupled with improved agricultural water management 'integrated on-farm drainage management'.

Conclusions

The study attempts to assess the effectiveness of resource conservation technologies such as choice of crop species and cropping systems CA-based practices, efficient water and fertilizer management for the sustainability of salt-affected irrigated dryland. The findings from this study strongly contribute to understand the potentiality of those innovations to improve economic, environmental, and soil health indicators. These findings are useful to scientific communities and policy-makers working on sustainable intensification and climate change adaptation in salt-affected irrigated drylands.

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Nutrient dynamics and bioamelioration in agroforestry system under spatially variable sodic soil

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Keywords: Agroforestry, Bioamelioration, Nutrient dynamics, Spatial variability, Sodic soil, Soil properties

Introduction, scope and main objectives

Sodic conditions bring about degradation of clay minerals leading to accumulation of amorphous oxides of silica, alumina and iron associated with repeated synthesis of clay minerals. Spread of sodic soil is more that 50 percent of total salt affected soils of India. Multipurpose trees (MPTs) under agroforestry system provide direct as well as indirect function in agricultural sustainability. It was, therefore, considered worthwhile to study the nutrient dynamics and bioamelioration properties, if any, of MPTs in agroforestry system.

Methodology

A forty-month old agroforestry system in Saraswati forest range of Haryana, India under four multipurpose trees (MPTs), viz., agroforestry species, viz., *Acacia nilotica, Dalbergia sissoo, Casuarina equisetifolia* and *Prosopis juliflora* was selected for the study of bioamelioration of Sodic soil, if any. Soil spatial variability of pH, EC, organic carbon, $CaCO_3$ and available P content in three depths, viz., 0–0.2 m, 0.2–0.6 m and 0.6–1.1 m were analyzed (Jackson, 1973; Olsen *et al.*, 1954). Semi-variogram models (linear, Gaussian, exponential and spherical) were studied for identification of best fit model from nugget, sill and range parameters.

Results

Fractile diagrams based on cumulative frequency distribution functions showed that all soil parameters were normally distributed in sodic soils of Saraswati forest range of Haryana. A sharp decrease in surface soil pH, EC and ionic concentrations of water extract was observed within three years of growth under all the plantations. *Prosopis juliflora* decreased ionic composition of the water extract (CO_3^{2-}, HCO_3^- and Na^+) more than other species. The increase in organic C was maximum *Prosopis juliflora* (3.2 g/kg) and the least in *Casuarina equisetijolia* (1.7 g/kg). As regards the available nutrients, available P declined while an increase in available K was observed under all the plantations. The highest value of available K was noticed under *Prosopis juliflora*. The Fe and Mn concentrations in the profile increased in agroforestry system as compared to virgin soils.

The RMSE values revealed that error in predicting $CaCO_3$ content was higher in surface than subsurface layers. The RMSSE was, nevertheless, closer to 1 in surface layer indicating good fit to theoretical semi-variogram model and low uncertainty. EC exhibited lower error of prediction in surface layer than subsurface layer. The uncertainty as expressed by RMSSE was very close to 1 for all three soil layers. Least RMSE for the 20–60 cm soil layer was found for log (OC) prediction. On the other hand, RMSSE was very close to 1 for 0–20 soil layer; RMSSE value of prediction was 0.77–0.78 for subsurface soil layers depicting larger uncertainty of prediction. RMSE values for phosphorus content were lowest in 0–20 cm soil layer. However, RMSSE was very close to 1 for all three soil layers indicating low uncertainty of prediction.

Discussion

The lowest pH under *Prosopis juliflora* may be related with the highest amount of organic matter accumulation as evident by organic C content (Dey, 2008, 2009). Tree roots increase the CO_2 level in the soil which helps mobilizing and dissolving in $CaCO_3$ and it results in exchange of Ca^{++} with Na^{+} on the soil exchange complex, thus resulting in decreased calcium carbonate content on the surface and subsurface (Dey, Mongia and Singh, 2004a). High variations of Olsen-P in sodic soil can be described by water soluble silicon (Dey, Mongia and Singh, 2004b). Cross validation of results of krigged map of soil properties, in terms of RMSE and RMSSE showed in general, good fit to theoretical semi-variogram model leading to low uncertainty.

Conclusions

The afforestation of sodic soil by tree plantations helps in bioamelioration of sodic soil by lowering pH and soluble salts of the soil, creating favourable root environment and building organic matter and fertility status of the soil. Among the MPTs, *Prosopis juliflora* was found better for bioamelioration of sodic soil. With increasing scarcity of gypsum and cost of its transportation, bioamelioration through MPTs are useful for bringing more land under productive agricultural use and contribute towards circular economy.

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Integrated rehabilitation of Andean terraces (andenes) in saline-sodic Entisol soils of pre-Columbian Inca town Caspana, Atacama Desert, Chile

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Keywords: integrated rehabilitation of terraces (andenes), saline-sodic soils, Atacama Desert, Chile

Introduction, scope, and main objectives
The general objective is to consolidate a network of relevant territories for the national cultural and natural heritage in the context of agricultural production systems of the Andean terraces (andenes) in the saline-sodic Entisol soils of the micro-watershed of the river and pre-Columbian Inca town of Caspana, Atacama Desert, Chile.

The Caspana valley has saline sodic Entisols formed on igneous volcanic substrates of the sandy and stony granite type. Its bioclimatic zone (after Köeppen) is desert climate and high steppe climate. It presents a marked stratification, and a product of the depositional processes of lithic materials from the Andes mountain range.
The specific objectives are:

- To rescue, preserve, protect and value ancestral regional agriculture.
- To develop adaptation strategies to the effects of climate change in a hostile and highly complex desert saline-sodium-soil with a participatory approach at the community level.
- To adapt advances to variations in modernity of an economic, social and regional nature around salt-affected soils (SAS), respecting customs and traditions.

Material and Methodology
Soil diagnosis and management of saline-sodic soils with a high sodium content, high electrical conductivity, high concentration of boron, arsenic and variable contents of organic matter were considered.

Results
Soil and conservation techniques were employed, through the maintenance, improvement and repair of ancestral terraces. The vegetation cover of the microbasin watershed sector was improved through agricultural-ecological actions. Other measures were employed to improve the soil through mechanical work, soil washing, amendments by calcium sulfate and guano (manure) application, preventive phytosanitary and planting salt-tolerant crops (potatoes, beans, carrots, prickly pears, medicinal plants, flowers, condiments, alfalfa, wheat and corn.) There was also a general move towards organic agriculture, alternation of agricultural crops, livestock management and using forest species (*Prosopis tamarugo, Prosopis chilensis* and *Shinus molle*).

Discussion
It is important to link the terrace systems affected by salinization processes of SAS with the search for soil management models (saline, sodic saline, and non-sodic saline) in relation to practices such as: mechanical soil washing; application of amendments of S, Ca and organic matter; irrigation and phytosanitary management; management and diversification of forestry and livestock species and ecological protection.

Conclusions

In this sense, these approaches to restoration, with an integrated and adaptive management of the micro-watershed of saline-sodium soils and landscapes, represent a viable and sustainable alternative: a way to restore the natural and cultural heritage of the pre-Columbian civilizations that preceded us, with their knowledge and experience of the interrelation of man with his natural environment.

The views expressed in this information product are those of the author and do not necessarily reflect the views or policies of FAO.

Implications of agricultural drought processes on salt affected soils under climate change context: recommendations for prevention and development of soil ecosystem services

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Keywords: agriculture, drought, SAS, climate change, SES

Introduction, scope, and main objectives

The 2010 Global Forum on Salinization and Climate Change identifies salinization as one of the main causes of soil degradation and warns of the increase in areas with soils affected by salts due to the intensification of agriculture and changes in temperature and precipitation patterns because of climate change.

The main objective of this paper according to climate change scenario forecasts (AR6) are, how arid and semiarid salt-affected soils will put greater pressure on water resources, which will require greater use of water for irrigation and the search for and use of groundwater, generally with a high salt content. Similarly, the increase in temperature would increase evapotranspiration, a process that facilitates the accumulation of bases such as sodium, calcium, and other salts.

Population growth and climate change is projected to increase the pressure on land and water resources, especially in arid and semi-arid regions. This pressure is expected to affect all driving mechanisms of soil salinization comprising of an alteration in soil hydrological balance, sea salt intrusion and wet/dry deposition of wind-born saline aerosols, all leading to an increase in soil salinity.

Results

The results indicate that by the end of the twenty-first century, drylands of South America, southern and Western Australia, Mexico, southwest United States, and South Africa will be the salinization hotspots.

Discussion

Many regions are projected to experience an increase in the probability of compound events with higher global warming. Concurrent heatwaves and droughts are likely to become more frequent. Concurrent extremes at multiple locations will become more frequent, including in crop-producing areas, at 2 °C and above compared to 1.5 °C global warming.

Recommendations for prevention and development of soil ecosystem services in salt-affected soils

Biogeochemical cycles and climate changes can either weaken or strengthen the potential of these methods to remove CO_2 and reduce warming. Ecosystem responses to warming have not yet fully included climate models, such as CO_2, NO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires.

Agricultural and ecological droughts, meteorological and hydrological droughts, changes in intensity and frequency of meteorological droughts, changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water balance and a projected reduction in mean soil moisture by one standard deviation corresponds to soil moisture conditions.

Conclusion

Soil salinity influences soil stability, biodiversity, ecosystem functioning and soil water evaporation. It can be a long-term threat to agricultural activities and food security. To devise a sustainable action plan and policy, it is crucial to know when and where salt affected soils occur.

The views expressed in this information product are those of the author and do not necessarily reflect the views or policies of FAO.

Identification, mitigation and adaptation to southeastern United States soil salinization

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Keywords: Adaptation, agriculture, forest, saline soil, salinity, salinization, sea-level rise

Introduction, scope and main objectives

The Atlantic coastal plain of the United States (U.S.) is losing hundreds of square kilometres of agricultural and forested land per year (White *et al.*, 2021, Gedan *et al.*, 2020). The loss is driven by soil salinization through storm surges, tidal influences, drought, human influences, and sea level rise (Tully *et al.*, 2019). The objective of our work was to develop a manual to help coastal producers (farmers, foresters, and livestock managers) in the southeastern United States remain proactive and resilient to this threat.

Methodology

The manual was created from a literature review and discussions with regional experts (including USDA Department of Agriculture Natural Resources Conservation Service staff) on soil salinization and working lands. The draft manual was peer reviewed by an independent group of experts in coastal salinization and saltwater intrusion issues prior to publication.

Results

The Identification, Mitigation, and Adaptation to Soil Salinization in the United States Southeast manual delineates five stages of soil salinity ranging from Stage 0 (no impact) to Stage 5 (marshland). Each stage has an assigned range of electrical conductivity (EC) values ranging from 0 dS/m (Stage 0) to >25 dS/m (Stage 5). The characteristics of each stage (e.g. EC, commodity impact) are included so the user can identify the stage of their soil. Each stage has adaptation recommendations, and Stage 1 (only) has mitigation options (e.g. remediation, constructing water control structures). Adaptation options include planting field buffers, switching to crops with higher salt-tolerances, planting alternative crops, or enrolling land into a conservation easement. When the land is no longer able to be economically profitable it becomes non-commercial land and could provide benefits through ecosystem services.

Discussion

The manual provides a critical resource to help coastal producers across the southeastern United States assess and protect their working lands from current and future salinization. Regional farmers, foresters and ranchers do not know when episodic events (e.g. hurricane) will impact their lands. However, the long-term (chronic) rate of sea-level rise is well documented for the southeastern United States. This manual will assist with both the episodic and chronic impact of saltwater intrusion. Understanding how saltwater is interacting with the landscape is essential to assessing current and future salinization issues. Management plans can be developed using adaptation in each stage to extend the productivity of the land.

Conclusions

This manual can be used to identify soil salinization, mitigate it if in early stages, and adapt to it in during any stage, using knowledge specific to the south-eastern United States. Although the manual is useful for assessing soil salinization impacts for a given area, the manual does not provide any guidance (e.g. a map) of where current and future salinized soils are likely to exist or develop. Future efforts should focus on forecasting potential problems areas to allow land managers to prepare mitigation plans. Also, the manual does not provide details about post-commercial land use (e.g. as a conservation area). Revisions of the manual should include this important topic.

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Modeling risks of salt-induced irreversible soil degradation

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Introduction, scope and main objectives

Degradation of soil hydraulic conductivity resulting from the use of saline and sodic irrigation waters is a major environmental danger, especially in dry areas. The mechanisms of how salinity and sodicity lead to reductions in hydraulic conductivity (e.g. slaking, swelling, clay dispersion) are the focus of a vast body of scientific literature, but the rehabilitation process is far less understood. Existing models treat degradation and rehabilitation in the hydraulic conductivity as reversible. The scant experimental evidence that exists, however, suggests that these processes feature hysteresis, i.e. the system follows different paths for degradation and rehabilitation. Our objective is the development of a model for the dynamics of soil salinity and sodicity, which is explicitly capable of considering hysteresis in hydraulic conductivity.

Methodology

We introduce the SOTE model, a minimalistic model designed to study the long-term dynamics of soil water content, salinity, and sodicity, as driven by irrigation practices and climatic conditions. We integrate the SOTE model with a novel framework in which a soil's history of degradation and rehabilitation are used to assess future response.

Results

We use the integrated version of the SOTE model to explore the effect of irreversibility on the risk of soil degradation. When the potential for hysteresis is taken into account, risk of long-term degradation from a typical irrigation regime and climate conditions in Israel increases from 0 percent to 50 percent in a span of ten years. Rehabilitation, meanwhile, requires 100 more days when using a hysteresis-based model.

Discussion

As a tool for more effective management of marginal quality water and land resources, models that more accurately reflect soil degradation and rehabilitation can improve risk assessment.

Conclusions

Our results emphasize the importance of considering hysteresis when assessing salinity and sodicity induced degradation risks, which no existing models do.

Salinity Management and Use of State and Transition Models for Salt-Affected Soils

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Keywords: STM, Salinity, ES

Introduction, scope, and main objectives

Ecological Sites (ES) are spatial functional subdivisions of the landscape, defined by soil properties and climate. Unique State-Transition Models (STMs) that describe temporal dynamics of each ES and land use can be detailed (NMSU, 2021).

Methodology

Common salinity management principles in STMs are (NRCS, 2014):

- Soil electrical conductivity (EC) must be monitored to avoid negative effects on selected crops, and is affected by cropping system, irrigation, and nutrient/amendment addition.
- Applying irrigation water in amounts too low to leach salts or too high in salt content result in salt accumulation.
- Leaving crop residue on the surface limits evaporation to retain soil moisture allowing rainfall and irrigation water to be more effective in leaching salts.
- Avoid management that leads to low organic matter content, poor infiltration, poor drainage, saturated soil, or compaction.

Results

Management options for salt affected soils on a Sandy Basin ES in Western Riverside California area are illustrated in an example STM. Management that improves or degrades salinity, resource concerns, conditions, and on-site indicators are described.

Discussion

Common management detailed in STMs to manage salt affected soils is specific to an ES. STMs detail conditions and transitions between states. STMs are particularly useful in planning and applying adaptive actions to manage salt affected soils because they organize temporal dynamics into a decision framework (NRCS, 2021a).

Conclusions

Ecological Sites (functional groups of soils with similar properties) and STMs provide a convenient accessible framework for management decisions and their impact on salt affected soils (NRCS, 2021b).

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Salt Accumulation Processes in Soils of the South Aral Region

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Introduction
The Aral Sea tragedy resulted in a whole series of negative consequences–from the degradation of the animal world to the aridization of the climate. Among the negative phenomena, there is a significant change in the wind regime in the Aral Sea region, which may be accompanied by the removal of a huge amount of sand and salt from the drained bottom of the Aral Sea. Further shallowing of the Aral Sea and the continuous formation of new centers of salt aerosol carryover aggravate the problem.

Results
The Aral Sea region is an area of salt accumulation for a long period. Active mountain building processes in the adjacent territory are accompanied by the constant removal of the soil-forming substrate containing salts and their distribution over the plain territories. In the southern Aral Sea area, soil salinization (mainly sulfate and chloride) is a widespread and progressive process. So, in 1975, 43 percent of the irrigated land was salinized, in 1985– 80 percent, in 1997–94 percent. Since 1960, takyr and saline soils have increased by 91 thousand hectares, salt marshes, and sands–by 43 thousand hectares. The soils of the lower reaches of the Amu Darya accumulate more than 1 million tons of salts annually (Tleumuratova, 2009).

Discussion
In areas with an arid climate, where evaporation is much higher than precipitation, conditions are created for the accumulation of salts in groundwater and soil-forming rocks. In these areas, mainly saline soils are located. The high salt content in salt marshes determines the structural features of their profile and properties. In most cases, the salt marsh profile is poorly differentiated into genetic horizons. During the period of flow regulation, almost all hydromorphic soils are characterized by a high degree of salinity. This process is especially typical for the initial stages of soil desertification. Sulfate and chloride-sulfate types of salinization changed to sulfate-chloride and chloride, and the salt content in the meter layer of bog soils increased from 0.23–0.45 percent to 0.31–1.25 percent, in meadow soils–from 0.23–0.53 percent to 0.57–0.82 percent. This tendency poses a threat to the development of secondary salinization of hydromorphic soils. The degradation of hydromorphic soils is manifested in a decrease in the productivity of forage lands. The entire territory is characterized by a strong degree of desertification, covering more than 50 percent of the area, the loss of biological diversity, and practically irreversible disturbances in the morphological structure of landscapes.

In areas of irrigated agriculture, the main sources of salt accumulation in the soil are groundwater. With their close occurrence to the surface and a rather high content of soluble salts in them in an arid climate, moisture from the groundwater horizon rises to the surface from the soil water level along with the capillary voids of the soil and evaporates, while the salts dissolved in it remain (Tolkacheva, 2000). Based on the studies carried out to study the water composition of the collector-drainage network in the regional differentiation in the Republic of Karakalpakstan, it can be noted that if in 2010 the maximum indicator reached 5 g/l (Chimbay region), and the minimum was 2 g/l (Takhtakupyr region), then in 2017 there is a gradual increase in these indicators. The highest indicator was also in the Chimbay region and amounted to 6.3 g/l , and the minimum indicator was 2.2 g/l (Kegeyli region).

Conclusion

In the conditions of the ecological trouble in the South Aral Sea region, largely associated with the shortage of water resources with the current state of technical equipment of irrigation and drainage systems, these problems are becoming especially important for the region.

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The emergence of a governance landscape for saline agriculture

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Keywords: salinization, governance, international cooperative initiatives, policy, saline agriculture

Introduction, scope, and main objectives

Salinization is one of the main challenges of contemporary agriculture. Climate change with more persistent droughts and sea-level rise is expected to increase this challenge making it one of the most common land degradation processes (Ladeiro, 2012). Research shows that one billion hectares of land are negatively affected by salinity, including more than 20 percent of all the irrigated arable land (Ghassemi *et al.*, 1995; Qadir *et al.*, 2014). At the same time, an increasingly complex institutional landscape has emerged across multiple issue areas of global environmental governance related to salinization (Negacz *et al.*, 2021). This can be seen in a myriad of public, private, and hybrid international institutions and initiatives coming together to address the issue of growing salinization through saline agriculture. At present, their actions are characterized by a lack of coordination (Vellinga *et al.*, 2021). Therefore, the aim of this paper is to describe the development of a governance landscape of cooperative initiatives for saline agriculture and to discuss how to harness their potential and orchestrate their efforts.

Methodology

For the purpose of this study, we define cooperative initiatives as "(i) international and transnational institutions, which not only have the (ii) intention to guide policy and the behavior of their members or a broader community but also explicitly mention the (iii) common governance goal, accomplishable by (iv) significant governance functions" (Widerberg *et al.*, 2016: 13). Using a systematic approach, we create a database of cooperative initiatives for saline agriculture by applying semi-automated content analysis, internet snowballing, and expert interviews. To describe the evolving institutional landscape and make policy recommendations, we code characteristics of each initiative, including inter alia, their members, governance functions, focus areas, goals, and geographic coverage. We analyze the characteristics of these initiatives using descriptive statistics to illustrate the patterns across the sample. The data was collected from publicly available information on the websites of the initiatives.

Results

The preliminary results show that there is an increase in the number of cooperative initiatives over time. The initiatives are often led by diversified sets of actors, varying per region. Their main governance functions focus on information sharing and networking as well as operational activities. The initiatives address both conventional crops and halophytes and are predominantly located in Europe, North Africa, and Asia.

Discussion

We discuss these findings in relation to ongoing scholarly debates in global environmental governance on orchestration and polycentric governance. We compare the collaborative initiatives focusing on saline agriculture to other governance regimes such as climate, biodiversity, and oceans. Finally, we propose that the evolving governance landscape of collaborative initiatives for saline agriculture offers a window of opportunity for synergy effects between actions coordinated by the FAO and undertaken by international cooperative initiatives.

Conclusions

Our findings suggest that saline agriculture is increasingly present on the policy agenda. Furthermore, the orchestration of this fragmented landscape provides a pathway to harness the potential of international initiatives for saline agriculture for addressing land degradation and food security.

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Salt-affected soils at the farm scale: successful experiences and innovation needs

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Keywords: soil salinisation, farm-scale, irrigation, chemical remediation, phytoremediation, management, land-use changes, operational groups

Introduction, scope and main objectives

The short review reports a selection of innovations that successfully countered soil salinisation. We reviewed different case studies at the farm-level, in order to be able to identify strategies and define a framework to deal with soil salinisation in Europe.

Methodology

The studies were selected from practical experiences at the farm scale and show good agricultural practices related to irrigation scheduling, chemical and phytoremediation, crop selection and crop rotation, microbial management, and land-use changes.

Results

The irrigation management is specific to each type of irrigation system, being the irrigation frequency its most flexible variable. In the case of surface irrigation, Pereira *et al.* (2007) used simulation models for improving irrigation scheduling, showing how larger volumes of water and less irrigation events helped to prevent salinization arising from rise of water tables, while meeting the crop water requirements and leaching from the root zone, as well as providing water savings.
Soil sodicity can be reduced by using chemical amendments. Amezketa, Aragüés and Gazol (2005) tested four amendments in crusting prevention of two calcareous soils (non-sodic and sodic) and remediation of a sodic soil. The four chemical amendments: mined-gypsum, coal-gypsum, lacto-gypsum, and sulfuric acid, were effective in crusting prevention and sodic remediation, but sulfuric acid was the most efficient, leading to quicker reduction of soluble salts and Na in the soil leachates. The three gypsum materials were equally effective in the sodic remediation process and in the crusting-prevention of the non-sodic soil, whereas lacto-gypsum was less efficient in the crusting-prevention of the sodic soils.

Phytoremediation can be used for Na removal through a similar mechanism to that of chemical remediation, i.e. by making Ca available to replace Na in the soil's exchange complex.
New varieties are being developed that can successfully cope with high salinity values. In addition, the plantation of halophytes is becoming an agronomical niche in some very high salinity areas. Grafting can also constitute an approach to grow less tolerant crops in soils susceptible to salinization.

Saghafi *et al.* (2019) suggested the beneficial effects and the success of the microbial amelioration of salt stress, through the inoculation of the crop seeds and the soil with specific bacterial strains.

Discussion

The success of the previously presented adaptation strategies depends on several factors, and in some cases, they may not be able to counter the problem. As an alternative, the adaptation to local salinisation problems can be to consider a change in the land-use. This can offer opportunities to implement soil ecosystem services beyond food production, such as providing and regulating environmental, health, climate, and cultural services. In cases that agricultural uses can lead to severe soil degradation, alternative soil uses can be a solution, as for example converting them into recreation and ecotourism areas, cultural heritage, or natural protection areas (Amezketa and de Lersundi, 2008).

Conclusions

The reviewed case studies constitute a set of very different approaches that can be taken to deal with salt-affected soils at the farm level. Although the studies present successful approaches, they also help to identify knowledge gaps and innovation needs. Such is the case of nutrient and microbial management for improving the crop's tolerance to saline soils, which shows high potential but demands further research and experience in order to be more widely implemented.

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The use of halophytes in the production of feed and their salt storage capacity in the fight against soil salinization

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Introduction
An increase in the level of salinity is the main reason for a decrease in crop yields. In this regard, reclamation of saline soils by washing them in order to remove excess easily soluble salts has been, and remains, the main and most radical means of successfully reintroducing these soils into agriculture. However, even on reclaimed lands, the negative effect of salts in the root-inhabited soil layer remains.

In this regard, the development of effective methods of combating soil salinization is a very urgent task in the region.

Research methodology
The objects of research were saline pasture soils, using forage species of halophytes: *Kochia scoparia, Climacoptera lanata, Atriplex nitens* and *Suaeda altissima*.

The degree of salinity of the soil was determined on experimental plots where feed halophytes were grown. For control, soil samples were taken on a natural pasture. The level of soil salinity was determined by measuring the dry residue of the water extract of the soil.

The use of halophytes in the production of feed
Shrubs and semi-shrubs of *Chenopodiaceae* are being introduced into the agriculture more and more intensively as drought-and salt-resistant forage plants for desert pastures.

The test results allowed us to identify some promising types of halophytes that are characterized by responsiveness to irrigation with saline waters, allowing to intensify irrigation feed production in the conditions of the Kyzylkum desert. The prospects of using *Climacoptera lanata* for the production of feed without irrigation have also been established.

Results of the study of salt storage capacity
In order to select the salt-accumulating species of halophytes, we conducted vegetation experiments with the participation of such species as *Climacoptera lanata, Kochia scoparia, Atriplex nitens* and *Suaeda altisima*. All types belong to the forage species of the plant.

Before sowing seeds, the level of soil salinity was determined in all variants of the experiment. At the end of the vegetation period of plants, the level of soil salinity in all vegetation vessels was re-determined.

Among the tested plant species, only *Climacoptera lanata* contributed to a decrease in the level of soil salinity. In our case, the level of soil salinity after growing *Climacoptera* decreased by 0.17 percent, which indicates the salt-accumulating ability of this plant. It should be noted that the level of reduction in soil salinity also depended on the amount of plant phytomass. In nature and in crops, the value of phytomass in *Climacoptera lanata* is usually 1.5–3.5 t/ha of air-dry mass. The average weight of one plant can vary from 1.5–5 kg or more. In the vegetative vessels, the average weight of one plant varied from 12.6–16.2 g.

Conclusion

Thus, the results of vegetative experiments indicate that among the tested halophyte species, *Climacoptera* is able to reduce the level of soil salinity due to its salt-accumulating ability. In this regard, it can be assumed that growing this plant on saline soils can significantly reduce the level of salinity.

Saline Agriculture: Potential and prospective to manage saline landscape for food and ecosystems services

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Keywords: Soil, Salinity, Eucalyptus, SOC, Organic matter, reclamation

Introduction, scope and main objectives

In Pakistan, around 30–40 percent of cultivated lands are under secondary salinization causing serious threat to national food security. Reclamation of such lands using chemical and physical method has limitations and expensive ones, thus farmers are giving up such lands barren resulting shrinkage of food production systems as well as increase of desertification process (Harvey and Pilgrim, 2011). Saline agriculture i.e. use of salt tolerant halophytic plants especially woody perennials are best option for restoration of these lands. Apart from playing a key role in mitigating of soil salinity, tree plantation has proven to be directly profitable to growers. Keeping above facts in mind, a study was carried out on naturally salt-affected wastelands to assess the plantation potential and its effect on improving soil health, wood biomass production and carbon sequestration potential.

Methodology

The research trial was conducted for five years at three sites around Faisalabad district of Pakistan. The sites were barren land due to high salinity with damaged soil properties, low infiltration rate and no cropping history for the last ten years. The climate is arid to semi-arid with mean annual rainfall of 250–500 mm. *Eucalyptus camaldulensis* seedlings were transplanted in field during September. Non-experimental plots were also selected, with the aim to determine any changes in soil condition without plantation, under the same environmental conditions. Soil and plant determinations were carried out twice periodically. The results were then compared with those obtained from plantation sites.

Results

The Eucalyptus plantation significantly influence both plant and soil parameters. Tree plantations help in progressive reduction of soil salinity. There was improvement in soil physical properties like infiltration rate, organic matter contents and bulk density due to plantation when compared to no plantation and enhanced mitigation of salinity, biomass and ecological resurgence at sites have tree plantation.

Discussion

Plantation helps in decreasing the salinization process by ameliorating soil microclimate and physical conditions (Timmer and Bhojvaid, 1998). Canopy helps in lowering soil temperature and ultimately reduces evaporation by providing shade and mulching effect, which, in turn, leads to lesser upward movement of salts. The process is enhanced by physical impact of plant roots within soil profile in improving the soil structure and stabilize soil aggregates (Boeuf-Tremblay, Plantureux and Guckert, 1995). Root secretion of exudates (Damodaran and Mishra, 2016) increases root respiration, as well as root extension and proliferation (Qadir *et al.*, 2005). Channels are made within soil profile, thus movement of water and solute becomes swift through soil profile and improves the hydraulic conductivity, infiltration rate and water and solute movement in the soil profile (Akhter *et al.*, 2004)

Conclusions
The salt-affected wastelands with 'zero opportunity' can be brought under plantation, which will not only bring improvements in soil health, but also environmental benefits like SOC sequestration, ecological resurgence and biological diversity will be over and above.

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Innovative Thinking and Use of Salt-Affected Soils in Irrigated Agriculture

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Keywords: Salinity, innovation, civilization, insanity, paradigm shift, salinity dynamics, diagnostics, integrated approach

Introduction, scope and main objectives

Historically, humanity and salinity lived one aside the other. Besides, technological advancements salinity is ever on the hike, and business as usual (BAU) seems to be not a viable option to tackle salinity sustainably. Doing same thing over and over again and expecting a different result is INSANITY (Albert Einstein), so we need a paradigm shift (seeing something in a new and different way that creates a huge change in thinking and behavior) in our understanding to manage salinity holistically. The BAU has resulted into a daily loss of 2000 hectares' farm land due to salinity, and currently, 63 M ha of total irrigated land (310 M ha) is salinized causing annual global economic losses of 27.3 billion USD. The objective of this keynote is to highlight the salinity issues and gaps as a wakeup call, and sharing innovative thinking and ideas–currently do not exist, but expected to happen in future–to bring a significant change in future salinity expansion.

Methodology

A comprehensive picture of salinity from various aspects will be shared, and future expectations of ambitious innovations will be placed in front of the distinguished participants, to give new and difficult thoughts, but doable with the current high-tech and deep thinking of intellectuals. The innovative ideas one day will be on the ground as salinity solution. Most soil labs in the developing world are using procedures in USDA Handbook 60 as these were developed and tested on their local soils, leading to invalid prediction of SAR and gypsum requirement (Shahid *et al.* 2013, 2018a). In addition, justification to screen crops against salts present in local soils in contrast to using NaCl will be presented. The gaps in salinity research and innovative ideas (biotechnological innovations) to tackle salinity spread will be shared.

Results

The newly developed correlation between ECe and TSS, and SAR determined from this curve and from Handb 60- curve will be shared, and differences highlighted, as well as GR conversion factors (Shahid *et al.*, 2018a) will be presented. Research on crop screening against salinity is progressing since decades using NaCl, even where thenardite (Na_2SO_4) dominates in saline soils (Shahid *et al.*, 1990). Real time dynamics of rootzone salinity gives rapid answer for timely salinity management (Shahid *et al.*, 2008). Moving from sedentary salinity labs to mobile labs provide farmers rapid on-farm salinity diagnostics and timely management. In the KN some serious gaps in the past salinity research and emerging innovative ideas will be shared as a way forward to resolve salinity issue to significant extent leading to improved productivity of improvised farms and food security.

Discussion

Prediction of SAR, by taking soluble Na^+ by difference [(Na = TSS-(Ca+Mg)], where TSS are noted from Fig. 4, p. 12 USDA Hb 60, against ECe, may predict soil a sodic, and it may not be sodic. This will be supported by sharing new innovative curve between ECe and TSS from UAE saline soils (Shahid *et al.*, 2013, 2018b). The conversion factor of gypsum requirement (GR) from meq/100 to tons per acre 6 inches (0.86) and per acre foot (1.72) is blindly used, without determining such factor for local soils affected by salinity/sodicity, leading to predict under- or over estimation of GR. These and other gaps will be shared along with innovative ideas to manage irrigated agriculture salinity.

Conclusions
Current practices are not sufficient to tackle salinity problem, BAU is not a viable solution, innovative thinking and paradigm shift, addressing the gaps in holistic ways and biotechnological innovations are the only viable options to manage salinity in future.

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The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Bangladesh coastal region: Sustainable land management (SLM) best practices

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Keywords: land resources, SLM, salinity, waterlog, coastal region, climate extremes, Agro-climate

Introduction, scope and main objectives

The coastal zone (17 066 sq km) of Bangladesh consists of 19 districts comprising 147 sub-districts. The area is within the agro-ecological region Ganges Tidal Floodplain (AEZ-13) and this region occupies an extensive area of tidal floodplain in the south-west of the country. The greater part of this region has smooth relief having different degrees of salinity. The soils of the area are predominantly Gleyic Fluvisols having acidic topsoil. The area has significant agro-climatic characteristics then other parts of the country (UNDP and FAO, 1988).

The major land resource management constraints of the area are: surface water salinity in dry season, poor communication, Big absentee land ownership, dry season salinity of soil and water in southern part (AEZ-13d to13f), Heavy textured soils, difficult tillage operation when dry, river bank erosion, water logging within polders, conflict among agriculture, fisheries (Shrimp) and salt producers, and Natural hazards.

Considering the agricultural options of the area land users are trying to adopt sustainable land management (SLM) best practices addressing "Gher" management for multiple cropping including fresh water conservation, sorjan cultivation, polder management, social/agro-forestry etc. This paper includes some best practices to avoid soil salinity and waterlog condition of the area.

Methodology

SLM best practices documented following Questionnaire on (SLM) Technologies (QT), which covers the following sections (WOCAT, 2021):

1. General information
2. Description of an SLM Technology
3. Classification of the SLM Technology
4. Technical specifications, implementation activities, inputs, and costs
5. Natural and human environment
6. Impacts and concluding statements
7. References and links
8. ANNEX.

Results

With limited time 20 SLM best practices were documented of which 14 were validated by local, regional and national level stakeholders.

a. Slightly to moderately saline area AEZ-13a and 13b

1. Integrated homestead farming in slightly saline area.
2. Rain water harvesting in saline area.
3. Changing cropping pattern to increase cropping intensity in slightly saline area.
4. Modifying landform to grow rice-fish and vegetable in saline area.
5. Women in large scale vermin compost production at villages of Batiaghata.
6. Adoption of Climate resilience vegetable farming in slightly saline area.
7. Usage of cut-off river water to increase cropping intensity in saline area.

8. Raising Community seedbed to facilitate quality seed for boro rice in coastal region.
9. Tree plantation to protect embankment/dykes.

b. Strongly saline area AEZ-13b

1. Commercial crab cultivation in strongly saline area.
2. Malia cultivation by less privileged community in strongly saline area.
3. Tower gardening in saline and intermittently shallowly flooded areas in coastal region.
4. Vegetable with rice and fish in moderately saline area.
5. Transplanted aman rice and golda shrimp/white fish cultivation.

Discussion

The farmers those have access to extension and marketing scaled up SLM best practices to adopt local situation of soil salinity and waterlog condition.

Conclusions

SLM combines technologies to integrate the management of physical and socio-economic principles to meet human needs while ensuring the long-term sustainability of ecosystem services and livelihoods. SLM integrates land, water, biodiversity, and environmental management to meet rising demands of land users offering solutions that go beyond technologic recommendations by including aspects of social participation and policy dialogue. It needs scale up and scale out as local demand.

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Salt affected soils in Prakasam district of Andhra Pradesh - Livelihood diversification of farmers

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Key words: Salt affected, soils, Prakasam district, livelihood, diversification

Introduction

In India agricultural production is being restrained by land degradation resulting from salinity. In salt affected soils farmers migrate to nearby towns and cities for work to make safe their livelihoods. There are several versions that the climate change is making soils saltier and forcing farmers to find alternate livelihoods. Salts are ruining the soils making them less productive and even non-productive for many crops. The salinity has a great impact on the diversification of livelihoods of the farmers in this area. In salt affected soils agriculture alone cannot provide livelihood security to farmers. Many farmers diversify their income sources in addition to agriculture. The study was carried out in Prakasam district of Andhra Pradesh during 2021 in Martur, Nagaluppalapadu, Parchur, Darsi, Mundlamur, Addanki mandals. The soils are Sandy clay loam to sandy loam in texture having pH >8.5 (1:2 soil water suspension), ECe >4 dS/m and ESP >15 and characterized as saline sodic soils. The soils are physically weak in structure with poor vegetation and ill drainage conditions. Low rainfall, lack of cover crops, high evaporation, more wind speed, high salt containing minerals in soil, insufficient soil moisture has paved the way to develop salt affected soils in parts of Prakasam District, Andhra Pradesh. The degradation of soil due to salinity and sodicity severely limit people's livelihoods.

As diversification options, farmers rear sheep and goat, practice dairy, plant orchards and agro-forestry trees like casurina, eucalyptus and Subabul in the salt affected soils, etc. In these salt affected soils natural vegetation include many trees like tamarind, raintree, pongamia, propsopis, acacia, neem, etc. Taking advantage of the natural vegetation, farmers even go for preparation of coal, fire wood, tamarind and collection of neem seeds. Diverse activities are practiced by these farmers in order to survive and to improve their standard of living. Risk reduction is the main motto for diversification. In these areas the annual rainfall is as low as 400–600 mm leading to very reduced crop returns. At this juncture a study was conducted with an objective to compare the livelihood diversification of farmers in salt affected soils with that of non-salt affected soils in Prakasam district of Andhra Pradesh. The study would depict the livelihood diversification options and reasons for such diversification options. The government and non-governmental organizations could utilize this data to train the farmers in their livelihood diversification areas to increase their entrepreneurial behavior thereby increasing their annual income.

Methodology

The study was conducted in Prakasam district of Andhra Pradesh during 2021 in Martur, Nagaluppalapadu, Parchur, Darsi, Mundlamur, Addanki mandals. A sample of 120 farmers having salt affected soils and 120 farmers having non-salt affected soils were studied. The farmers were selected using a simple random sampling procedure. Different livelihood diversification options of farmers in salt affected and non-salt affected soils were compared. Livelihood diversification index in both salt-affected and non-salt affected areas was calculated and compared using the formula of Simpson's index for diversity. The reasons for more or less livelihood diversification index in salt affected soils and non-salt affected soils were also studied. Livelihood diversification index was calculated and compared using the formula of Simpson's index for diversity.

D=1- i=1Sni(ni-1)N(N-1)

Where D is the diversity index, n is the number of respondents opting a particular livelihood, N is the total number of respondents. The value of D ranges from zero to one ranging from no diversity to infinite diversity. Frequency and percentage were also used to present the data.

Results and Discussion

The results indicated that 30.83 percent of the farmers practiced dairy, followed by sheep and goat rearing (20.83 percent), Agroforestry trees (17.50 percent), orchards (16.67 percent), tamarind and tamarind leaf collection (5.83 percent), neem seed kernel collection (4.17 percent) and coal preparation (2.50 percent) and fire wood (1.67 percent). The findings are in conformity with that reported by Yamba *et al.* (2017); Das and Ganesh-Kumar (2018) and Samuel and Sylvia (2019); Subbaiah *et al.* (2020). The livelihood diversification index recorded was 0.82. This indicates that the farmers practiced alternate livelihood strategies to cope up with reduced crop returns.

Livelihood diversification of farmers in non-salt affected soils indicated that less than two third of the respondents practiced dairy (60.83 percent) in addition to agriculture while the remaining practiced sheep and goat rearing (39.17 percent). The livelihood diversification index recorded was 0.34. Here the crop component is more hence the diversification is less compared to salt affected areas.

The reasons for more livelihood diversification index in salt affected soils indicated that a greater majority of the respondents mentioned that they are forced for diversification (83.33 percent), followed by more barren lands (75.00 percent), less income compared to non-salt affected area (66.67 percent). However, due to the crisis situation, livelihood diversification took place.

The reasons for less livelihood diversification index in non-salt affected soils indicated that the majority of the respondents mentioned that there is minimum scope for diversification (87.50 percent), more income compared to salt affected area (79.16 percent). Less diversification is due to the busy schedules and more income in non-salt affected areas.

Conclusion

Farming is always a challenge for farmers. In areas with scanty rainfall it is more challenging with a very less scope due to stunted and uneven plant growth. However, some farmers are taking up coping strategies for livelihood security by opting for other alternative and possible occupations under the existing situation along with farming with reduced input cost. By diversifying the livelihoods farmers could offset the reduced or lost crop revenues. These small opportunities and attachment to the native villages reduced the migration of farmers to nearby towns and cities.

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Forage production on halomorphic soils of the Flooding Pampa

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Keywords: Tall wheatgrass, megathermal graminoids, natric soils, natural vegetation, soil heterogeneity, seeded pastures.

Introduction, scope and main objectives

More than 12 million ha of the Argentinean Pampas are covered by lowlands with soils affected by water and exchangeable sodium excesses (INTA 1990; Taleisnik and Lavado, 2021). Periodical waterlogging and true floods are typical events. This area is mainly devoted to cattle husbandry. The natural vegetation is a monotonous-looking grassland, with four major types of plant communities with numerous variants: The "Mesophyte grasslands" associated with Udolls, "Humid mesophyte grasslands" associated with Natraquolls, "Hydrophytic meadows" associated with Albolls and "Halophyte steppes" associated with Natraqualfs (Oesterheld *et al.*, 2005). Recent research focused on to restore the natural vegetation by grazing management or implanting forages (Taleisnik and Lavado, 2017; 2021). Present communication stressed results obtained with tall wheatgrass (*Thinopyrum ponticum*), and megathermal graminoids.

Methodology

An experiment was carried out across three years in the "Depresión de Laprida", whose soils showed an intricate pattern of Natraquoll, Natraqualf and Natralbolls. Half of the 400 ha plot was plowed and tall wheatgrass was sown. There were non-replicated plots and appropriate statistics was applied on soil and plant data (Taboada *et al.*, 1998; Taleisnik and Lavado, 2017).

Experiments with Grama Rhodes (*Chloris gayana*) and Panicgrass (*Panicum coloratum*) were carried out in the "Cuenca del Salado" basin. The seeding of them was concentrated on Natraqualfs, because on other soils probed to be unsuccessful (Otondo *et al.*, 2015; Taleisnik and Lavado, 2017).

Results

In the Natraquoll, tillage did not affect the A horizon properties and in the Natraqualf, the severe limitations for plant growth were not changed. In contrast, the thin A horizon of the Natralboll was redistributed in depths and partially replaced by the sodic clayey B horizon. The behavior of tall wheatgrass differed and considering the productivity (biomass, persistence, soil cover, so on) of the native vegetation as 100 percent, the productivity of the tall wheatgrass in the Natraquoll was 144.4 percent, increased to 177.8 percent in the Natraqualf and was reduced to 77.2 percent in the Natralboll.

Both megathermals increased forage production with respect to the halophyte steppe and, considering the natural vegetation biomass production as 100 percent, Panicgras yields 209 percent and Grama Rhodes, 190 percent.

Discussion

In the Natraqualf the implantation of tall wheatgrass was positive from the productivity point of view, while in the Natraquoll parches was around the indifference point. In the Natralboll the effect of seeding was clearly negative to soil and vegetation. It must be added that this vegetation is more nutritious and palatable than that of the other soils, especially the vegetation of the Natraqualf (Taboada *et al.*, 1998; Taleisnik and Lavado, 2017).

The replacement of the Natraqualf´s native vegetation by megathermic forages was clearly positive. The latter can be considered a strategic forage resource to cover summer needs and also for making forage reserves (rolls) (Otondo *et al.*, 2015; Taleisnik and Lavado, 2017).

Conclusions

In the Flooding Pampa the soil type and its vegetation is the major factor to maintain the natural vegetation or to replace them. The implantation of seeded pastures should be focused on Typic Natraqualfs, the more saline and alkaline soils. Tall wheatgrass is seeded from several years ago and more recently Grama Rhodes and Panicgrass were introduced with noteworthy success.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Soils, groundwater movements and floods in Argentina lowlands

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Keywords: natric horizon, groundwater characteristics, floods, salinity of flooding water, perched water

Introduction, scope and main objectives

Approximately 11.6 million hectares of the ChacoPampean region of Argentina are covered by halo-hydromorphic soils, much of which have a natric B horizon in subsoil differing in its texture (INTA, 1990). Lowlands having natric soils undergo periodic cycles with water excesses, waterlogging and floods, as well as periodic droughts (Lavado and Taboada, 1988; Taboada *et al.*, 2001, 2020). The whole region has intricate relationships between rainfall, evapotranspiration losses, groundwater, and soil profile characteristics. In this work we aim to explain the relationship between the phenomena of recurrent floods and droughts, the salinization processes, and the general drainage characteristics of the Chaco-Pampean plain.

Methodology

We revised and revisited allusive peer-reviewed information from the authors as well as from other sources. This information was analyzed and synthesized in a new theory, aiming at integrating and explaining soil functioning and the recurrent flood and drought events.

Results and discussion

<u>Characteristics of landscape and soils</u>

The plains have a poor drainage network that impede the evacuation of water excesses during high rainfall periods (INTA, 1990). These mainly affect three sub-regions of the region: a) the Northern Lowlands at the North, b) the Inland Pampa at the West; and c) the Flooding Pampa at the East.

The different natric horizons also determine different groundwater regimes. There are free groundwater movements throughout soil profile in the Inland Pampa, where soils have light natric horizons, while groundwater rises are controlled by a tough natric horizon both in the Northern Lowlands and the Flooding Pampa. This groundwater control triggers air entrapment and volumetric expansion of soils by a "swelling inflation" process (Taboada *et al.* 2001). Trapped air decreases even more soil water storage capacity and contributes to fast flooding and droughts occurrence. In such way, at Flooding Pampa where the soils are fine textured, floods mainly a phenomenon of a huge and extensive perched water table. Shallow water storage above tough natric soils are the main factor causing severe droughts in the region.

<u>Flood types and salinization risks</u>

The origin of topsoil salinization depends strongly on the salinity of the flooding water and the prevailing type of salts, differing if the flood is caused by rainwater, or by groundwater rises (Lavado and Taboada 1988; Di Bella *et al.* 2017). In areas with tough natric horizon, groundwater rises are checked in depth, while in areas with light natric horizon groundwater movements are free throughout the profile and flood water could be saline. Floods caused by no saline water may only cause soil physical constraints by trampling or agricultural traffic, while floods caused by saline groundwater exert severe consequences as a function of the type of salts.

Conclusions

The different types of soils determine different types of flooding. Where there are soils with a tough natric horizon, floods are caused by rainwater. When there are soils with a light natric horizon, floods are caused by groundwater rises.

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The effect of halophilic, alkaliphilic and haloalkaliphilic rhizosphere bacteria on different vegetative growth characteristics, soil and GN15 almond rootstock nutrients

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Keywords: Extremophile bacteria, exo-polysaccharide, R/S ratio, proline, toxic ions, relative water content

Introduction
Currently, the use of soil biotechnology to exploit the potential of beneficial soil microorganisms to produce a maximum yield in stress conditions has received much attention (Koskey *et al*, 2021). Almond (*Prunus amygdalus* L.) yields are reduced by 25 percent, 50 percent, and 100 percent in electrical conductivity of 2.8, 4.8, and 7 dS/m respectively (Collin *et al.*, 2019). In this study, we aimed to investigate the effect of three types of extremophilic indigenous bacteria to induce salinity and alkalinity resistance in almond rootstocks under these soil stress conditions.

Methodology
Isolating, purifying, and preserving 54 different strains from three groups of bacteria (halophilic, alkaliphilic, and haloalkaliphilic) were carried out from the rhizosphere of almond groves soil samples in Khorasan Razavi (Iran). Afterward, three PGPR properties including tri-indole acetic acid, dissolution of mineral phosphates, and exo-polysaccharide were measured in all strains in the laboratory. Then, the roots of 108 GN15 almond rootstocks were inoculated with two superior bacterial strains and sterilized control from three groups of bacteria in four saline-alkaline artificial soils (2, 4, 8, 16 dS/m with 10, 15, 15, 20 SAR respectively). More than 50 different morphological characteristics, biochemical traits, soil and plant macro, micro nutrient concentration along with some specific ions (Na^{+} and Cl^{-}) were measured in the treatments.

Results
Alkaliphilic, haloalkaliphilic and halophilic were superior in terms of production capacity and amount of plant growth-promoting attributes, respectively. H10, H22, A11, A7, HA7, and HA9 were the best isolates in the laboratory.

Halophilic bacteria caused the largest increase in shoot fresh weight (19.83 g); however, the fresh weight of the roots (22.61 g) was maximal in the haloalkaliphilic group. The highest root-to-shoot ratio was observed in the HA9 strain of haloalkaliphilic bacteria with 1.31.

Soil pH was variable and significant from 6.9 to 7.5 in all treatments. Soil EC was significantly reduced in 8 and 16 dS/m treatments to the 5.2 and 9.2 dS/m respectively with the bacterial application.

With soil salinity increase, plant N and K decreased; and the concentration of plant Mg, Fe, Na, and Cl along with soil P, Na, and Cl increased. The increasing trend of EC, P, and Cl elements in the soil and Zn of plants under the influence of bacteria was similar to quantitative amounts of growth enhancers; and it was more in alkaliphilic, haloalkaliphilic, and halophilic, respectively. While the amount of plant Mg, P, and K and soil Fe were affected by the pH changing by bacteria and were observed in halophilic, alkaliphilic, and haloalkaliphilic, respectively.

The plant P was eight times higher than the optimal P of almond leaves and 39.5 times greater than the initial P of soil. Soil K of treatments was 21 times bigger than the initial soil K. Plant Fe was

12 times more than the soil Fe, and the concentration of plant zinc was about 0.3 mg/l more than on the soil. Also, plant sodium was one-eighth of soil sodium and plant Cl was one-half of soil chlorine under the influence of bacteria.

In general, the results showed that the halophilic bacteria increased biochemical properties such as chlorophyll, proline, and total sugar, decreased plant uptake of specific ions such as sodium and chlorine, and increased uptake of primary macronutrients such as plant N, P, and K. While alkaliphilic bacteria improved morphological characteristics such as plant height, leaf area, increased the absorption of microelements (Fe and Zn). Haloalkaliphilic bacteria were effective in magnesium uptake, root development, and improvement of plant water relations.

Discussion

These data showed higher efficiency and performance of native soil bacteria at higher salinities (16 dS/m). The greater effect of haloalkaliphilic bacteria on root growth than shoot growth can be attributed to the production of more indole auxin compounds compared to other properties in them that increased root growth (Kudoyarova *et al*, 2019).

The halophilic bacteria showed less PGPR properties in the lab but they were more effective than the other two groups, due to their different complicated mechanisms to the availability and absorption of essential elements or inhibition of absorption of toxic ions which represents the complex interactions of soil, plants, and bacteria in saline and alkaline soils (Gamalero *et al.*, 2020).

Conclusions

The 8 dS/m salinity acted as a turning point for almond rootstocks under the influence of extremophilic bacteria. So that with salinity increase to more than that, the use of bacteria strains improved different parameters. This study indicated that the results of soil nutrient concentration with quantitatively measured values of PGPA in the laboratory were more consistent than the plant concentration of elements. H10 and H22 strains from the halophilic group were the most effective strains in increased resistance in the almond rootstocks.

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Applying Sustainable Agricultural Management Practices in Saline and Sodic Soils to Increase Soil Organic Carbon Sequestration Potential and Mitigate Climate Change

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Keywords: salinization, sodification, Soil Organic Carbon Sequestration, Climate Change

Introduction, scope and main objectives

Saline and sodic soils affect the organic matter decomposition by decreasing soil microbial activity and therefore have a negative impact in Soil Organic Carbon (SOC) sequestration. This work compares the SOC in 2020 and 2040 (projected for 2040) in different classes of salt-affected soils in Greece.

The objective of this work is to highlight the importance of applying sustainable agricultural management practices to facilitate larger SOC sequestration and mitigate salinization-sodification. Moreover, specific agricultural practices are going to be suggested according to specific soil conditions in Greek croplands.

Methodology

The relationship between SOC and salt-affected soils was calculating by applying statistical analysis (correlation coefficients). More specifically, the input data were retrieved by: a) the Greek Map of SOC (2020), b) the projected Greek SOC Map for 2040 under the Business-As-Usual (BAU) scenario, Sustainable Soil Management SSM-I , II, III and c) the Greek Map of salt-affected soils, which were prepared by Triantakonstantis and Detsikas (2021a, 2021b, 2021c), under the guidelines of Food and Agriculture Organization of the United Nations–FAO (Omuto *et al.*, 2020; FAO, 2020). The BAU scenario refers to the current land use and land management practices. SSM-I (low carbon inputs), SSM-II (medium carbon inputs) and SSM-III (high carbon inputs) refer to practices that are proven to remove CO_2 from the atmosphere and sequester carbon in the soil.

Results

It is worth mentioning that 20 percent of the Greek agricultural areas have strong salinity while 73 percent are areas with moderate salinity. In our study, the results showed a strong negative correlation between SOC (2020, 2040) and the different classes of salt-affected soils. When the salinity becomes stronger the predicted SOC of 2020 and 2040 appears lower. Areas with Moderate Salinity appear to have more SOC compared with those of Strong Salinity. In significance level 0.001, both the correlation coefficients Spearman's Rho and Kendall's Tau B indicate the importance of relationship between SOC and the different classes of salt-affected soils.

Discussion

Agricultural policy needs to know how to appropriately treat soils to sequestrate more SOC and mitigate climate change. According to Triantakonstantis and Detsikas (2021b), the application of sustainable soil management practices could mitigate about 14–56 percent of current national agriculture emissions. Therefore, farmers should apply sustainable agricultural practices by giving them appropriate motivations. Agricultural practices should be focused on the draining systems, salt leaching, suitable fertilizers (with low salt index) and salt resilient cultivations (e.g. barley and cotton). Moreover, usual check for capillary ascension of salt from lower horizons and stern scrutiny of pumping underground water from aquifers that contact with seawater is an important action as well (GNCCD, 2001).

Conclusions
Greek agriculture areas appear to have problem with saltiness. According to scenarios of global warming the current situation is expected to become more urgent with unpredictable consequences. Moreover, the need for healthy soils is a mandatory issue for covering the necessary agricultural products due to the increase of global population. Therefore, applying sustainable soil management practices in salt-affected soils is a necessity and a national strategic action plan should be conducted.

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Impacts of climate change on forest growth and soil salinity in saline-alkali lands

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Keywords: Soil salinity; Climate change; Saline-alkali land; Forest growth; Yellow River Delta

Introduction, scope and main objectives

Saline-alkali land is seriously threatening the balance and stability of the ecosystem (Shan *et al.*, 2018). In Yellow River Delta, the area of saline-alkali land increased by 0.37 million ha within 40 years, severely restricted the further development of the region (Xia *et al.*, 2020). Climate change is an important factor affecting land degradation (Toledo *et al.*, 2011). Therefore, approaching the impacts of climate change on forest growth and soil salinity is of great significance to ameliorate this degraded land and push up forestry development.

Methodology

In this study, five species of 22-year-old trees were selected, and the tree biomass was measured by standard site methods and tree ring sampling to pursue the impacts of climate change on forest growth. The stand was inventoried by random sampling, and inventory plot area is 20 m × 20 m. For every plot soil profiles were created and soil samples were collected according to 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm and 80–100 cm. Soil salinity was measured by Electric Conductivity Meter DSS 11. All tree height and diameter at breast height (DBH) values were determined at each standard site. According to the actual diameter range of the tree species, the number of plants and the proportion of each diameter class were calculated. According to the diameter class, 1–3 standard trees were determined, and the trunk was analyzed to determine the growth process and biomass of the trees.

Results

The results showed: (1) In Yellow River Delta, the most adapted tree species are *Fraxinus chinensis* and *Robinia pseudoacacia*. (2) Precipitation is the main meteorological factor affecting tree growth. (3) Soil salinity can be reduced with trees growing. Soil salt concentration in forested land was decreased for every soil profile. Especially for 0–60 cm, the effect of trees on soil salinity alleviation was obvious.

Discussion

Soil salinization is impacted greatly by climate change. *F. chinensis* and *R. pseudoacacia* are the most adapted tree species in the region, which implies that in spite of adverse site conditions there are still tree species can grow well. And with trees growing soil salinity could be refrained to some extent.

Conclusions

To cope with climate change, developing forestry is vital, and the effect of forest on preventing land degradation will be significant.

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Mapping and Monitoring Saline and Sodic Soil Reclamation in Indo-Gangetic Plains of India Using Geo-Information Tools

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Keywords: Saline and sodic soils, Reclamation, Geo-information, Environment

Introduction

The Indo-Gangetic Plains (IGP) covering 43.7 million ha area in India produces half of the country's food grains. However, its 2.35 million ha is also affected by soil salinity and sodicity, significantly reducing crop productivity. For increasing food production, about 0.60 million ha area has been reclaimed in the IGP under the World Bank supported Uttar Pradesh Sodicland Reclamation Project during 1993–2018, about 0.40 million ha directly from the project cost and the remaining by the farmers on their own. An important aspect of the project has been the use of geo-informatics in project planning, implementation, and monitoring, which included the use of aerial photographs, Landsat and IRS satellite data, described in this paper (Rao *et al.*, 1991; Singh, 1994).

Methodology

A multi-stage remote sensing approach was adopted to meet the requirement of the reclamation program. While the large reclamation sites were selected based on Landsat TM derived map, the field plots for reclamation were selected based on aerial photographs, IRS LISS III + PAN merged, and LISS-IV data (Verma and Singh, 1998). Land levelling, field bunding, drainage provision, gypsum application, and following rice-wheat crop rotation with green manuring in the summer season were the main components of reclamation.

Results

Land use change was monitored to assess the success of reclamation after a period of five years using high resolution IRS data. The field plot level monitoring showed conversion of 73 percent to 91 percent of the barren sodic plots to ricewheat cropping. The increase in cropping intensity from the pre-reclamation period of 124 percent to about 200 percent during post-reclamation led to higher farm production and an estimated 109 percent income growth among the poverty affected households. Environmental impact assessment carried out by studying pre- and post- project soil quality, ground water level and its quality, surface water quality, and biodiversity also showed positive improvement (Singh et al., 2004).

Discussion

The Site Implementation Committee (SIC), Women Self Help Groups and Water Use Groups were formed to ensure a strong beneficiary participation. About 94 percent of beneficiaries were marginal farmers. In a few reclamation sites, however, it was observed that despite reclamation protocol being followed, some plots reverted either from single crop to barren or from double crop to single crop in 6–8 years. A study based on remote sensing revealed that these areas were near the banks of unlined canal, with a water table <2 m b. g. l. leading to poor drainage condition due to either non-existent or choked drains (Yadav *et al.*, 2010). Such areas were later excluded from the project to save cost.

Conclusions
The project has led to sustainable reclamation, indicated by significant improvement in soil health, increased cropping intensity, higher grain production, increase in farmers' income and their socio-economic status. Improvement in soil microbial biomass, and floral and faunal biodiversity were also observed. No adverse impact was found on the quality of ground and surface water. The project has thus been able to not only achieve food self-sufficiency for the farm families, but also helped in national food security and environmental sustainability.

Acknowledgements
The authors gratefully acknowledge the Managing Director and officials of UPBSN, Director, RSAC-UP, and the scientists involved in the project.

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Theme 4. Testimonies from the field – Good practices to manage salt-affected soils

Bioremediation of sodic soils through halophilic microbes

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Keywords: Halophilic bacteria, sodic soil, bio-amelioration, Indo-Gangetic plains

Description of the good practice

Bio-remediation through halophilic plant growth promoting bacterial strains helps in recovery of salt-affected soils especially sodic soils by directly supporting plant growth and increasing crop yields in salt stress. This approach has scope to live with salt and optimize crop production to meet food demands and livelihood security of resource poor farmers.

Context of the practice

In present times the availability of mineral gypsum is scarce and also both chemical and physical methods of reclamation of sodic soils is not cost-effective. The microbial strains available as growth enhancers for different crops do not perform effectively under salt stress and their activity decreases when used in salt affected soils due to osmolysis. The soils of vast areas of Indo-Gangetic plains are sodic or saline sodic.

The positive impact of the practice in addressing soil salinity / sodicity

In view of reducing the cost on sodic soil reclamation, salt tolerant bacterial strains of halophilic plant growth promoting bacteria (HPGPB) were isolated from the native sodic soils of Indo-Gangetic plains. The screened bacterial isolates have the multiple mechanisms, such as production of hormones IAA, ACC deaminase, exo-polysaccharide, siderophore, phosphate solubilization, and nitrogen fixation which makes them play important role in plant growth promotion under salt stress. The efficient strains of halophilic growth promoter were mass cultured and prepared in suitable standardized media as liquid bioformulations *viz.* Halo-Azo and Halo-PSB for easy inoculating seed/seedling treatment or for soil application. Application of these bioformulations helps to supplement plant nutrients and reduces stress through their activities in the rhizosphere and enhances plant growth under the salt stress. It ensures better root development, effective nutrient uptake and thereby vigorous crop growth. These formulations also help in improving soil health, minimize environmental pollution by lowering down the use of chemicals.

Results indicated increase in rice yield by ~11.5 percent with the inoculation of seedlings with liquid bioformulations Halo-Azo and Halo-PSB over un-inoculated control. Similarly, wheat yield was enhanced by average of 14.03 percent with seed inoculation.

Other benefits of the practice

The application of liquid bio-formulations of HPGPB improved growth and yield of crops under salt stress and they also improved soil health. There was substantial improvement in soil pH and exchangeable sodium content. Buildup of soil organic C and N apart from improvement in microbial biomass C and dehydrogenase activity was observed with application of liquid bioformulations.

Costs of the practice

They are affordable for most of the small and marginal farmers. Bioformulations are also ideal input for reducing the cost of cultivation and for promoting organic farming in salt affected soils. The there year average B:C ratio enhanced from 2.10 to 2.31 in rice and enhanced from 2.26 to 2.59 in wheat with the use of bioformulation of halophilic microbes.

Challenges for scaling up the practice

During the years 2017–2020, these bioformulations have been adopted by farmers covered nearly 417 ha and 554 ha of sodic lands in various districts (Lucknow, Raebarelli, Unnao, Sitapur, Hardoi, Sultanpur, Lakhimpur, Kausambi, Pratapgarh, Mau, Agra and Eatwah) of UP in different crops (rice, wheat, mustard, brinjal, cauliflower, field pea, tomato and sugarcane). Looking to the potential of this technology, it has been commercially licensed through ICAR-Agrinnovate India Ltd for large scale production and marketing. The demand is increasing among farmers and several Government and social agencies are promoting its adoption at large scale to optimize yields from degraded sodic soils.

Acknowledgements

Authors acknowledge the support and facilities provided by Indian Council of Agricultural Research–Central Soil Salinity Research Institute as well as Uttar Pradesh Council of Agricultural Research for fund support. Stakeholders including farmers groups, KVKs and NGOs support for validating this technology in different sodic areas of Indo-Gangetic plains is duly acknowledged.

Using water hyacinth as soil amendment to reclaim and boost productivity of calcareous sodic soils

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Keywords: Organic amendment, calcareous soils, $CaCO_3$ dissolution, sodic

Description of the good practice

Surface soil amendment with locally available water hyacinth is rich in organic matter and helps in dissolution of native calcium carbonate thereby self-ameliorate the calcareous sodic soils.

Context of the practice

It is difficult to reclaim calcareous sodic soils having high clay content through chemical amendment and also the availability of mineral gypsum is scarce and costly for agricultural use in present times. The water hyacinth having more than 80 percent organic matter is commonly available in village ponds and is of no use. The alkali soils of Bihar state and parts of UP and Punjab in Indo-Gangetic plains are dominated by high $CaCO_3$ content. They have high sodium saturation that adversely affects the water infiltration and soil structure. Availability of soil $CaCO_3$ may be quite considerable for the amelioration of sodic soils. Also, it has been reported that soluble $CaCO_3$ had significant contribution towards increase in exchangeable Ca^{2+} of sodic soils. The use of organic matter, has long been advocated as an organic amendment for the reclamation of these soils since it tends to improve soil aggregation, aeration and water holding capacity. Conversely the production of CO_2 during decomposition of organic matter can lower the pH and lead to dissolution of $CaCO_3$. The present study was, therefore, undertaken to study the effect of organic matter on $CaCO_3$ dissolution and for predicting $Ca^{2+}+Mg^{2+}$release from sodic soils which differ in $CaCO_3$ content.

The positive impact of the practice in addressing soil salinity / sodicity

In a preliminary study in calcareous sodic soil (pH 9.4 to 9.8, EC 2.42 to 4.26 dS/m, $CaCO_3$ 2.2 to 28.16 percent, organic carbon 0.22 to 0.38 percent). The soil samples were amended with water hyacinth at 2 Mg/ha at field capacity moisture and incubated at $28\pm1^{\circ}C$ for 60 days. The release of Ca+Mg increased due to dissolution of $CaCO_3$. There was 14.4 to 22.6 per cent higher release of Ca+Mg was observed in water hyacinth amended soils as compared to no water hyacinth application. The study indicates that native $CaCO_3$ dissolution can help in ameliorating sodic effect when water hyacinth was applied to sodic calcareous soils.

An experiment was conducted to ascertain the effect in calcareous sodic soil with $CaCO_3$ content of 12.8 percent amendment with 2 Mg/ha of water hyacinth and thereby ponding water of 5cm depth for 10 days.

Other benefits of the practice

The application of water hyacinth as soil amendment improved soil physico-chemical and biological properties, improved infiltration, bulk density and enhanced productivity of rice and wheat by 28 and 19 percent. It was observed that after two consecutive years of rice, the surface soil pH reduced from 9.32 to 8.44, carbon build up was 1.4 g/kg and free $CaCO_3$ content reduced to 10.3 percent.

Costs of the practice

Water hyacinth is freely available in villages in most of the community ponds, water bodies and reservoirs as weeds. Its application as soil amendment involves only labour cost of INR 450 (US$ 5) for nearly 2 Mg/ha in same village. This is affordable for most of the small and marginal farmers. The 2-year average B:C ratio enhanced from 1.60 to 2.41 in rice and wheat with the use of water hyacinth as amendment.

Table 1. Effect of water hyacinth on native $CaCO_3$ dissolution in calcareous sodic soils

Days	Treatment	$CaCO_3$ 2%	$CaCO_3$ 10%	$CaCO_3$ 22%	$CaCO_3$ 28%
2D	-WH	4.15	5.15	5.30	5.58
	+WH	4.65	5.24	5.71	5.81
7D	-WH	4.85	5.22	5.65	5.69
	+WH	5.25	5.47	5.82	6.02
15D	-WH	4.98	5.30	5.88	5.90
	+WH	5.12	5.49	5.94	6.41
30D	-WH	5.18	5.61	6.04	6.22
	+WH	5.72	6.25	6.58	7.12
60D	-WH	5.20	6.40	8.05	8.95
	+WH	6.02	7.85	9.77	10.11

Challenges for scaling up the practice

The practice is presently adopted in scattered manner is some parts of the problematic soil region but can be scaled up with mass scale production of water hyacinth and preparing dried and chopped materials for easy use, application and transportation. This will enable wider adoption of this technology.

Acknowledgements

Authors acknowledge the support and facilities provided by Indian Council of Agricultural Research–Central Soil Salinity Research Institute. Stakeholders including farmers groups and Farmers Science Centres support for testing this technology in calcareous sodic soils is duly acknowledged.

Integrated management of nutrients from organic and inorganic sources increase productivity, soil health and climate resilience of sodic soils

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Keywords: Sodic soils, integrated nutrient management, soil carbon sequestration, organic, climate resilience

Description of the good practice

Three integrated nutrient management systems for sodic soils provide benefits in terms of increased productivity, improved soil quality and resource saving. The practices include: green manuring with *Sesbania* aculeata, integration of a legume crop (*Vigna radiata*) in the main cropping systems and soil incorporation of its residues, partial retention and soil incorporation of cereal crop residues. Reduced application of inorganic fertilizers (almost 50 percent) can be afforded with these practices.

Context of the practice

Salt affected soils are inherently low in organic carbon (C), which is lifeline of a fertile soil. Organic carbon controls many functions which play vital role in plant nutrition by controlling cation exchange, aeration, water holding, leaching of salts, and mineralization etc. Increased levels of sodium salts in soil adversely affect microbial and enzymatic activity which plays role in nutrient transformations. Not only presence of salts and pH play important part but physical changes may also assert significant role, indirectly. For example, sodic conditions result in compaction of soil and this restricts root growth to explore more soil volume for plant nutrients. The sodic soils which inherently have very low soil carbon and poor soil stability (slaking and dispersion are the key processes) get benefitted in terms of enhanced C sequestration, improved hydraulic conductivity, and improved nutrient availability throughout growing season. The integrated management systems also provide better climate resilience and mitigation of greenhouse gas emissions.

The positive impact of the practice in addressing soil salinity / sodicity

The practices have been found to decrease soil pH, though effects could be seasonal. The availability of nutrients is inherently low in sodic soils but these practices enhance nutrient availability.

Other benefits of the practice

Integrated management of nutrients provided significant benefits in terms of nitrogen mineralization and plant availability, micronutrient uptake by plants and increased crop productivity. Almost 50 percent cut down in inorganic fertilizer use could be afforded with use of green manuring, integration of a legume crop in the main cropping system and soil incorporation of residues, partial retention and soil incorporation of cereal crop residues, and even use of farmyard manure.

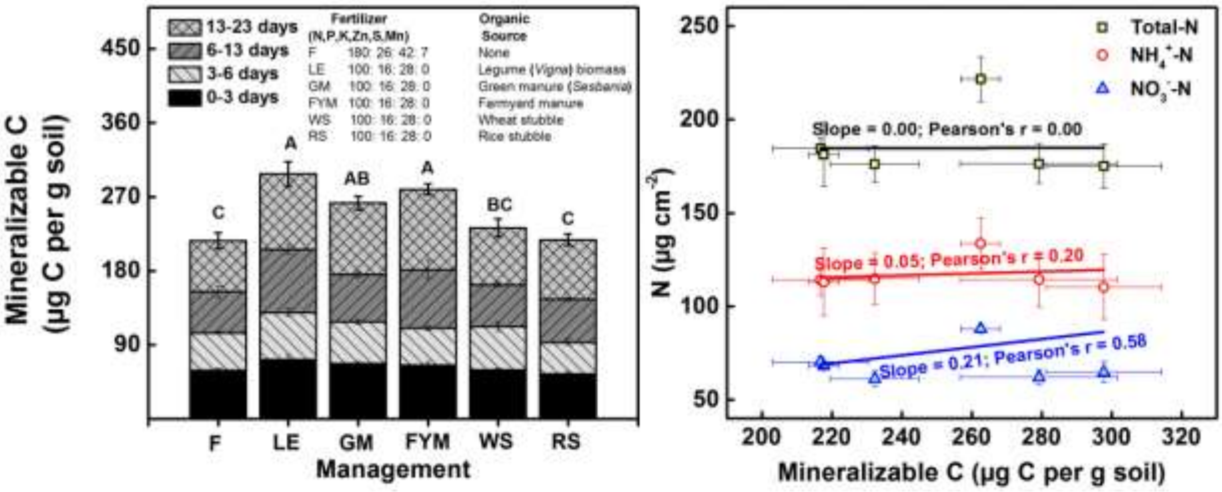

Figure 1. Effect of different nutrient management system on mineralizable C and N in soil.

Costs of the practice

There are no extra costs when the organic materials added to management include main crop residues. In case of green manuring or integration of a legume crop in the main cropping system and soil incorporation of its residues minimal costs towards seed materials, planting costs, and irrigation water. The practices have immense benefits compared to the costs.

Challenges for scaling up the practice

Use of inorganic fertilizers, particularly the nitrogen fertilizers, which are highly subsidized in most countries of the world, poses a challenge to adopting any alternative practice that may otherwise provide immense benefits for land, water and environmental quality. Integrated management practices have marginal extra costs yet they provide long- term benefits in checking salinization and increasing productivity.

Acknowledgements

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Land shaping practice for management of low-lying salt affected coastal soil

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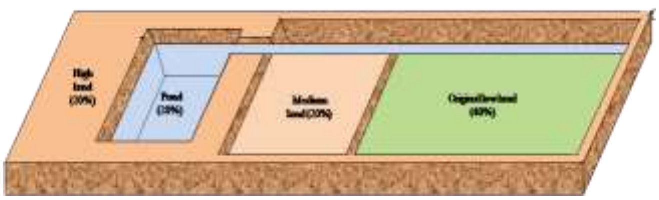
Keywords: *Salinity, water logging, coastal region, land management, land shaping*

Description of the good practice

Land shaping is the practice where the surface of the farm land is modified primarily for harvesting rain water for creating source for irrigation especially for dry season, reducing effect of groundwater salinity, reducing drainage congestion and growing multiple and diversified crops along with fish round the year. Different land shaping practices are described in brief.

Farm pond

About 20 percent of the farm area is converted into on-farm pond of about 3m depth to harvest excess rainwater. The dug-out soil is used to raise the land to form high land/dike (20 percent area of 1 m height) and medium land (20 percent area of 30 cm height) besides the original low land situation (40 percent area) (Figure 1).



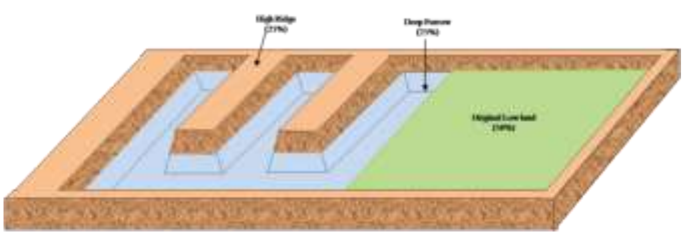
Schematic diagram

Farm pond at farmers' field during wet season

Figure1. Farm pond practice. Indian Sundarbans, 2014

Deep furrow and high ridge

About 50 percent of the farm land is shaped into alternate ridges (25 percent area, 1.5 m top width ×1.0 m height × 3 m bottom width) and furrows (25 percent area, 3m top width × 1.5 m bottom width × 1.0 m depth). Dug out soil from furrows is used for making ridges (Figure 2).



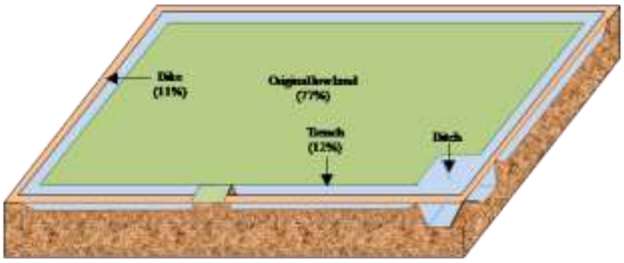
Schematic diagram

Deep furrow and high ridge at farmers' field during wet season

Figure 2. Deep furrow and high ridge practice. Indian Sundarbans, 2014

Paddy-cum-fish

Trenches (12 percent area, 3 m top width × 1.5 m bottom width × 1.5 m depth) are dug around the periphery of the farm land leaving about 3.5 m wide outer from boundary and the dugout soil is used for making dikes (11% area, about 1.5 m top width ×1.5 m height × 3m bottom width). A small ditch is dug out at one corner of the field as shelter for fishes when water will dry out in trenches (Figure 3).



Schematic diagram

Paddy-cum-fish at farmers' field during wet season

Figure 3 Paddy-cum-fish practice. Indian Sundarbans, 2014

High/ridges/dikes in different land shaping practices remain free of water logging during wet season (*kharif*) with less soil salinity build up in dry (*rabi*)/ Summer season. These areas are used for growing vegetables and fruit crops/ multi-purpose tree species round the year. The pond/ furrows/ trenches are used for rainwater harvesting for irrigation in dry season and polyculture of fish round the year. During *kharif* HVY of rice is grown in medium land in farm pond practice. The original low land in all practices is used for more profitable paddy + fish cultivation in *kharif* season. The low water requiring crops like sunflower, groundnut, cotton, etc. are grown on the medium land and lowland during *rabi* / Summer season. Poultry/ livestock farming can also be practiced in the farm along with crops and fishes.

Context of the practice

Agriculture is the major occupation of the smallholder farmers in the coastal delta regions of South and Southeast Asia. However, it is less productive because of several constrains like salinity build up and lack of irrigation water during dry season, deep waterlogging of fields and drainage congestion during the wet season. Implementing innovative land management practice like land shaping could be a good agriculture practice to overcome those constrains of coastal agriculture. Land shaping practices have the potential to enhancing production, productivity, income and employment.

The positive impact of the practice in addressing soil salinity / sodicity

Soil salinity build up is less in the root zone/ surface layer (0–30cm) (Figure 4) and also in profile (Figure 5) of in the raised land (high land, medium land, high ridge, dike) and original low land created under different land shaping practices compared to control (without land shaping).

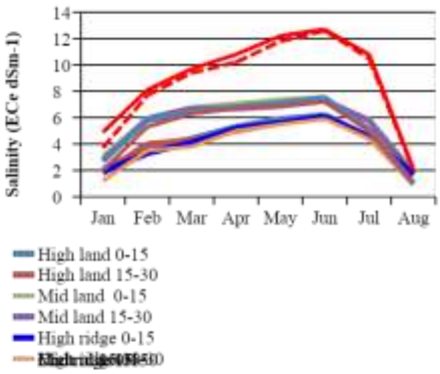


Figure 4. Seasonal variation in soil salinity in root zone under different land situations created under land shaping practices and control (without land shaping)

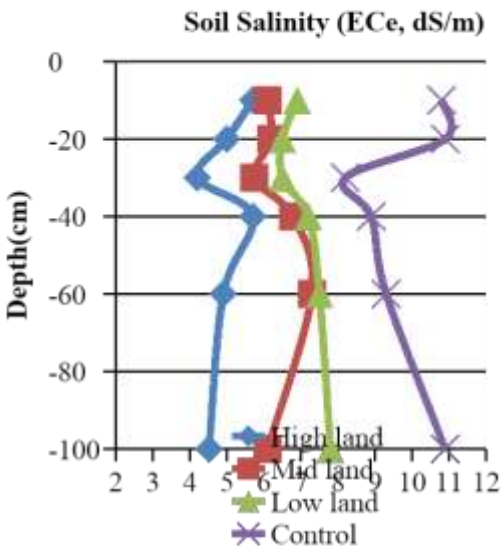


Figure 5. Profile soil salinity under farm pond land shaping practice and under control during dry season (March)

Other benefits of the practice

Implementation of land shaping in coastal delta regions of India Sundarbans resulted in increase in cropping intensity up to 240 percent from a base level value of 100 percent. Due to creation of different land situations and following cultivation of crops round the year org. C, av. N, P & K and biological activities in root zone have been increased. Farming activities under land shaping have enhanced the employment opportunities for the farm families by 1.6 times per year. As the farmers get employment in their own farm land throughout the year, this has checked the seasonal migration rate of the farm family in search of their livelihood.

Costs of the practice

On-farm demonstration have shown the success of land shaping practice in coastal delta region of Indian *Sundarbans* in terms of increasing farm income and providing gainful employment to the farmers (Table 1). However, these land shaping involved high initial investment, particularly on soil excavation. The financial analysis has revealed a direct relationship between investment on a land shaping and value of Internal Rate of Return (IRR), Net Present Value (NPV), Benefit Cost Ratio (BCR) (Table 1).

Table 1. Financial feasibility of land shaping in coastal delta region of Indian *Sundarbans*

Criteria	Farm Pond	Paddy-cum-fish	Deep furrow & high ridge
Initial investment (INR/ha)	145770	135800	87850
Internal Rate of Return (%)	46	42	36
Net Present Value (INR)	285059	232450	96817
Benefit Cost Ratio	1.58	1.55	1.20
Payback Period (years)	1.41	1.78	2.13

Challenges for scaling up the practice

Land shaping practices are financially viable and attractive proposition for the coastal salt affected region. However, major constraints for adoption of land shaping are marginal land holdings that too divided into several parcels, high initial investment, distance from residential village etc. There is a need to resolve issues on large scale dissemination of land shaping practice covering the areas of input-supplies and management, market and marketing environment– the driver of change in cropping pattern and production, credit needs and absorption of the farmers, and the role financial institutions therein.

Acknowledgements:

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Salinity and prevention of wind erosion in the southeast of Lake Urmia

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Keywords: Urmia Lake, Bush, Soil salinity

Description of the good practice

It is important to exploit the potential of thrush plants in resolving the growing salinity crisis in this arid and semi-arid region. The purpose of this study was to investigate plantation in the southeast of the lake for salinization and to prevent wind erosion.

Context of the practice

The drought process of Urmia Lake (Iran) caused the saturation of the water to drain out of the water and, as a result, the extent of the droughts increased, resulting in the creation of saline arid zones with large amounts of salt around the lake.

The positive impact of the practice in addressing soil salinity / sodicity

By planting saline plants (Halophyte) in the region, in addition to being able to be used as a barrier against wind and prevent wind erosion, but also have a significant impact on the process of reducing soil salinity.

Other benefits of the practice

Can be said that in one of the selected areas, the high volume of plantation has caused the salinity in this area to be estimated less than other areas.

Costs of the practice

There is no detail information about cost and benefit of this practice.

Challenges for scaling up the practice

The most important challenges are supplying the irrigation water of plant and sociological issues like resistance of people to accept the nonproductive species.

Figure 1. Areas under the wind in the east of Urmia Lake

Figure 2. Selected areas for growing Halophyte plants

Figure 3. Close view of selected areas for cultivation

Figure 4. Prepare planting sites

Figure 5. Establishment of halophyte plants

Innovative biotechnology for sustainable management of saline soil fertility, nutrition and productivity of cotton and wheat

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[2] Innovation Ideas LLC, United States

Keywords: saline soils, cotton, wheat, innovative biotechnology

Description of the good practice

Based on scientific research at the Institute of Microbiology of the Academy of Sciences of the Republic of Uzbekistan, we have developed a new environmentally safe and cost-effective resource-saving biotechnology for sustainable management of saline soil fertility and nutrition of cotton and winter wheat. Biotechnology is based on the complex application of two biopreparations. Biopreparations based on salt-resistant rhizobacteria of wheat and cotton, which have polifunctional properties, are used for pre-sowing seed treatment and a biopreparation on microalgae is used for leaf feeding of plants during the growing season. Working in a complex, these biopreparations restore the natural metabolism in the soil-microorganisms-plant system.

Context of the practice

As a result of the use of biotechnology, saline soils are purified from organochlorine pesticides, heavy metals and mycotoxins, the degree of salinity is reduced and the fertility of saline soils is increased, increase the moisture-retaining capacity of the soil and plant leaves, reduce irrigation water costs by 25–50 percent and crop maturation time by 15–20 days

The positive impact of the practice in addressing soil salinity / sodicity

The practice has a positive effect on reducing the salt content in the soil, reducing the degree of salinity, restore and increasing fertility of saline soils, normalize the alkaline pH value of soils, increase the biodiversity of soil microflora and fauna, improve the macro-microelement nutrition of plants throughout the growing season. Stimulate the development of a powerful root system and the aboveground part of plants. This biotechnology is considered a good practice, as it reduces the degree of salinity of soils and increases the productivity of cotton and wheat (Figure 1).

Other benefits of the practice

As a result of the introduction of innovative biotechnology on saline soils of Syrdarya, Navoi, Bukhara, Ferghana, Andijan, Namangan, Khorezm regions and Karakalpakistan in 2019–2020, the condition of saline soils on an area of 30 000 hectares improved, irrigation water costs were reduced by two times and mineral fertilizers costs by 25–50 percent. As a result, the average cotton harvest in Uzbekistan increased by 8 c/ha (33 percent), the profitability was 284 percent (in the control–139 percent). The wheat harvest increased by 11.8 c/ha (22 percent), the profitability was 112 percent (in the control–37 percent).

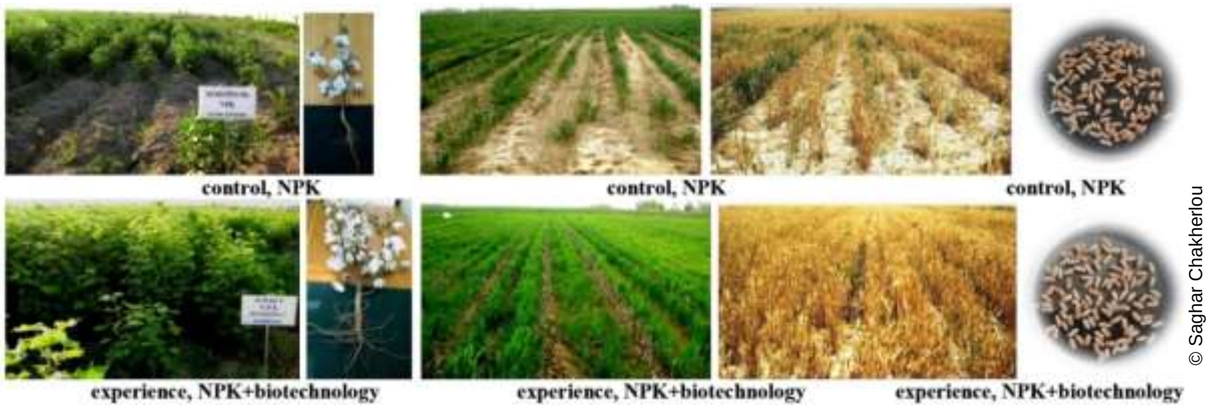

Figure 1. Field plots before and after the use of innovative biotechnology on cotton and wheat. Uzbekistan, Syrdarya region, highly saline soils, 2018

Challenges for scaling up the practice

For the widespread introduction of proven practices and the export of biopreparations, it is necessary to create a new biotechnological production, for which there is a certain potential and highly qualified specialists.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

Long-term combination of pruning residues incorporation, reduced tillage and drip irrigation to improve SOM stabilization and structure of salt-affected soils in a semi-arid Citrus tree orchard

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Key words: Drip-irrigation, Particulate organic matter, aggregate stability, Semi-arid agroecosystems, Soil organic carbon, reduced tillage, salt-affected soils, pruning residues

Description of the good practice

Soil salinization is a big problem around the world as a result of unsustainable land management practices and climate change. Salt-affected soils are characterized by poor soil structure and low organic matter contents. These soils have been used for agriculture since thousands of years. However, poor drainage, inappropriate irrigation, high evaporation rate and excessive use of chemical fertilizer caused severe degradation and abandonment of these soils, economic losses for the farmers and social migration.

Eastern Spain is one of the semi-arid irrigated areas where a high amount of Citrus (mainly oranges and lemons) is produced in Europe (Figure 1A). In Murcia, some of these lemon and orange orchards were established on salt-affected soils and under intensive management practices (Figure 1B). In addition, it is a common practice to burn the tree pruning residues (branches and leaves). However, in the early 1980s, conservation tillage for improved water retention and soil structure was implemented. Moreover, organic matter amendments (green manure, compost, biochar, and food processing wastes) were applied to improve the physical conditions of salt-affected soils.

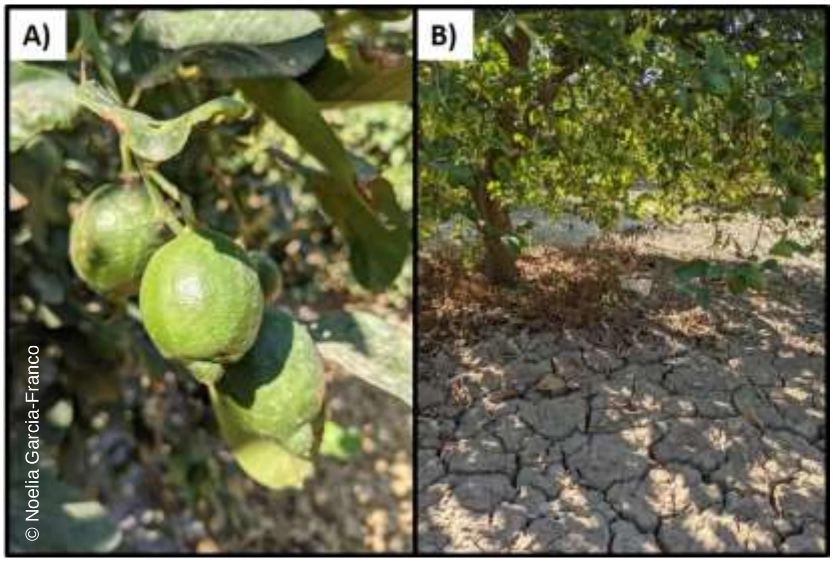

Figure 1. A) ***Citrus lemon*** **tree and B) salt-affected soil in the studied semi-arid area (Librilla, Spain)**

The combination of pruning residues incorporation through reduced tillage, and drip-irrigation systems is a promising approach to offset the negative effects of high salt content, increase organic matter storage, and maintain or even increase agricultural productivity without reducing the farmer´s profit. The incorporation of OM of tree pruning residues combined with drip-irrigation makes soils less susceptible to the negative influence of salts under semiarid climate conditions.

Context of the practice

Site description

The study was conducted in an irrigated agricultural orchard of citrus trees (Citrus limon var. Verna) located in "Paraje la Alberquilla" between "Sierra de Carrascoy" mountains and Librilla's town (Murcia), Southeast Spain (37° 52′ 18.8″ N, 1° 20′ 58.6″ W; 119 m a.s.l.). The climate is semiarid with a high evapotranspiration (between 900 and 1000 mm/yr) and with a mean annual water deficit around 600 mm. The soil is classified as Calcaric Solonchak. Since 1987, the traditional soil management system carried out by the farmers in the study area was intensive tillage (until 40 cm soil depth and three times per year) with flood irrigation only in the topsoil (IT). The irrigation water comes from the river Tajo. The amount of water used was around 600 m^3 of water were used each year for irrigation of the orchard (4400 ha) in January, April, June, August and September. In 2000, at two adjacent fields sustainable land management (SLM) practices were implemented (Figure 1, table 1): (i) no-tillage plus lemon pruning residues applied on the topsoil as mulch and drip-irrigation (NT + PM), and (ii) reduced tillage plus incorporation of the lemon pruning residues to a soil depth of 15 cm (RT + PI) and drip-irrigation (Table 1). The drip-irrigation system consists of an automatic flow of water (approximately an average of 760 L per tree and per month adjusted to the varying climatic site conditions). Since 2015, 0.044 kg total nitrogen and 0.028 kg potassium chloride (KCl) (per tree and per month) were applied with the water of the drip-irrigation system. In addition, the farmers added 0.22 kg/m^2 of a commercial solution of 15 percent of CaO and 0.5 percent of MgO per tree and per month in NT + PM and RT + PI management systems, because gypsum, calcite, calcium chloride, and other chemical agents that provide Ca tend to replace exchangeable Na, effectively ameliorating salt-affected soils (Table 1).

Table 1. Description of different management practices in the management systems: i) intensive tillage with flood irrigation (IT); ii) no-tillage plus lemon pruning residues on the topsoil as mulch (NT+PM); and iii) reduced tillage plus incorporation of lemon pruning residues (RT + PI). Source: Garcia-Franco *et al.*, 2021, Soil and Tillage

Management practices	IT	NT+PM	RT+PI
Tillage	until 40 cm soil depth, 3 times per year	-	until 15 cm soil depth, 1 time per year
Addition of pruning	-	Mulching	Incorporation into the soil
Addition of Ca^{2+} and Mg^{2+}	-	+	+
Irrigation	Flood (since 1987)	Drip-irrigation (since 2000)	Drip-irrigation (since 2000)
Fertilization	-	+	+
Pesticides	+	+	+

The positive impact of the practice in addressing soil salinity / sodicity and other benefits of the practice

Our results showed that the combination of pruning residues incorporation + reduced tillage + drip-irrigation in a Citrus tree orchard in salt-affected soils is able to offset negative effects of salts on soil structure by:

i) offset the negative effect of salinity on soil aggregation
ii) increasing the soil porosity and macroaggregate formation
iii) maximizing the accumulation of soil organic carbon

iv) decreasing soil erosion and soil desertification
v) promoting a sustainable agriculture from a social, economic and environmental perspective.

Costs of the practice
No information on costs are available. (It will be available for the Symposium)

Challenges for scaling up the practice
The organization of workshops with other farmers and people responsible in the regional administration (description of main point about how management salt-affected soil regarding to environmental and socio-economic impacts) in this area may contribute to promote this combination of sustainable land management practices.

Acknowledgements
We would like to thank the families Ruíz Cayuela and Ruíz Pascual for inspiration for this project.

Haloculture for Hyper-Saline Drain Water Reuse and Combating Dust Prone Regions

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Keywords: Drain water, Dust Storms, Fisheries, Halophytes, Reuse

Description of the good practice

Khuzestan in the southwest of Iran is the bed of major Rivers. While its lowland deltas are suffering from salinity and waterlogging issues. Extension of irrigation and drainage networks in the area releases billions of cubic meters of drain water down to the outlets. Discharge of this huge volume of water has developed new challenges for the downstream regions. Evaporation ponds are developing in some regions (Figure 1), while in some cases dredging and pumping is necessary to avoid reflux of drain water back to the fields.

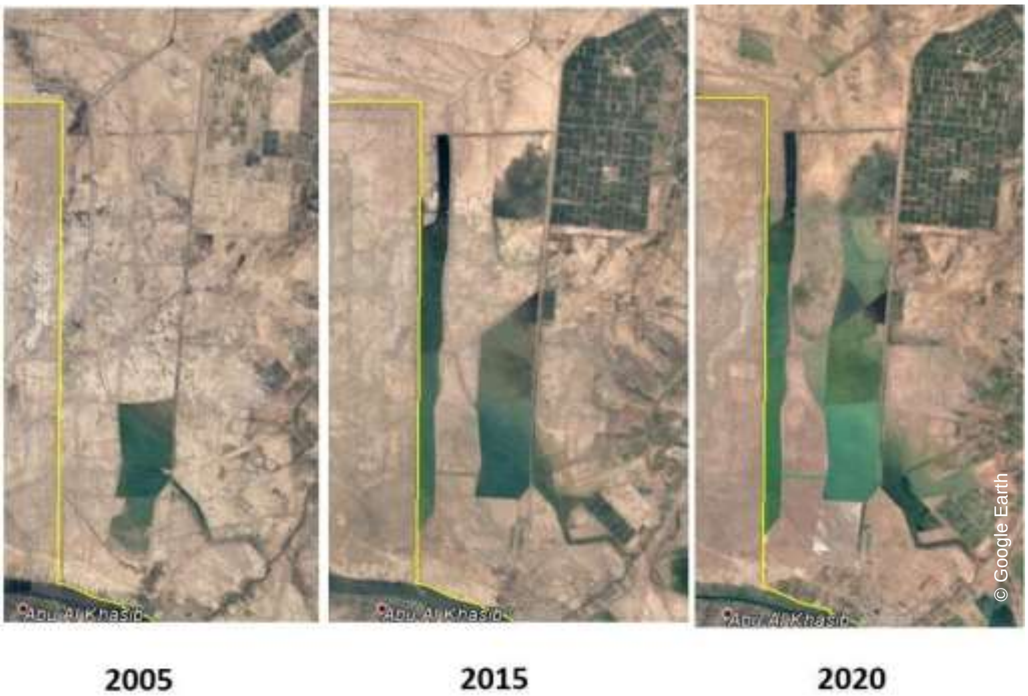

Figure 1. Development of evaporation ponds for discharge of drain water at Iran-Iraq border

Invasion of dust storms is another environmental issue harmed frequently some parts of the Middle East. The flat and dry areas with fine particles are considered to have major role in dust production. The downstream areas of Khuzestan have these conditions in addition to dispersed soil particles due to high salinity and sodicity makes this area more prone for dust production.

Different measures have been proposed to combat dust storm hot-spots including different mulches and flood spreading on the hot spots. As the government is the unique donor for performing such projects, it impossible to provide the fund by the government. Haloculture, as integrated and sustainable use of the potentials of saline environments for production, was proposed based on the capabilities and restrictions of salt affected dust storm cannons of Khuzestan. Such a project uses the saline drainage water as input water, reduces the volume of drainage water, stabilizes the soils and makes it wet and produces wealth through its products. The salary of the project could be used by the local communities to scale up the project on the large scale.

The Haloculture project (Figure 2) was performed in an area of about 50 ha in one of the hotspots of dust storm in Khuzestan since 2017. The area was equipped with 4 ha of ponds for fish and shrimp cultivation, the effluent of ponds is used for irrigation of two parts. One part is equipped with tile drainage facilities which is allocated to cultivation of halophytes for forage and grain, the collected drain water is used for Artemia Production. The other part without tile drain is planted with Tamarix cuttings which acts as bio drainage and produces wood.

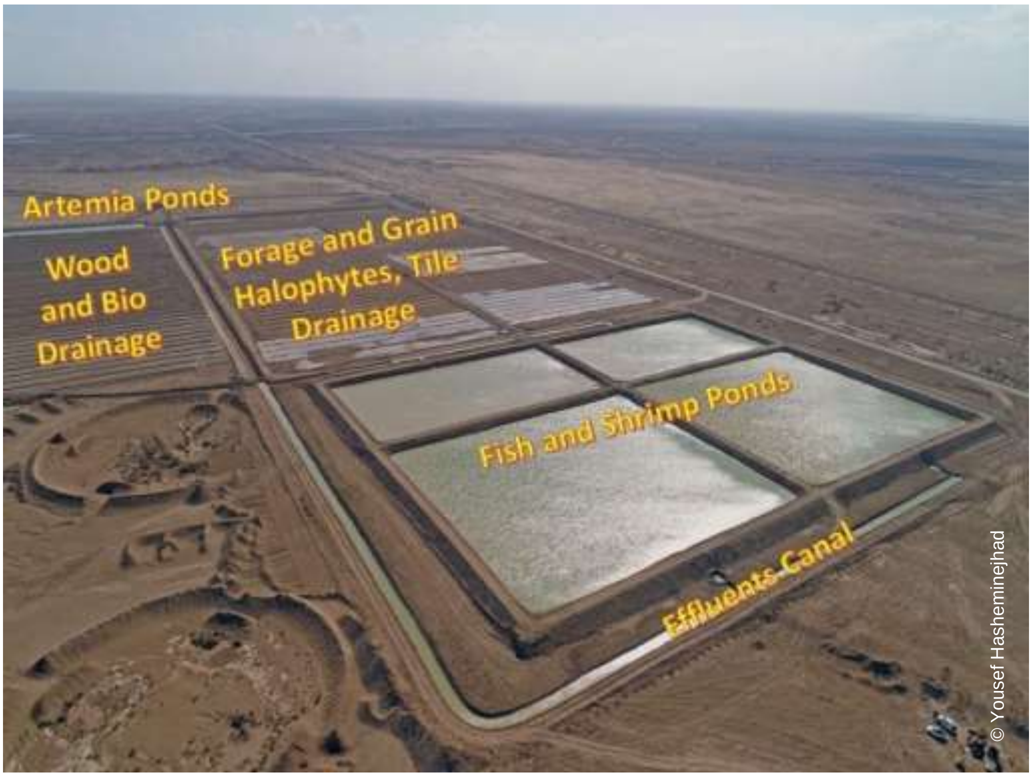

Figure 2. Installed Haloculture complex and its main components

Context of the practice

Soils in the area are alluvial soils formed by the deposits of the Karkheh River which are heavy textured soils, with poor drainage and salinity- waterlogging problems. The upper parts of the basin are equipped with modern drainage networks. The discharge rates and salinities of main drains fluctuates periodically between 4–16 m^3/sec and 8–32 dS/m respectively.

The positive impact of the practice in addressing soil salinity/sodicity

Periodical monitoring of soil salinity changes in the area through soil sampling and EM-38 surveys showed significant decrease of soil salinity due to irrigation. Figure 3 shows the changes in surface soil salinity during different sampling times. Similar results obtained for the deeper soil layers which are not repeated here. Infiltration rate measurements also showed improved soil permeability due to irrigation with the saline drainage water.

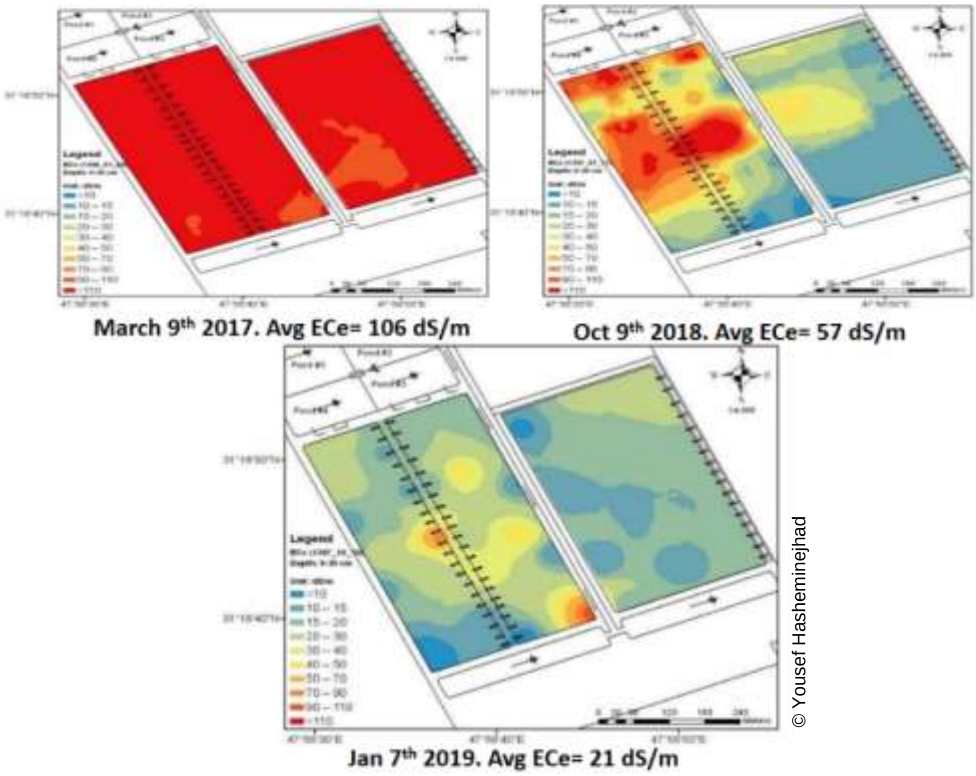

Figure 3. Changes of surface soil salinity (0-30 cm) during different sampling times

Other benefits of the practice

- Stabilizing dust storm producing soils in the extent of the project
- Producing forage through different halophyte species
- Producing Quinoa grain
- Producing wood and bio-drainage
- Technology transfer to the local communities and experts for maintaining the project
- Direct job creation for four persons in the project

Costs of the practice

Installation of the project costs for an area of 50 ha about USD 35000. Regarding the socio-environmental services and economic benefits of the project in the long term it is quite low. The same area could produce at least 40000 Kg of dry forage, 4000 Kg of quinoa grain, 2000 Kg of fish and shrimp and 20000 Kg of tamarix wood annually after complete establishment which the value of its products is at least USD 10000 /year.

Challenges for scaling up the practice

More detailed environmental and socio-economic surveys are necessary before up scaling the pilot plan.

Acknowledgements

Special thanks to Biotechnology Development Council for sponsoring this project.

Cover crops for the management of saline seeps in areas of high flooding risk

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Keywords: winter cover crops, shallow water table, saline groundwater

Description of the good practice

Cover crops (CC) contribute to mitigate soil surface salinization to and manage shallow water table in areas of high flooding risk. They should be used to confine the movement of salts from saline seeps and groundwater to higher portions of the landscape. This is important during the long bare winter fallows that are usual in Argentinean cash crop production.

For successful germination and establishment, CC must be sowed when soil moisture is high enough to reduce surface salinity and salts have been leached further down in the soil profile. However, analysis of soil and natural vegetation of the site are very helpful. In the Argentinean Pampas *Sporobolus sp.* indicates flooding while in saline soils *Distichlis sp.* and *Salicornia sp.* are common. *Conyza sp.* and *Salsola sp.* appear in improved conditions.

Generally, a mixture of winter CC is the best option under multiple threats (salinity, sodicity, waterlogging, etc.). While barley showed to be the best CC for saline soils, triticale has good performance in waterlogged conditions. Well adapted legumes are Lotus tenuis and Melilotus albus, while vetch has low salt tolerance.

An example of the results that can be achieved with this practice is resumed in Figure 1. A cover crop of 70 percent triticale and 30 percent vetch was planted at a density of 80 kg/ha in a 92-ha field in early fall. Salinity at the soil surface was reduced in the entire area, especially in the lowest portion of the landscape. The water table also receded considerably, reducing flooding risk, despite high rainfall (207 mm) during the CC growing season. Thus, 45 ha could be recovered for crop production, representing almost half of the field after only one CC season. Currently the field is managed with a rotation of winter CC and summer cash crops.

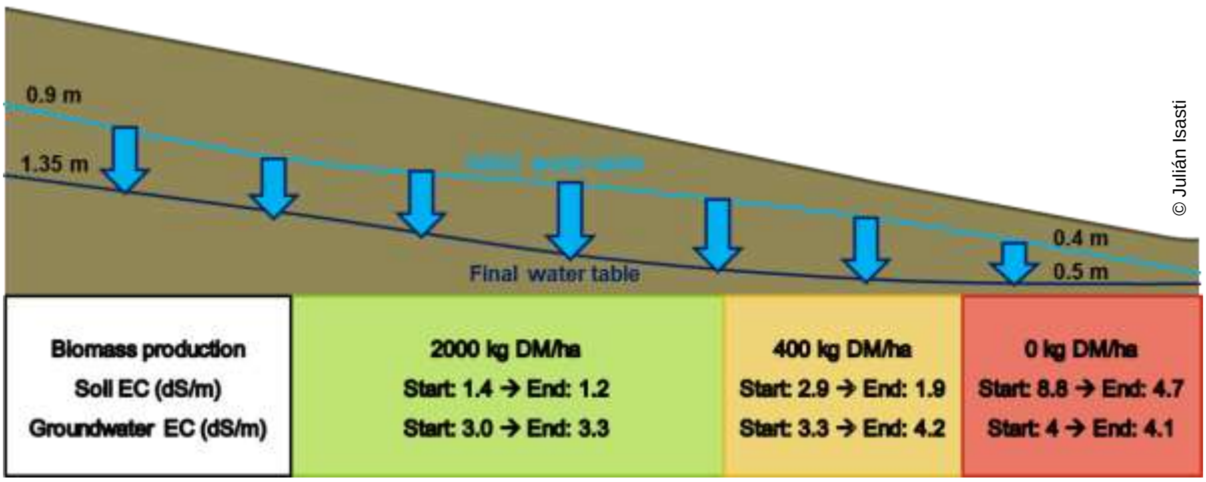

Figure 1. Cover crops reduce soil's surface salinity and contribute to the lowering of a shallow water table

Figure 2. Shallow saline groundwater is a major threat for plains with poor drainage. Chacra América, 2020

Figure 3. CC improve soil structure, water infiltration, and salt leaching. Chacra América, 2020

Figure 4. Triticale (right) sowed over natural saline vegetation (left). Chacra América, 2021

Figure 5. Legumes in mixed CC contribute to soil fertility by fixing nitrogen. Chacra América, 2020

Figure 6. Sorghum is an excellent cash crop after winter CC. Chacra América, 2021

Context of the practice
CC are recommended in semiarid and sub-humid (700–900 mm/year) temperate plains of poor drainage with a high risk of flooding and salinization due to a saline shallow water table. They have been successfully employed in the lowlands of the Western Argentinean Pampas, where the rise in groundwater level due to land cover change is threatening millions of hectares of productive land. These sandy-loam textured soils are being degraded due to groundwater salinity and waterlogging.

The positive impact of the practice in addressing soil salinity / sodicity
CC can contribute to mitigate the salinization of the soil's surface and to lower the shallow water table in areas with a high risk of flooding. Thus, with recurrent use of this practice salinity is confined to the lower portions of the soil profile, allowing successful planting of crops and pastures.

Other benefits of the practice
Apart from reducing the capillary flow of salt water to the soil surface and lowering the water table, CC add carbon to the soil thus improving soil structure and pore system, which in turn favours the leaching of salts and sodium. Legumes can also provide nitrogen for following cash crops.

Costs of the practice
The cost of CC is low compared to the benefits they produce. They imply only two operations per year, seeding and termination (with herbicides or a roller), and seeds of winter cereals/legumes can be produced by the farmer.

Challenges for scaling up the practice
At a basin level, the use of CC is not enough to manage the excess of water and to reduce shallow water tables during flooding events. This practice should be implemented with a systemic approach, including pastures and trees in recharge areas and salt-tolerant crops in discharge areas.

Acknowledgements
The research involved in the development of this practice was possible due to the funding and the efforts of Chacra América (Aapresid), INTA and the Faculty of Agronomy of the UNLPam.

Controlled subsurface drainage for the management of water table, soil salinity and nutrient losses in waterlogged saline vertisols of TBP command area of Karnataka, India

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Keywords: Controlled drainage, Depth to water table, Salt removal, Salt and water balance, Nitrogen loss

Description of the good practice

Installation of controlled drainage device

In a controlled SSD system, the groundwater table control system consisted of a small device made up of PVC pipes which is fitted with the outlet of the lateral drain in the manhole (Figure 1). In this system, an 80 mm diameter PVC "T" pipe fitted with an outlet of lateral drain pipe inside the manhole and other ends of "T" pipe is closed with end cap. To maintain the desired groundwater table depth in the paddy field, say 0.3 m, a riser pipe (of 0.70 m) was provided from the bottom horizontal PVC pipe through the T section. Again, one more "T" pipe is fitted at top of the riser pipe. This simple device made up of two PVC "T" pipes and one riser pipe is efficient in maintaining desirable the water table at the desired depth in paddy fields (Figure 2).

Conventional SSD system **Controlled SSD system**

Figure 1. Conventional & Controlled SSD systems

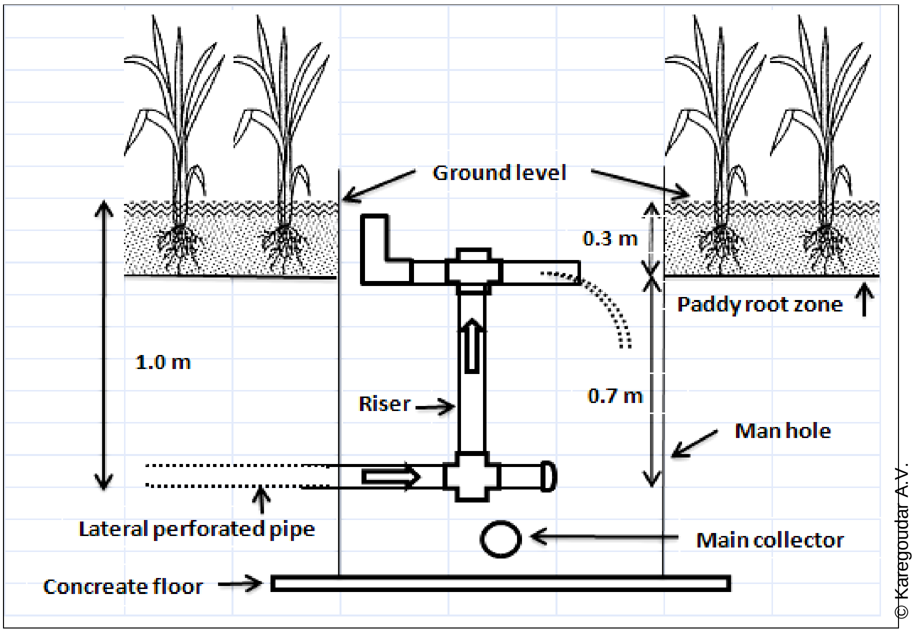

Figure 2. A view of controlled drainage device installed in a manhole

Context of the practice

The rural economy of Bellary, Koppal, and Raichur districts of Karnataka state, India was improved after the introduction of irrigation (1953) through Tungabhadra Project (TBP), in these districts. At TBP inception, Authorities provided guidelines for crop areas in the Command. Accordingly, to guidelines, head and middle reach farmers of the irrigation command had to grow light irrigated crops in an around (47 percent) area during Kharif (Rainy season, July–October) and in around 31 percent area during Rabi (Post rainy season, October-March) season. The farmers of the downstream or tail end of the command were supposed to grow paddy in around 8 percent area and sugarcane in 4 percent area to make effective utilization of excess water coming from the upstream (head and middle reach) area. The farmers followed these guidelines till 1970. However, paddy was introduced in many pockets of the command with the migration of farmers from Andhra Pradesh (AP) who well-versed with paddy cultivation. Paddy being more remunerative than other crops, farmers of head and middle reach also started cultivation of paddy, deviating from guidelines. The continuous violation of guidelines created canal water shortages for paddy crops in tail-end areas and also developed secondary salinization (96 215 ha) in the downstream/tail end in the command (CADA, 2013).

In order to reclaim these salt-affected lands TBP-CADA (Tungabhadra Project-Command Area Development Authority) undertook surface and subsurface drainage (SSD) works in the TBP command. However, farmers, particularly in tail-end areas, started blocking outlets of lateral drains to avoid over draining in view of the shortage of canal irrigation supply and loss of nutrients. In addition, farmers are also resorted to using natural stream/ drain/ Nala waters (locally called Halla) added a new dimension to the salinity problem. On basis of a simulation study using SALTMOD model by Manjunath *et al.* (2011), it was predicted that complete blocking of the SSD system during both the cropping seasons had adverse effects on the performance of the SSD system and increased soil salinity in the drainage area.

The situation in the tail-end area was really complex. The SSD systems were installed to control waterlogging and soil salinity. As farmers were interested in paddy crops only, they were not allowing the system to function with fear of a shortage of irrigation water. In view of this background, there were two thoughts among the researchers, the first was drain spacing might be increased to avoid over-draining and the second option was adoption-controlled drainage.

As per available information, controlled drainage was widely dependent on watertable level, rainfall, irrigation quantity, and management intensity (Mejia and Madramootoo, 1998). It worked on the shallow (Benz, Doering and Reichman, 1982) groundwater table concept (controlled way) hence it minimized drain outflow by 24 percent (Drury *et al.*, 1996) under maize crop in clay loam soils thereby reduced 43 percent nitrate loss. Under a loamy sand condition in southern Sweden (Wesström *et al.*, 2001) controlled SSD reduced drainage outflow by 79 to 94 percent and also reduced nitrate concentration from 78 to 94 percent. In lake bed soil (fine-textured) at Ohio State, Canada, it reduced 40 percent volume of drainage water and 45 percent of Nitrate-Nitrogen transport (Fausey, 2004). In sandy loam soil (Zhonghua *et al.*, 2006) with flat topography-controlled drainage reduced subsurface discharge through field ditches up to 94 percent under rice crop in China. Under clay loam soil controlled SSD reduced 64 percent of drainage depth and 50.4 percent of nitrogen loss than conventional SSD at 50 m spacing under paddy situation in TBP command at Karnataka, India (Karegoudar *et al.*, 2019). Based on the experience shared by many scientists across the world about the controlled drainage approach effectively reduced drain discharge, reduced nitrate and phosphorus loss, maintained shallow water table and improved the crop yield under different kinds of soils.

In view of this background, it was thought to increase lateral drain spacing by 10 m from present recommended spacing of 50 m for TBP Command. As controlled drainage was found effective in reducing drain flow in different drainage project world-wide, controlled drainage was also considered as one option. Therefore, an experiment was planned at the Agriculture Research Station, Gangavathi in rice fields with conventional and controlled SSD with 50 (2.8 ha) and 60 m (4.0 ha) drain spacing with an objective to find a suitable drainage management strategy to manage soil salinity as well as to address irrigation water shortage during paddy crop. Gangavathi town is one of the largest and most productive rice growing areas in Karnataka state. It represents irrigated transplanted rice belt of Tungabhadra project (TBP) command area. Agro-climatically, Agriculture Research Station Gangavathi falls under the Northern Dry Zone of Karnataka state (semi-arid eco-subregion) lying between 15° 27′ 14.1″ N and 76° 32′ 06.12″ E at an altitude of 419 m above mean sea level with an average annual rainfall of around 542 mm. The soils of the experimental site at Agricultural Research Station, Gangavathi are medium Vertisols derived from granite-gneisses containing lime/soda-lime feldspar that are basic in nature.

The drainage water quantity and quality, soil salinity, salt balance, water table, paddy yield nitrate losses, economic analysis for 50 and 60 m drain spacing with conventional and controlled drainage were monitored for seven seasons to search for better drainage water management strategy for the tail-end areas of TBP Command.

The positive impact of the practice in addressing soil salinity

Compared to conventional subsurface drainage system, the controlled drainage system was helpful in saving irrigation water to the extent of 27 to 28 cm (28 to 35 percent) and reduction in nitrate loss by 42 to 70 percent by maintaining (Figure 3) shallow water table depth under both in *Kharif* (5.3 and 4.1 cm) and *Rabi* season (4.6 and 4.1 cm) at 50 and 60 m lateral spacing, respectively. The mean root zone soil salinity (0–30 cm) was reduced under both conventional and controlled drainage systems. Around 15.0 and 9.0 percent marginally higher paddy grain yield was observed under conventional drainage compared controlled drainage system over the seven cropping seasons at 50 and 60 m drain spacing, respectively. Looking at water shortage and economic feasibility, 60 m lateral drain spacing with controlled drainage appears to be adaptable /feasible in the study area. It was expected that conventional and controlled drainage systems would give similar economic benefits in the long-term. Considering saving of irrigation water with reduced drain volume and nitrogen loss, the controlled SSD appeared to be a more environmentally-friendly strategy. Further combining of irrigation water management in paddy fields along with controlled drainage would be an interesting topic for future research.

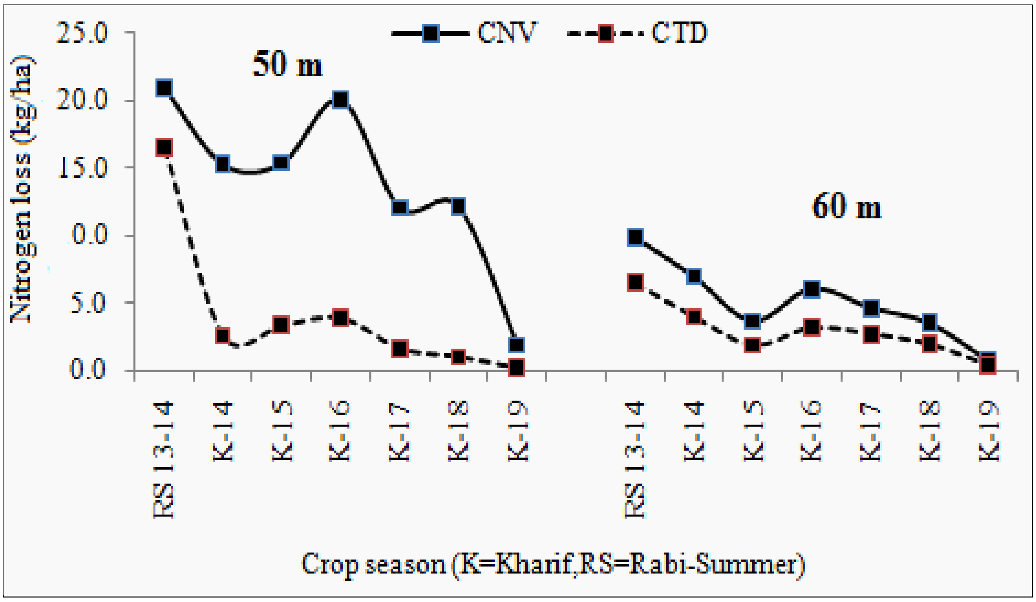

Figure 3. Season wise nitrogen loss (kg/ha) for the conventional and controlled SSD under different spacing

Other benefits of the practice

Controlled sub-surface drainage system demonstrated that it could save about 20 percent (240 mm/ha) of irrigation water per season compared to conventional SSD system in the reclamation of waterlogged saline soils in TBP command area. Therefore, an additional area of about 19 200 ha could be supplemented with this saved water which in turn may add up to the production increase of about 0.0576 MT (at 3 t/ha) of paddy in the command area. Similarly, controlled sub-surface drainage could reduce loss of NO_3-N to the extent of 50 per cent per season (i.e. urea fertilizer to the tune of ₹ 68.80 lakh per season in TBP command area.

Costs of the practice

The adaptation of the controlled drainage system to the existing SSD required an additional cost of about 1000/ha (USD16/ ha).

Challenges for scaling up the practice

Since the additional cost required for the implementation of the good practice is minimal, as such no bigger challenges are expected. However, conduct of more demonstrations and other extension related activities would be helpful in scaling up the practice not only in TBP command area but also in other irrigation projects in Karnataka as well.

Acknowledgements

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Gravel mulches as an effective tool for salinity management in orchards of salt-affected arid regions

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Keywords: Dryland agriculture, Gravel mulch, Sustainable agriculture

Description of the good practice

Introduction

Water evaporation from the soil and subsequent movement and deposition of water-soluble salts in the root zone, is the main reason for soil salinization of farms in arid regions. Stone mulches can be used as an effective tool for soil salinity management. They reduce irrigation water needs, conserve soil moisture, prevent and control root zone salinity, and thus, improve crop yields. The objective of this practice is to introduce and recommend gravel mulches for soil moisture conservation and root-zone salinity management in orchards of arid regions.

Orchard establishment

Gravel mulched orchards are established in three stages: terracing, windbreaks and mulching.

Terracing

Rainfall in arid areas is usually limited and low. Thus, if the land slope is steep, the farmers should use terracing techniques to break the slope. Thus, water runoff is reduced and infiltrates more into the soil (Figure 1).

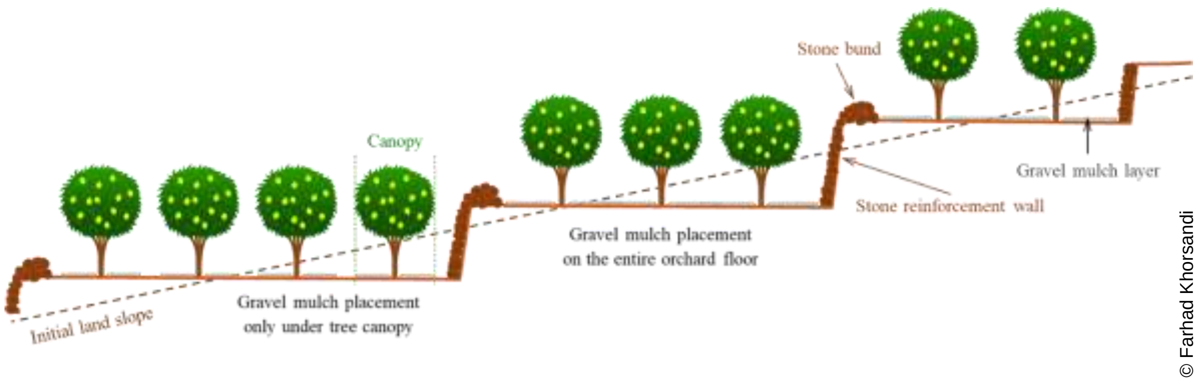

Figure 1. Schematics of terracing and gravel mulch placement in the orchards

Windbreaks

Strong seasonal winds are common in many arid regions. It causes wind erosion, and accelerates water evaporation from soil, water storage ponds, and plants (transpiration). Therefore, farmers should take proper measures to control wind speed by constructing windbreaks (living tree windbreaks, stone walls, etc.).

Mulch placement

Farmers can use different types of stones (such as sands, pebbles, pumice, scoria, etc.) as gravel mulch.

- Grain size and thickness are important factors that affect the efficiency of gravel mulches. Grain size can vary from 5–100 mm. However, a mixture of gravels with 4–8 mm in size is recommended. The thickness varies from 5–15 cm. But 8–12 cm thickness is recommended (Figure 2).

- Before application of gravel mulch, the land should be leveled, and 2 cm of manure must be applied to where the gravel mulch is going to be placed. These operations maybe done either by hand or mechanically.
- The lifespan of gravel mulch is very long (20–35 years). The mulch replacement is not necessary until it is completely mixed with the topsoil and has lost its effectiveness.
- Gravel mulch can be placed at the tree rows, covering the tree canopy, or be applied to the entire orchard floor (Figure 1). The tree crown must be free and not buried under the mulch (Figure 2).

Agronomic operations

The most important agronomic operations in gravel mulched orchards are weeding, fertilization, irrigation and salinity management in the root zone.

- Gravel mulch is very effective in controlling weeds. Thus, there is no need for herbicides.
- Various methods can be used to provide the trees with adequate nutrients, such as vertical fertilizer channels, foliar spraying and soluble fertilizers.
- Farmers may want to use supplemental irrigation for the trees in certain seasons or months. In general, due to the high permeability of gravel mulches, they do not interfere with irrigation operations. In drip irrigation, droppers can be placed either on the top of gravel mulch or under it.
- To increase the amount rain-water for trees, it is very useful to construct a gentle slope in between the rows towards the trees. This will direct the runoffs towards the foot of the trees (Figure 2).

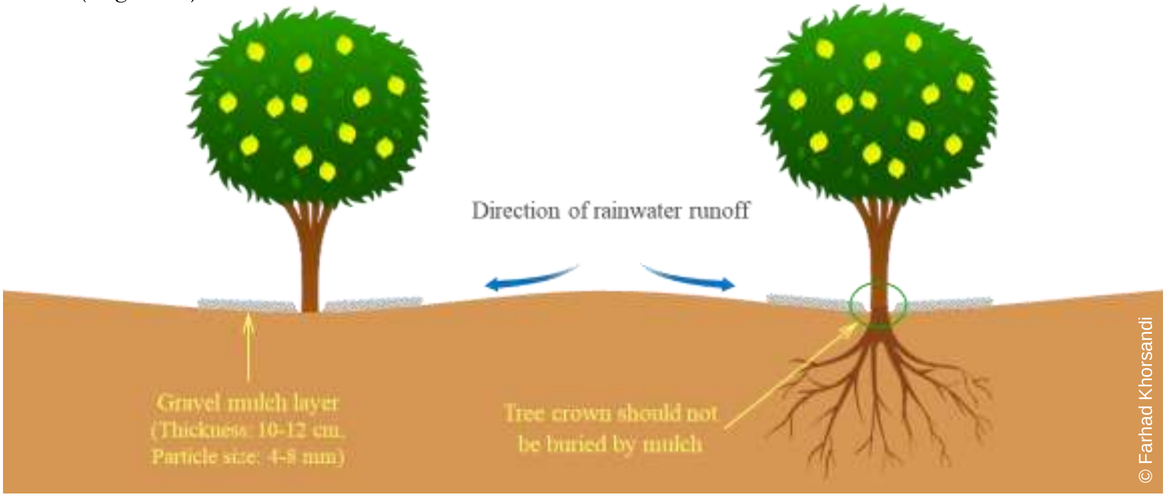

Figure 2. Proper placement of gravel mulch, and shaping the orchard floor

Context of the practice

This practice is applicable in salt-affected, arid regions, where fresh water resources for agricultural purposes are scarce and limited. This practice enables the farmers to continue producing and generating income, in areas where agronomic activities would be impossible due to lack of water.

The positive impact of the practice in addressing soil salinity/sodicity

Lanzarote and *Fuerteventura* islands, Canary Islands (Spain); and *Loess plateau* in north/northwest China.

Other benefits of the practice
Combating desertification, improved living conditions and better quality of life

Challenges for scaling up the practice
This is an easily adaptable practice from technological point of view. However, farmers need to be convinced via pilot plants and farms.

Addition of biochar in saline soils to increase productivity in wheat in central Mexico

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Keywords: Recsoil, terra preta, carbon sequestration, passive pool

Biochar to increase corn and wheat production in saline soils
Biochar is a carbon produced by the thermal transformation of vegetable biomass and uses technology designed to carry out combustion with a low presence of oxygen. Among the various sources of biomass used to manufacture this product are crop residues, tree biomass, and paper residues, among others. The biomass used in our studies includes corn cob (*Zea mays*), oak firewood (*Quercus* spp.), castor bean (*Ricinus communis*) and avocado tree pruning residues (*Persea americana*). Our experience suggests the use of soft biomass such as corn cob or castor bean, as they have short conversion times, the above with respect to other types of biomass. The technology necessary to produce biochar is varied and consists in some cases of complex pyrolysis equipment, both in its handling and of large size, up to easy-to-handle rustic equipment suitable for small producers such as those developed by the authors (Figure 1) and that have been used in avocado, corn and wheat fields.

Figure 1. Manufacture of biochar from corn cobs using rustic equipment in the town of Tarimbaro Michoacan, Mexico

Context of the practice
The work area is the agricultural region of the Morelia-Querendaro Valley at 1923 meters above sea level (Figure 2). The valley is an intermountain region of the Trans-Mexican Volcanic Belt. The Vertisols' are the dominant soils. The climate of the study site is of the temperate subhumid type with rains in summer and average temperature of 19 ° C and precipitation of 796 mm per year (Figure 2), the Köppen climatic key adapted for Mexico is (A) Cb (w1) (w) (e) g. This region is one of the main producing areas of basic grains for the state of Michoacan. The intermountain valley is the product of the volcanism that gave rise to the Cuitzeo lagoon, the second largest in central Mexico. The main economic activity is irrigated and seasonal agriculture. Irrigated agriculture uses gray water from the City of Morelia, which has favored the salinization of the region's soils. The hydrogen potential (pH) of the soil is in the range of 6.2 to 8.3. The electrical conductivity (dS / m) has a range value, 0.26 to 2.35. Variability in soil salinity is associated with management; for example, irrigation, fertilization, intensity in production, among others.

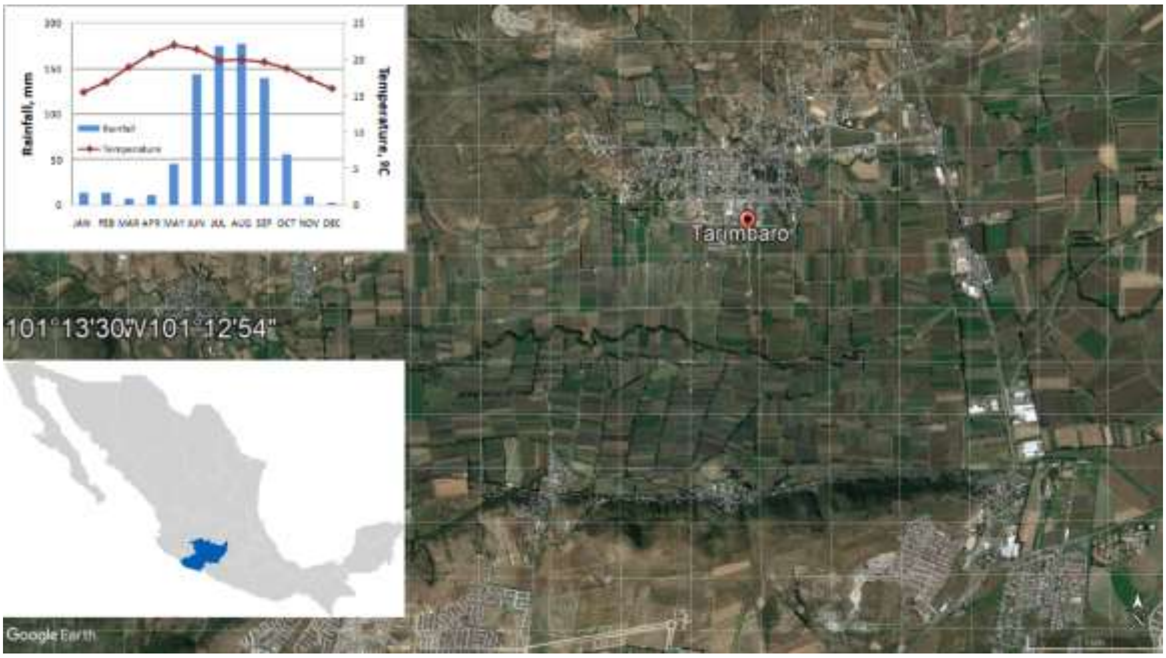

Figure 2. Production site of basic grains in the Morelia-Querendaro Valley in the Volcanic Belt of Mexico. Climograph of own elaboration with information from National Water Commission of Mexico (CONAGUA)

<u>Increase in productivity after adding biochar in saline soils</u>
The benefits of applying biochar on soils have been widely explored in the scientific literature. Currently, the data on the effect of biochar on pH and electrical conductivity in soils are not conclusive, and in some cases it is contradictory. However, benefits are reported in plant nutrition. In our studies, the changes in chemical properties have not been statistically significant; possibly because they are short-term studies (1 to 2 years, in corn and wheat, respectively). But they present significant data regarding production levels as seen in Figure 3.

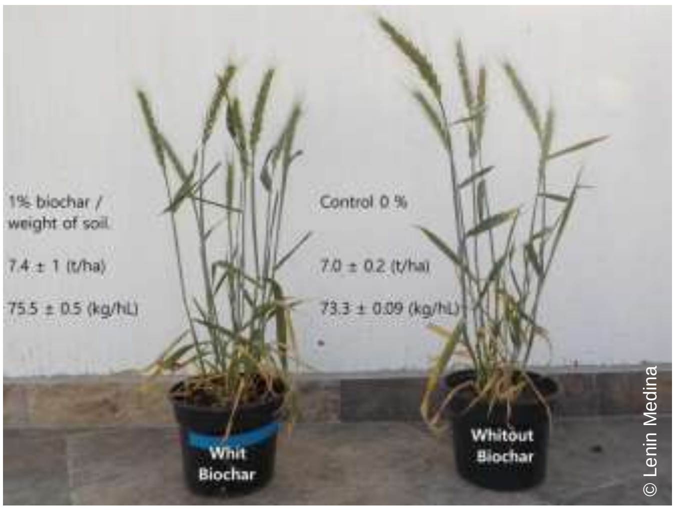

Figure 3. Production of wheat with biochar and without biochar under controlled conditions on basic grain production soils.

Recarbonization of soils
Biochar in farming areas of Central Mexico can be a strategy to increase the production and Re-carbonization of soils. The application of biochar with the rates suggested (1 %) in our investigations, can store up to 9.2 ton / ha in soils cultivated with wheat.

Costs of the practice

The construction cost of a rustic bioreactor like the one presented here amounts to approximately 45 dollars and conversion rates of 25 percent from biomass to biochar. The capacity of the bioreactor is 25 kg and two hours of conversion time. The biomass used comes from the residues of corn cobs from a previous agricultural cycle; therefore, the cost for the producer is low. The increase in the production of wheat with biochar, compared to the production without biochar, represents a profit of USD 96 per ton. Applied to regional yields of 7 ton per ha, it represents a profit for producers of USD 672 per hectare.

Challenges for scaling up the practice

The main challenges for the adoption and scaling of the biochar practice in this region, consists of the training for producers to build the reactors and have reactors of a larger size, but at low cost.

Acknowledgements

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Mix water tools for risk reductions when using non-conventional water resources

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Description and objective

The main objective of our research was to evaluate two different tools to mix different non-conventional water resources (a simplified and an advanced decision support system, DSS) and adapt it for irrigation of salt affected areas. To test the DSSs under severe saline conditions, the trial has been carried out on a Research Platform inside of a plastic greenhouse through the cultivation of halophytes in the southeast of Spain (Fig. 1), monitoring the relation between water-soil-plants, and then explore the possibilities to adapt conventional farming systems into saline agriculture.

Figure 1. Salicornia trial overview at different stages of the growing season at CEBAS-CSIC pilot farm

The "simplified" DSS is based on scientific literature on crop salt tolerance, crop water and nutrient requirements and the cation ratio of soil structural stability (CROSS) as a soil structure index, and historical meteorological data, this Excel-based tool explores different scenarios which can take place mixing different water sources for irrigation. The "advanced" DSS is an innovative remote-control system has been created. This system, used for the safety and sustainable mix of different water resources for irrigation, is based on a hardware infrastructure safe and reliable, made at a real Data Centre. Besides the monitoring system, an innovative software able to evaluate an appropriated mix of irrigation water quality, according with crop-soil-climatic conditions of each farm, has been developed. Each farmer has a personal sheet in the webpage where, with the help of continuous monitoring system, he can know exactly the irrigation water quantity and quality on the field, so a more sustainable reuse of non-conventional water is made.

In summary, we consider that the easy and intuitive functioning of these tools, together with its reliability based on a scientific approach, could help farmers of salt affected areas who have to deal with blending waters to take better management decisions, evaluating the soil-plant-water continuum. The simplified DSS is free for the farmers within the project and the advance DSS will cost around 3000€ plus the water storage infrastructure (around EUR 2000)

Benefits
Both tools are being implemented on different pilot farms where the project is being carried out (Spain, Jordan and Italy). Working closely with the rest of partners, data are collecting to evaluate two main aspects: 1. to check the reliability of our DSS's and 2. to evaluate the use NCW applying different irrigation strategies in several locations.

Main outputs/beneficiaries from the project
Two hundred thirty-seven pilot farmers (91 ha) equipped with tailored subsets of 9 innovative solutions, increasing WUE by 30 percent and substituting CW by NCW up to 100 percent. They will act as change leaders in communities of about 50 000 farmers (100k ha) and beyond, reinforcing commitment to a more sustainable use of irrigation water at Med basin level.

Eighty Extension Agents and eight local players (water user's associations, local authorities, providers of irrigation equipment) trained and actively involved in participatory water resources management planning process (Fourth Memorandum of Understanding-MoUs) and four financial institutions involved to scale-up investments.

Future Challenges
The rise and continuous development of smart agriculture is leaving a large gap between the ways we produce food worldwide. Regarding this, there are different socioeconomic aspects that highlight these differences, one of them could be the access to the knowledge and the interpretation of the scientific data by the farmers. This type of tools might help to reduce that gap, bringing knowledge and know-how to farmers in remote areas. That is why, the future challenges will be the development of a site-specific tool through the integration of more crops/varieties/rootstocks, introducing new, easy and cheap measurable parameters (ET / LF / turbidity / TSS) and as final step, to develop an App easy to use by the growers.

Agronomic Management for Rice Cultivation in Inland Saline Soil of Northeast Thailand

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Keywords: inland saline soil, rice cultivation, agronomic management, Sesbania rostrata, aromatic rice

Description of the good practice

For Thailand, saline soil covers an area of 840 000 ha. About 395 000 ha is found in the northeastern region, while other area of 445 0000 ha is coastal saline soil. Saline soil in northeast Thailand shows very low fertility, causing major problems for farmers in managing the land and crops.

Management and remediation of saline soils depends upon the degree of salinity and specific salinization processes. The Land Development Department (LDD) an involved organizations have tried to solve this problem for a long time. For slightly (EC_e 2–4 dS/m) to moderately (EC_e 4–8 dS/m) saline soils in Thailand are typically used for rice cultivation, however, rice yields are very low. The good practices for increasing rice yields under saline condition include selection rice variety of KDML 105, application of organic soil amendments such as green manure, transplanting of older seedlings at thirty to thirty-five days old, closer spacing of 15×20 cm, increasing number of seedlings.

Due to the high price of chemical fertilizers, green manures has been put as high priority for rice cultivation. Numerous studies indicate that *S. rostrata,* stem-nodulation legume shows high potential as a green manure crop in saline soils for rainfed lowland rice systems in the Northeast Thailand. *S. rostrata* was planted before rice cultivation at seed rate of 30 kg/ha and incorporated at 60 days after sowing.

From these successful studies on the management of saline soil, the Land Development Department has transferred the appropriate technology to farmers in salinity affected areas by training and demonstration plots until present. However, salinity problem cannot be solved by one agency alone. Thus, stakeholders' participation is required for sustainable land management.

Figure 1. Inland saline soils & Rice in saline soil

Figure 2. Land levelling & Incorporation of green manure

Context of the practice
During the dry season, many localities of Northeast Plateau will develop a salt crust. The soil fertility is very low. The climate of Thailand is classified as tropical.

Figure 3. Landuse

The positive impact of the practice in addressing soil salinity / sodicity
Utilization green manure is a practical method to improve soil organic matter, nutrients and structure while soil electrical conductivity decreased. Finally, it increases rice yields by up to 30 percent.

Figure 4. After soil improvement

Other benefits of the practice
Farmers can produce seeds for sale back to Land Development Department and get more income.

Figure 5. Seed production

Costs of the practice
Total costs are about 15 000 Baht per ha. The costs including labor cost for land preparation, planting rice, harvesting, rice seed, green manure seed and chemical fertilizers.

Challenges for scaling up the practice
Utilization of green manure has remained constrained by factors such as insufficient availability of seed, low seed germination, photoperiod sensitivity and increased variable costs. The other one is participation of stakeholders for sustainable land management.

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2. Researcher and staff of Soil Salinity Research and Development Group, Land Development Department
3. Researcher and staff of Land Development Regional Office 3 (Nakhorn Ratchasima province), 4 (Ubon Ratchathani province) and 5 (Khon Kaen province)
4. Farmers in saline area

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Laser land leveling: Enhancing water productivity in Tungabhadra command area

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Keywords: Laser levelling, waterlogging, direct seeded rice, water production efficiency

Description of good practice

Rice is the important crop of Tungabhadra Project (TBP) command area, though only 8.6 percent (29 032 ha) of the TBP command has been earmarked for paddy cultivation. Recently it has been increased to more than 70 percent (255 366 ha) and in all these cases, rice is traditionally grown by transplanting under puddled fields. For this puddling operation, farmers in this area are going for intensive tillage under continuous ponded water nearly 10 cm throughout the season, which serves to break down soil aggregates, reduced macro-porosity, dispersed clay fraction, and farming dense zone of compaction at depth. In this method, the farmers are using excessive irrigation water and fertilizers with unscientific method, which is leading to wastage of precious natural resource i.e. water and land becoming degraded by waterlogging and salinity. It has been estimated that 96 125 ha land has been affected by salinity and waterlogging in TBP command.

The water availability during *Kharif* and late *Rabi* is a biggest problem in tail end region. The direct seeded rice (DSR) will facilitate better establishment of second crop in *Rabi* for tail-end farmers. There are few reports evaluating mulching for rice, where 20–90 percent input water savings and weed suppression occurred with plastic and straw mulches in combination with DSR compared with continuously flooded transplanting rice (Lin *et al.*, 2003). Presently, the farmers of this region use traditional methods (viz. tractor operated bucket leveler) of land leveling (Figure 1) which are good enough to meet only the partial requirement of land leveling. It still leaves the scope of improvement in land leveling in the field to avoid and to become waterlogged. Laser land leveling could be the solution for this problem in command area (Figure 2).

Figure 1. Traditional method of land leveling

Figure 2. Operation of laser land leveling

Figure 3. DSR sowing under laser leveled land and growth of paddy at farmer's field

Context of the practice

Laser land leveling is one such important technology for using water efficiently as it reduces irrigation time and enhances productivity not only of water but also of other non-water farm inputs. It does not only minimize the cost of leveling but also ensures the desired degree of precision. It enables efficient utilization of scarce water resources through elimination of unnecessary depression and elevated contours. Precision land leveling facilitates application efficiency through even distribution of water and increases water use efficiency that results in uniform seed germination, better crop growth and higher crop yield. It was estimated that around 25 to 30 percent of irrigation water could be saved through this technique without having any adverse effect on the crop yield. Keeping this in view, this study was undertaken with the objective to access the effect of laser land leveling on water use and productivity under different methods of cultivation of paddy crop (Puddled transplanting, PTR and Direct seeded rice, DSR) by comparing it with the traditionally leveling and their economic feasibility.

The positive impact of the practice in addressing soil salinity/sodicity

Around 10–15 percent water saved in PTR in laser leveled land compared to PTR in traditionally leveled land. This savings in water could be attributed to uniform distribution/standing of water under laser leveled land which also helps to minimize/avoid development of water logging and secondary salinization.

Higher Paddy yield (87.5 q/ha) was recorded under PTR in laser leveled land (Significantly higher compared with PTR in traditionally leveled land) and followed by laser leveled DSR land (78.75 q/ha) and least in case of PTR in traditionally leveled land (75.10 q/ha).

Other benefits of the practice

- Saves irrigation time and energy by uniform distribution of water
- Increases the fertilizer use efficiency as uniform distribution of fertilizer is possible
- Increases yield and profitability
- Avoids waterlogging and further degradation of soil health.

Costs of the practice

The cost (Rs./ha), gross returns (Rs./ha), net returns (Rs./ha), and benefit cost ratio of the good practice i.e. DSR in laser leveled land (Figure 3) was 40 350, 141 750, 101 400 and 3.51.

Challenges for scaling up the practice

This technology is very much needed and can be replicated at the tail end of the command where there is acute shortage of water for the cultivation of paddy and no scope for taking up of two crops as is the case with the head reach of the command. This technology can also be adopted by head reach command area farmers' which not only ensure proper distribution of irrigation water and fertilizer in the entire command and also help to take care of the problems of waterlogging and secondary salinization especially at the tail end of the command. This technology is having scope to propagate in TBP command area of about 3.65 lakh ha.

Acknowledgements

We express our sincere gratitude to the Government of Karnataka for sanctioning of the project and giving financial support to conduct the experiment.

Halopriming; a low cost and economical shotgun solution for improving crop stand and productivity under salt affected condition

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Keywords: stand establishment, soil heterogeneity, salinity, seed priming, NaCl

Description of the good practice

Halopriming is a simple and low-cost technique which involve soaking of seed in solutions of different salts before sowing. These salts include NaCl, KCl, $CaCl_2$, gypsum and some others are added into soaking media to tolerable limits to control water uptake in seed. Halopriming increases the capacity of seed for osmotic adjustment upon sowing under salt stress condition. Haloprimed seed increases germination and seedling emergence under salt stress by improving water uptake associated with reduced solutes imbalance between soil and seed. In fact, halopriming increases Na^+ and Cl^- in roots, organic acids and sugars in leaves of plants to counter ion the soil salinity or sodicity that ultimately enhances salt tolerance in crops. Halopriming benefits are not limited to only crop stand, later growth, earlier crop development and better yield performance is harvested. This makes it practicable and economical approach to reduce harmful effects of salinity in crop plants such as wheat (Jafar *et al.*, 2012), sugarcane (Patada, Bhargva and Suprasanna, 2009), canola (Farhoudi and Sharifzadeh, 2006), milk thistle (Sedghi *et al.*, 2010), chickpea (Saha, Chatterjee and Biswas, 2010) and melons (Sivritepe N., Sivritepe H. and Eris, 2003), (Sivritepe *et al.*, 2005).

Normal soil | Saline soil

Figure 1. Halopriming to improve wheat performance under natural saline condition

Context of the practice

Halopriming had been tested in different geographical regions of world including Pakistan, India, Iran, South Africa, salt affected soils with different salinity levels and texture and participatory demonstration on farmer's fields has been practiced.

The positive impact of the practice in addressing soil salinity / sodicity

Halopriming has been practiced in reducing the detrimental effects of salinity/sodicity in improving stand establishment, growth, and yield by reducing Na^+/K^+ ionic ratio, reducing osmotic and ion toxicity (Table 1)

Table 1. Growth and yield benefits associated with halopriming in field crops

Crop	Salt type	Growing condition	Improvement	Reference
Wheat	$CaCl_2$ (1.5%)	Greenhouse	Osmotic adjustment, Yield	Tabassum *et al.*, 2017
Mung bean	50 mM NaCl	Greenhouse	Seedling growth	Saha *et al.*, 2010
Canola	KNO_3	Greenhouse	Seed germination and seedling growth	Omidi *et al.*, 2009
Sugarcane	NaCl (100 mM)	Field	Seed germination, shoot and root growth	Patade *et al.*, 2009
Wheat	$CaCl_2$	Field	Emergence and yield	Jafar *et al.*, 2012
Wheat	Gypsum	Field	Emergence and yield	Harris *et al.*, 2001

Other benefits of the practice

No such studies showing the seed halopriming induced benefits on soil properties are reported.

Costs of the practice

Economic feasibility of halopriming is associated costs associated with salts used for soaking, handling of haloprimed seeds, yields and net field benefits in terms of high-cost input to output ratio. Only one study reports the percent increase in income and cost-benefit ratio for halopriming when compared to non-primed seed (Table 2).

Table 2. Cost-benefits associated with halopriming under natural saline condition

Crop	Percent increase in income over control	Percent increase in Benefit to cost ratio over control	Growing environment	Reference
Wheat	119.72	35.62	Saline	Jaffar *et al.*, 2012

Challenges for scaling up the practice

As a cost-effective technique, seed priming methods including halopriming has been practiced in many countires including Pakistan, India, Iran, South Africa, Zimbabwe, Nepal, China, Bangladesh and Australia. Therefore, can be recommended to farmer to harvest the benefits to synchronize emergence and crop stand, optimize the yields using limited resources under salt affected soils and self-sufficiency in crop production that may help to improve their socio-economics conditions. As a challenge, to harvest the maximum benefits of halopriming, emphasis should be given to seed drying and packaging for safe storage to maintain viability of primed seed during storage.

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The application of the effective actions for improvement the chemical and physical properties of Saline-Alkaline soils

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Keywords: Saline-Alkaline soils, not contact method of electro-melioration, local reclamation, micro-sites, improvement, economic efficiency

Description of the good practice

The methods of chemical reclamation of saline-alkaline soils by application of sulfuric acid require the transportation of a huge amount of ameliorants from other countries.

The newly proposed none-contact method of electro-melioration of Saline-Alkaline soils is based on the fact, that (Patent Armenia № 1361 A2, 2003) the chemical reclamation of soils by using preliminary acidifying solutions of mineralized ground water is implemented in a special apparatus (Fig. 1.).

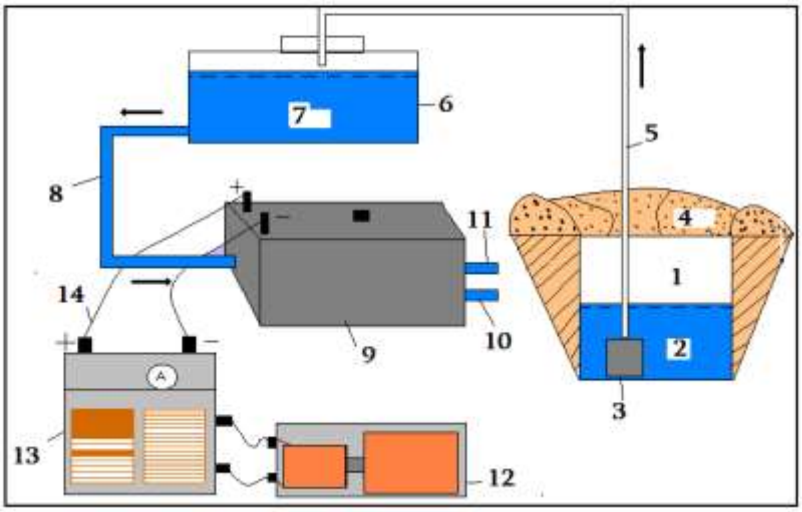

Figure 1. The scheme of work of the apparatus for electro-processing of the mineralized ground water: 1-hole, 2-mineralized ground water, 3-pump, 4-beds, 5-pipes, 6-feeding tank, 7-mineralized water, 8-nutritious pipe, 9-apparatus of electro-processing of mineralized water, 10-pipe for an output of the acid solution, 11-for an output of alkaline water, 12-electro-aggregate, 13-transformer for decreasing of voltage, with the rectifier of current, 14-electro-lines for feeding of the apparatus

To decrease the means of the reclamation of alkaline soils, it is necessary to use the local reclamation technology, this allows to reclaim the salt affected soils and to allocate them under fruit gardens. The essence of this technology is that not all the sites of the real area, but only the nutritious micro-sites of trees (1,5 x 1,5 m^2) are reclaimed. Thus, on 1 ha of site, only 500–700 m^2 of the area is really reclaimed and they are allocated in the orchards, without an expensive drainage systems construction. The experiment is carried out on a farmer site on the 0.1 ha of area. Proceeding from the distance between lines (6 m) of trees plowing by depth of 25–30 cm is made and the construction of the protective beds in the height of 20–25 cm around the micro-areas have been made.

Context of the practice
The Ararat plain in the territory of Armenia, located in the North of the plain the border of the Aragats Mountain, and in the South of the Ararat Mountain. The modern surface of Ararat plain is presented as the quaternary alluvial sediments of the Araks River, covered with proluvial-deluvial sediments. The climate in the area is dry and continental with cold winters and hot summers. The annual sum of rainfall is below 200–300 mm. The following soils have been formed in the Ararat plain: Semi desert brown soils, Irrigative meadow brown, Hydro morph solonetz-solonchaks (Saline-Alkaline soils). The object of our experiments serve is solonetz-solonchaks, which are characterized by high alkaline reaction (pH 10–11), medium and heavy mechanical composition, strongly alkalization (ESP 60–70 percent), high salt content (0.5–2.0 percent).

The positive impact of the practice in addressing soil salinity / sodicity
The maximal contents of toxic ions are accumulated in the 25–50 cm layer of soil (20–22 meq/100 g). After giving 30 percent norm of electro-processed mineralized water (Fig. 2), decreasing of mentioned ions is observed (17–6.0 meq/100 g). After the chemical reclamation and leaching the contents of toxic ions are sharply decreased and in 0– 100 cm layer of soil varied in the interval of 2–3 meq/100 g.

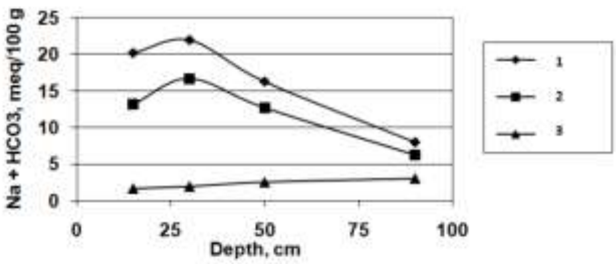

Figure 2. The dynamics of toxic ions in the (Na exch. + HCO_3) profile of Solonetz-Solonchak soils: 1-before reclamation, 2-after giving 30 % norm of ameliorant, 3- after chemical reclamation and leaching

Other benefits of the practice
The implementation of the project allows to get the following positive results:
a. reduction of leaching and irrigation volume of water,
b. reduction of chemical ameliorants norms and costs for its transportation,
c. exclusion of the use of tanks, dispensers,
d. exclusion of collector drainage system construction,
e. increasing of water and land resource use efficiency, poverty reduction, restoration of ecosystem, reduction of desertification processes.

Costs of the practice
The cost of reclamation of 1 ha of Saline-Alkaline soils by the traditional method makes 30000 USD. The cost of 1 ha local reclamation of saline alkaline soils makes 7000 USD. The cost of electric energy for processing the mineralized water makes 5000 USD.

Challenges for scaling up the practice
For the widespread introduction of this technology, it is necessary to manufacture apparatus for the processing of mineralized waters with a high capacity of 10–20 l/s, as well as a solar station with a power of 5 kW, compactly assembled on mobile technique.

Halophyte (Dixie Grass) Plantation for Rehabilitation Severely Saline Soil in Northeastern Region, Thailand

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Keywords: severely saline soil, northeast Thailand, Sporobolus verginicus (Dixie grass), rehabilitation, vegetative measure

Description of the good practice

In the northeastern Thailand, saline soil covers an area of 395 000 ha and causes major problems on soil and crop management practices. Management depends upon the degree of salinity and specific salination processes. For severely saline soil, planting halophytes is an effective strategy for soil remediation, ecological and environmental improvement.

Previous studies showed that *Sporobolus virginicus,* coarse type (Dixie grass) could very well adapted to survive in severely saline soil and suitable for this area. Land Development Department (LDD) promoted planting Dixie grass for rehabilitation severely saline soil. LDD recommended plant at spacing of 20×20 centimeters on abandoned area and on ridges between rows of *Acacia ampliceps*. This good practice was promoted and transferred to severely saline area in many provinces. One of case study was Mr. Charong Munkarn's land, located at Kutchok sub-district, Buayai district, Nakhon Ratchasima province. After three years of planting Dixie grass, it found that this barren land was covered by plants and much improved in biodiversity by the evidence of many varieties of wild grass, dragonflies, rats and birds. Farmers can grow rice and they use Dixie grass as feed for livestock. The stakeholders were land owners, livestock farmers, local administration, local government agency and researchers all worked together with mutual benefit. Although planting halophytes was an improvement method (of vegetative measure) of severely saline soil with low input, the recovery/accomplishment time (in saline soil improvement) could not be as fast as that of the engineering measure with much higher investment.

Figure 1. Severely saline soil

Figure 2. Dixie grass

Context of the practice

An example of successful farmer participating in the project located at Buayai district, Nakhon Ratchasima province. The area is 0–2 percent slope and salt crust more than 50 percent found on the surface soil. The weather is semi-arid, and the rainfall is 751–1000 millimeters per year.

The positive impact of the practice in addressing soil salinity / sodicity

The severely saline soil was rehabilitated from the Dixie grass planting; salinity obviously decreased. These induce biodiversity of both fauna and flora such as birds, butterflies, rats, earthworms and native flowers. The farmers can use their land after planting Dixie grass for 2–3 years.

Figure 3. Rice field after planting Dixie grass three–five years

Figure 4. Dixie grass (after three years) as pasture for cattle

Figure 5. Better biodiversity and environment (after three years)

Other benefits of the practice
Dixie grasses can be used as cattle feed. Farmer can sell the Dixie shoots for propagation to Land Development Department. They can get higher income.

Costs of the practice
Total costs for technology are about 15 000 Baht per ha**.** The costs include labor cost for planting Dixie grass, Dixie seedling cost (10 000 plants per ha) and fertilizers as compost and chemical fertilizers.

Challenges for scaling up the practice
The challenges are to raise awareness and participation in the rehabilitation of saline soils within the community, and to create a model from successful farmers in order for farmers in nearby areas to have incentives in their own areas. And the staff must continuously educate and publicize the project.

Acknowledgements
1. Land Development Department
2. Land Development Regional Office 3, Nakhorn Ratchasima province
3. Mr. Charong Munkarn, farmer.

The management of subsurface drip irrigation (SDI) by unconventional water in pistachio orchards in severe soil salinity and alkalinity condition

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Keywords: Saline-alkaline waters, Soil degradation, Sustainable production, Toxic elements, Economic-social significance

Description of the good practice

Currently, high water and soil salinity and alkalinity are the biggest challenges for the stability of pistachio production in Iran (Figure 1). Most pistachio orchards are irrigated by furrow irrigation. The subsurface drip irrigation (SDI) method with unconventional water can be reduced damage and consumption of water by at least 50 percent compared to furrow irrigation.

Figure 1: Accumulation of salt in the soil surface, south of Bardaskan City, Khorasan razavi, Iran

Context of the practice

The seedlings were planted in the Pistachio Research Station with the 58° 45 19 and 34° 57 12 geographical attributes. In this method, a pipeline (16 mm) with a dropper was implemented at a depth of 70 cm and a distance of 120 cm from both sides of the seedlings. The droppers were placed one meter apart and their flow rate was four L/h at a pressure of two atmospheres (Figure 2).

Figure 2: Movement of water to the soil surface in SDI method (Pistachio Research Station, Khorasan razavi, Iran, 2018)

The positive impact of the practice in addressing soil salinity / sodicity

Since the SDI irrigation method was implemented in 2012 until now, water salinity has very gradually increased (Table 1).

Table 1. The trend of changes in water properties used in SDI

Year	EC (dS/m)	pH	$(CO_3)^{2-}$	HCO_3^-	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	SAR
			meq/lit						
2013	11.5	7.4	0	1.9	85.5	24.7	13.9	68.2	15.5
2015	11.7	7.6	0	3	85	24	15.2	80.7	18.2
2017	12.2	7.3	0	3.2	91.5	25.6	14.4	78.6	17.6
2019	14.2	7.5	0	1.8	135.5	36	20	85.1	16.1

<u>The reduction of water consumed in the SDI method compare to the common irrigation (furrow method)</u>

The consumption of water has reached nearly 2400 m^3/ha after the eighth year of implementation (2020). The amount of water consumption for trees of the same age in the furrow irrigation (traditional irrigation) was more than 5000 m^3/ha. Water requirement to produce a kg dry matter was 761 and 1851, in the SDI and furrow method respectively.

<u>Reduce the amount of salt entering the soil</u>

If the average inflow of water into the soil per hectare for the first eight years is 1800 m^3 and the average of water salinity is almost 11.6 dS/m, about 21 tons of salts has entered the soil every year. This amount was estimated more than 43 tons in-furrow irrigation; which is about twice of salt entered in the SDI.

Other benefits of the practice

<u>Dispersion of salt in SDI method and the comparison with the furrow irrigation</u>

The electrical conductivity in the topsoil (0–30 cm) was 110 dS/m.This amount was 12.33 and 14.52 dS/m for 30– 60 and 60 to 140 cm of soil layers, respectively (Table 2) which was suitable for growth due to the expansion of roots at a depth of 60 to 140 cm in the soil in SDI.

Table 2. Some of the most important chemical properties of the soil at the site of SDI (Sharafati, 2018)

Depth	pH	EC	T.N.V	Ca	Mg	Na	Cl	SO_4	SAR
cm	-	dS/m	%	Meq/L					-
30-0	7.1	110	15.3	180	135	661.4	775	280	52.7
60-30	7.8	12.33	14.3	20	20	79.6	90	20	17.8
140-60	7.8	14.52	16.5	22	20	100.6	100	32	21.9

Table 3. Some of the most important soil chemical properties in furrow irrigation site (Sharafati, 2018)

Depth	pH	EC	T.N.V	Ca	Mg	Na	Cl	SO_4	SAR
cm	-	dS/m	%	Meq/L					-
0-50	7.53	38.82	15	70.6	51	242.8	-	-	29.9
50-100	7.6	42.63	14.16	68.3	51	273.6	-	-	34.9

Improvement of horizontal and depth distribution of roots

1) There were no roots from the soil surface (0–30 cm) except the main root.
2) The main root has developed horizontally at a depth of about 60 cm.
3) The root development zone started from a depth of 60 cm and continued to a depth of more than 140 cm.
4) The roots did not accumulate in the area of water outflow (under the droppers) and were evenly distributed in the entire volume of soil below the area of water outflow. While in furrow irrigation the expansion of the roots starts mainly from the topsoil and reaches the maximum density up to a depth of 50 cm

Ease of management of topsoil tillage in the SDI method

To solve the soil surface compaction by agricultural implements and workers, two strategies were performed in SDI: First, at the end of the growing season and before the onset of autumn and winter rains, the topsoil (On average 7 cm) was collected by agricultural implements and moved out of the orchard and second, plowing was done to a depth of about 50 cm (Fig. 3) which was not possible in the furrow method due to the depth of root expansion.

Figure 3: Soil surface plowing with cultivator discs, Pistachio Research Station, Khorasan Razavi, Iran, 2015

Nutrition trees with less consumption of chemical inputs in the SDI method

Nutrition and supply of macro nutrients were done via an irrigation system in the SDI (Table 4). To provide micro nutrients and achieve vegetative growth and proper yield, foliar application of nutrients was done six and four times a year for SDI and furrow method.

Table 4. Comparison of fertilizer consumption (macro elements) and foliar feeding/ha in the two irrigation methods

Irrigation method	Urea	Potassium Sulfate	(.Liquid organic phosphorus (L	Foliar application
Unit	Kg	Kg	Kg	.l
SDI	100	20	15	30
Furrow irrigation	250	50	30	20

Costs of the practice

Because the SDI method 1) has reduced water consumption by more than 50 percent, 2) the lowest amount of salinity effects on the trees, 3) the suitable vegetative growth and bearing of trees (Figure 4) 4) decreased the orchard maintenance costs including labor, fertilizer, irrigation, etc. (Table 5) was cost-effective.

Table 5. Comparison of production costs and gross income in furrow irrigation and SDI method per hectare ($). Costs and incomes are displayed as negative and positive values respectively.

Irrigation method	Irrigation costs	Fertilizer costs	The cost of pest, lisease and eed control	The cost of land preparation, harvest, and processing	Total production costs per hectare	Gross income	Sum total
SDI	-140	-320	-280	-480	-1410	+12800	+11390
Furrow	-320	-800	-400	-600	-2120	+11200	+9080

Figure 4: Pistachio trees (Badami-sefid Cv.) in subsurface drip irrigation method, Pistachio Research Station, Khorasan razavi, Iran, 2021

Challenges for scaling up the practice

1) The small orchards area and therefore the high cost of implementation.
2) Unfamiliarity of gardeners with this method of irrigation.
3) Insufficient management and technical knowledge for proper utilization of this method, especially in soil and water salinity and alkalinity condition

Acknowledgements
It is necessary to thank the Khorasan Razavi Agricultural and Natural Resources Research Center and the staff of Feyzabad Pistachio Research Station.

Transforming homesteads of moderately saline area to adopt climate extremes in coastal region (Bangladesh)

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The main focus of practice/technology

Main focus of the technology is to use smallholding for multiples crops avoiding coastal climate extremes.

Description of the practice / case study

Coastal areas of Bangladesh is characterised by salinity of soils and water in dry season, accumulation of salt on the soil surface, limited fresh water in ponds or ditch, soils became hard to plough. On the other hand, most of the lands remain flooded up to 1 m for more than six months. The area is predominantly single cropland with poor to moderate yield. Climate extremes like cyclone, Sidre, heavy downpour also limit farming in this area.

Endeavours initiated by government and non-government sectors (In this case Community Development Centre, (CODEC)) to increase cropping intensity have been observed in south-west coastal areas of Bangladesh. Practice of transforming homesteads to a small area of unique production unit in moderately saline areas coastal region. Growing vegetables, raring livestock and poultry and producing fish in one compact parcel of homesteads to skip soil water salinity and water logging in dry (rabi) and kharif (wet) growing periods respectively. A unit of about 0.22 ha consisting of a "farm pond" for fish and sweet water source for small scale irrigation; growing vegetables on raised pond ridge/dykes, tower gardening or in sag begs to skip soil salinity and water logging; raring livestock and poultry, vermin compost preparation to improve soil health from livestock refuse beside the residence. Pond is used to reserve fresh water, dykes and raised platforms are utilized for growing year-round vegetables such as cauliflower, knolkhol, tomato, potato, bottle gourd, chilli, spinach etc. in dry (rabi) season; sweet gourd, okra, rib gourd, snake gourd in wet (Kharif) season. The other sub-technologies (such as tower garden, pocket method, sag bag method, pitcher irrigation, mulching, bed system, pit system, vine of pond, use of compost fertilizer, use of sex pheromone trap, bottle method, use of banana chopping) are also practiced for reducing water salinity, and tipi-tap method for irrigating land. Farmers of the unions (local administrative unit) namely Joynagar, Tildangha, Bererkhal, Bajua, Laxmikhola, Pankhali and Saherabad of Dacope sub-district are practicing this type of technologies with their own composition of sub-technologies since 2010. It helps to skip disaster and climate risk management in Agriculture at homestead areas in coastal zone.

Context of the practice / case study

Context of the practice includes the transformation of a fallow or rarely cropped homestead into a multiple cropping to avoid salinity and climatic extremes.

The current land use type is "homesteads" with low yielding vegetables. Before adoption of such technology, it was used for growing vegetables with risk of soil salinity in dry season and waterlogging in monsoon. At present, this land is used simultaneously for agriculture, aquaculture and livestock

The coverage of the practice / case study

This practice is adopted by 50 farmers, where farm size varies from 0.1 to 0.5 ha at different unions under Dacope sub-district of Khulna district.

The positive effect of the practice / technology on salinity / sodicity status of soils

The positive impacts of the technology are:

- Skip soil salinity in dry season
- Skip waterlogging.
- Increased production.
- Livelihood improvement.
- Improvement of soil health.

Table 1. About the practice / case study

Location	Climate zone	Soil type	Baseline salinity/sodicity levels Mean±SD	Salinity/sodicity after the use of practice/case study	Duration of experiment	More info	Reference
Pankhali, Dacope sub-district of Khulna district. 22° 37′ 37″ N latitude and 89° 30′ 33″ E longitude.	Tropical wet	Gleyic Fluvisols	As the SSM practice is being implemented by farmers, the salinity level is not recorded but the area is known to be as moderately saline area.	Not recorded as the SSM practice is being implemented by farmers	Around 10 years	-	-

The positive effect of the practice / case study on soil health

The main purposes of the technology are to improve production (crop & fodder) and to adapt with climate extremes and its impacts like soil-water salinity and waterlogging.

Table 2. Other benefits of the practice / case study

Minimizing/Preventing soil threats	YES/NO/Non applicable	Explanation / Related soil property (short, referenced)
Minimizing soil erosion/soil losses	Non applicable	
Enhance soil organic matter content	YES	As farmers use vermin compost.
Foster nutrient balance and cycles (N,P,K)	Non applicable	
Prevent and minimize soil contamination/pollution	Non applicable	
Prevent and minimize soil acidification	Non applicable	
Preserve and enhance soil biodiversity	YES	Improved soil health, enhance soil biota.
Minimize soil sealing	Non applicable	
Prevent and mitigate soil compaction	Non applicable	
Improve soil water balance	Non applicable	

Table 3. Potential barriers for adoption of the practice / case study

Barrier	YES/NO	Explanation (short, referenced)
Biophysical	YES	Need proper land budget for each micro-practices
Cultural	YES	Peoples of the area are not acquainted with system, need awareness
Social	YES	Need strict observation, limited access to extension, lack of education.
Economic	YES	Poverty
Institutional	YES	Poor extension and education on the technology
Legal (Right to soil)	NO	Farmers own homesteads
Knowledge	YES	Inadequate knowledge on complex farming
Natural resource	NO	
Other		

Economic benefits of the practice / case study

The area previously remained fallow or poor crop cover. Adopting multiple micro-technology, for example, small pond for fish and reserving fresh water, pond dykes for seasonal vegetables, livestock refuse for preparing vermin compost, tower garden to avoid loss during high flood etc.

From the land user's context, the benefits compared with the establishment and maintenance costs are very positive for both short-term (one–three years) and long-term (> ten years) returns. The cost-benefit ratio is 1:1.5 in first two years and 1: 2.5 after two years. Farmers need financial support during the installation of such technology.

Photos and graphical representations of the practice / case study

Figure 1. Tower Garden in the homestead

Figure 2. Farm Pond and creeping net for vegetable over the pond

Figure 3. Usage of pond dykes to grow multiple vegetables with small scale irrigation from pond.

Acknowledgements
This technology was documented following WOCAT questionnaires-QT. The process of documentation was supported by a project from Department of Environment, MoEFCC, authors gratefully acknowledge the support. The authors also express gratitude to the farmers and the local extension officers to provide support and information during documentation.

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Coastal single cropped land converted to year-round cropping (Bangladesh)

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The main focus of practice/technology

Saline soils. The main focuses of this practice are to increase cropping intensity and to diversify cropping by avoiding waterlogged condition in wet season and salinity in dry season.

Description of the practice / case study

A large area of the coastal region is single cropland, that is transplanted aman rice in kharif-2 (wet season) or shrimp (Bagda or Golda) in gher areas. At present, farmers are changing the landforms depending on the scope and ability. They are changing the landforms by raising platform, making a ditch around or at one side of the land and the rest part remains left for growing rice. Raised platform is used to grow small fruit trees, vegetable (Eggplant, Tomato, Okra, Gourds etc.), ditch of 3–4m wide and 1 m deep is used for shrimp, mostly Golda (*Macrobrachium rosenbergii*) or white fishes and left-over areas for growing transplanted aman or boro rice.

It is generally done during Kharif-2 season in saline areas to make sweet water availability for year-round cultivation. The dyke of the area is 1 m wide at the crest and about 1 m high. The space is used to grow different vegetables, chili, etc. Trails are installed to allow creeping vegetables within the area.

The main purpose of this technology is to cultivate vegetables on the dyke of land throughout the year. Cost of this arrangement varies with the size and height of the dyke. The soil of the dyke becomes non saline after monsoon. Instead of single shrimp culture, rice is grown in the field and vegetables on the dyke which increase income from farm if regular maintenance of dyke is ensured.

Context of the practice / case study

The context of the practice is to skip soil salinity in dry season and waterlogging in monsoon.

The coverage of the practice / case study

This practice extensively covers Khulna and Satkhira district, the south-west part of Bangladesh. But composition and structure are different depending on the choice of the individual farmers. The basic approach is to adopt soil salinity and waterlogged condition of the landscape.

The positive effect of the practice / technology on salinity / sodicity status of soils

Qualitative impacts estimated and included in “Other benefits” of the practice section.

Table 1. About the practice / case study

Location	Climate zone	Soil type	Baseline salinity/ sodicity levels Mean±SD	Salinity/sodiciy after the use of practice/ case study	Duration of experiment	More information	Reference
Bherulia union, Dumuria sub-district of Khulna District. 22°21'59.02"N latitude and 89° 5'6.98"E longitude.	Tropical wet	Gleyic Fluvisols	Not estimated as the SSM practice is being implemented by farmers. The area is moderately saline.	Not estimated as the SSM practice is being implemented by farmers	Around ten years	-	-

The positive effect of the practice / case study on soil health

The positive effects of this practice are:

- Improved livelihood.
- Improved soil health.
- Improved food security.
- Salinity and waterlogged skipped.
- Usage of resources like soil, land, water etc. more efficiently than before.
- Changed micro-climate.

Table 2. Other benefits of the practice / case study

Minimizing/Preventing soil threats	YES/NO/Non applicable	Explanation / Related soil property (short, referenced)
Minimizing soil erosion/soil losses	**Non applicable**	
Enhance soil organic matter content	**YES**	Previously the dykes were small, low and used for walk way. In this practice, it is large enough to grow vegetables using compost. Leafs of vegetables enrich SOM content as a whole.
Foster nutrient balance and cycles (N, P, K)	**Non applicable**	
Prevent and minimize soil contamination/pollution	**YES**	Fertilizers used in pits, that limit contamination by excess fertilizer.
Prevent and minimize soil acidification	**Non applicable**	
Preserve and enhance soil biodiversity	YES	Improved soil health, enhance soil biota.
Minimize soil sealing	**Non applicable**	
Prevent and mitigate soil compaction	**Non applicable**	
Improve soil water balance	YES	Small scale irrigation could be done.

Zero or minimal side-effect of practice/technology on surrounding area

On-site or off-site effects were not reported.

Tradeoffs or conflicts with other practices

None

Table 3. Potential barriers for adoption of the practice / case study

Barrier	YES/NO	Explanation (short, referenced)
Biophysical	NO	
Cultural	YES	Strong awareness among stakeholders is needed.
Social	YES	Community to adopt marketing for new farm products.
Economic	YES	High initial cost.
Institutional	NO	Government extension institute and NGO are active.
Legal (Right to soil)	YES	Most of the land owned by few peoples, absentee owners.
Knowledge	YES	Poor excess to knowledge hub.
Natural resource	NO	
TOther		Total polder management with strict sluice gate operation to ensure proper drainage management.

Economic benefits of the practice / case study

Initial cost of establishment of this practice is about BDT 200 000/ (USD 2400) and the farmer can able to earn about BDT 350 000/ (USD 4100) per year per ha. There is a minimum cost for maintenance, amounting to only USD100 per year per ha. Therefore, this a very positive cost-benefit ratio.

Photos and graphical representations of the practice / case study

Figure 1. From left to right: Top: Creeping Vegetable on dyke, Vegetables on two dykes joined with net, Farmer describing his experience.Bottom: Unconverted land besides converted land, Harvesting vegetable from boat, Unconverted single cropped land.

Acknowledgements

This technology was documented following WOCAT questionnaires-QT. The process of documentation was supported by a project from Department of Environment, MoEFCC., author gratefully acknowledge the support. The author also expresses gratitude to the farmer and the local extension officers to provide support and information during documentation.

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Usage of Gher boundary for cropping (Bangladesh)

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The main focus of practice/technology
Gher (shrimp cultivation) boundaries usually remain bare in the area. This technology use 'Gher' Bunds for multiple cropping by normal washing out or leaching salinity.

Description of the practice / case study
"Gher" is a local word used for shrimp cultivation plot. The boundaries of these "Ghers" are nowadays raised and maintained to grow vegetables, fruits and also some tree species. In this case the boundary of the plot is raised at least 3 feet with grest width 1 feet plus depending on the height of the boundary (Bund/dyke). Within the "Gher" the land is used for both sweet water prawn (Golda) or saline water prawn (Bagda) with other different types of fishes (locally called Sada Mach) if suitable depending on the salinity of water. Some of the "Gher" lands are used for transplanted Aman with shrimp/fishes. Farmers dug a ditch along the boundary or in any corner of the field or at the center of the plot to preserve water and fishes during the dry season. In some of the cases the farmers used shallow tube well water to sustain the fishes. In non-to slightly saline areas they used it even for boro (winter rice).

Establishment / maintenance activities and inputs: The boundary is constructed above flood level (2–3 feet), the width is approximately 2–3 feet, and the ditches are 2–3 feet deep along the boundary or at the corner or at the center. To grow vegetables farmers used nylon nets for creeping supported by the bamboo or Dhaincha or strings. Top soils kept on top of the bunds to avoid relatively less fertile soil on the bunds. Main inputs are seeds of vegetables, nets, bamboo, strings, fingerlings of fish etc. Natural / human environment: The salinity of the soils from the bunds is washed away by rainwater, which facilitates vegetable production: Rain water dissolves salt and moves to the bottom of the bund, and soil becomes non-saline or slightly saline where vegetable could be grown. Full description in the WOCAT database.
(https://qcat.wocat.net/en/wocat/technologies/view/technologies_1171/)

Context of the practice / case study
The purpose of this technology is usage of "Gher" boundary for various types of crops, including year round vegetables and land for rice and fishes including shrimps to get more products from same land.

The coverage of the practice / case study
This type of technology is adopted almost whole shrimp farming areas of the coastal region. But is not used as a prototype of this technology. Variations observed in crops; size, shape and height of bunds; rice verity and fish (shrimp or normal fish).

The positive effect of the practice / technology on salinity / sodicity status of soils

- Bunds are desalinized by natural washing in rainy season, means ECe became <4.00 dS/m.
- Increased production per unit area.
- Crop diversification increased
- Livelihood improved.
- Positive impact on micro-climate.
- Increased food security

Table 1. About the practice / case study

Location	Climate zone	Soil type	Baseline salinity/sodicity levels Mean±SD	Salinity /sodicity after the use of practice/ case study	Duration of experiment	More information	Reference
Dumuria of Khulna district.89.41395 E, 22.80719 N.	Tropical wet	Fluvisols	Not recorded as the SSM practice is being implemented by farmers	Not recorded as the SSM practice is being implemented by farmers			

The positive effect of the practice / case study on soil health

- Growing more crops will benefit the farmer with more return- livelihood improved.
- Land could be used and managed by farmers themselves- community adoption.
- Changes in land management by the farmer to grow multiple crops indeed scale up their economy than before.

If available, give quantitative information on other indicators of soil health: recommended ones are soil productivity, SOC, bulk density, respiration rate, and optional ones are plant available phosphorus, soil erosion, soil biological activity, pH, available water capacity, soil infiltration rate, soil penetration resistance, soil pollution)

Table 2. Other benefits of the practice / case study

Minimizing/Preventing soil threats	YES/NO/Non applicable	Explanation / Related soil property (short, referenced)
Minimizing soil erosion/soil losses	**Non applicable**	
Enhance soil organic matter content	**YES**	Leaf litres and usage of vermin compost increased SOM.
Foster nutrient balance and cycles (N,P,K)	**Non applicable**	
Prevent and minimize soil contamination/pollution	**Non applicable**	
Prevent and minimize soil acidification	**Non applicable**	
Preserve and enhance soil biodiversity	YES	Relatively better than bare soil
Minimize soil sealing	**Non applicable**	
Prevent and mitigate soil compaction	**Non applicable**	
Improve soil water balance	**Non applicable**	

Zero or minimal side-effect of practice/technology on surrounding area

There are no off-site impact of the technology.

Tradeoffs or conflicts with other practices

Conflict between salt water shrimp (Bagda) and fresh water fish growing farmer.

Table 2. Potential barriers for adoption of the practice / case study

Barrier	/NO	Explanation (short, referenced)
Biophysical	**YES**	Changing the Gher bund size is costly.
Cultural	**YES**	Challenges of new investment
Social	**YES**	Land ownership may not allow to change the landtypes.
Economic	**YES**	Increased livelihood, increased food security
Institutional	**YES**	Poverty, lack of fund during initiation

Barrier	/NO	Explanation (short, referenced)
Legal (Right to soil)	YES	In some cases absentee land owner impede development process. Still there are conflicts of using water resources.
Knowledge	**YES**	Poor literacy, access to new value chain is limited.
Natural resource	**YES**	Conflict of usage for saline and fresh water sources
Other		

Economic benefits of the practice / case study

Additional cost to normal "Gher" establishment of this technology were estimated in 2013 as about USD 20.00 and USD 1.00 per ha for seed/seedling. Cost of "Gher" cost about USD 1000/ha. At present valuation outcome of the "Gher" from vegetables USD 800/ha, rice 192/ha and from fish USD 250/ha.

Photos and graphical representations of the practice / case study

Figure 1. Atypical Gher of Dumuria

Figure 2. A Gher Landscape from bird's eye

Figure 3. Gher under vegetables and creeping in to Gher and Bean in the other side

Figure 4. Farmer who manage the Gher

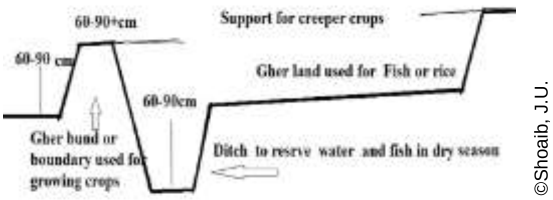

Figure 5. A sketch of Gher

Figure 6. Gher bunds where not used for crop

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Harnessing productivity of Sodic soils through salt tolerant varieties of rice and matching management practices

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Description of the good practice

Management practices for rice production in salt-affected soils are different from those in normal soils. Experiments were conducted to test the hypothesis that combining matching management practices (Mmp) including the number of seedlings/hill, plant spacing, age of seedling and nitrogen levels with high yielding salt tolerant variety (Stv) would enhance productivity and profitability of rice in sodic soils. These practices were developed through on-station by optimizing existing best management practices (Bmp) recommended for the region to match the requirements of the variety.

Context of the practice

The study site was representative of large areas of abandoned sodic soils (pH of 9.4, EC 0.61 dS/m, OC 0.29 percent) in the Indo-Gangetic plains. The soil presents physical and nutritional constraints to plant growth due to poor soil water and soil air characteristics caused by high bulk density (>1.5 g /cm^3) and low infiltration rate (<2 mm/day). The climate of the experimental site is subtropical monsoon, with average annual rainfall of 817 mm. The average rainfall during cropping seasons was 940 mm, and average annual evapotranspiration was 1580 mm, which varies with air temperature.

The positive impact of the practice in addressing soil salinity / sodicity

The Mmp included using 4 seedlings per hill at 15 × 20 cm spacing and application of 150-60-40-25 kg N-P_2O_5-K_2O-$ZnSO_4.7H_2O$/ha. The Mmp resulted in 35 percent higher grain yield over Bmp. Ganga Kaveri, Moti and Narendra 359 rice varieties used to represent farmers' varieties (Fv), did not produce higher yields even with BMPs because of their relatively lower tolerance of salt stress. However, under the same management practices, yield of Stv 'CSR43' was 17 percent higher than the farmers' varieties.

Other benefits of the practice

Salt tolerant variety had on an average, a yield advantage of 0.62 t/ha over farmers' varieties across locations. However, combined effect of Stv with Mmp resulted in a 35 percent increase in grain yield over Bmp with farmer's varieties. Matching crop establishment and nitrogen rates, resulted in significantly higher yields and cost/benefit ratios. On-farm validation trials of these practices showed that the Mmp alone increased grain yield by 35 percent over existing Bmp being followed by the farmers.

Costs of the practice

Application of 175 kg N/ha resulted in the highest gross and net returns, while 150 kg N/ha resulted in the highest benefit to cost ratio (BCR), however, differences between 150 and 175 kg N treatments were not significant. The BCR recorded with 150 kg N/ha was 78 percent and 15 percent higher than control and 200 kg N/ha (Fig. 1). Above 150 kg/ha, the net additional gain became negative, indicating decreasing returns from additional N application. Hence, 150 kg N/ha was considered the economical optimum for Stv in these sodic soils. The polynomial 5th order equation effectively explained the net gain against corresponding nitrogen treatments (R2 = 0.994).

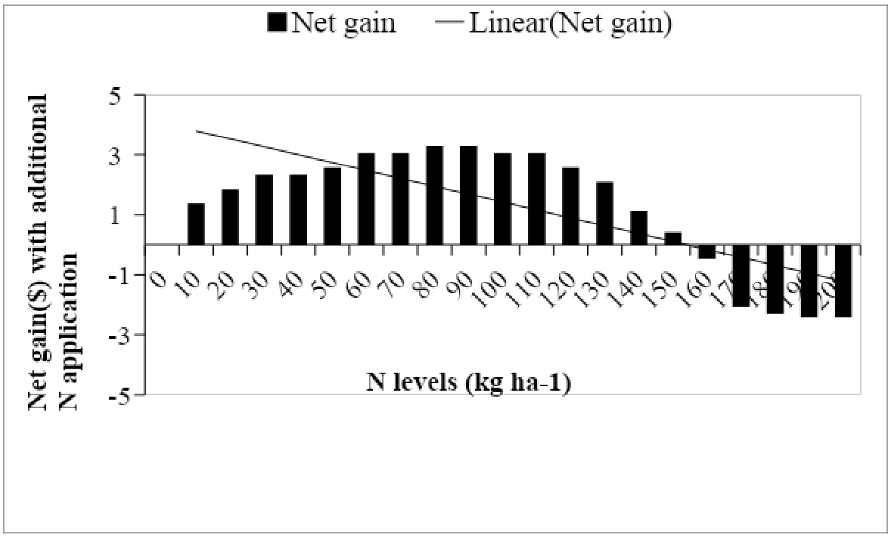

Figure 1. Analyses of the economic optimum amount of N for STv under sodic field conditions

Challenges for scaling up the practice

These cost-effective management options for sodic soils can further be refined to match other new tolerant varieties as they become available. The adoption of Mmp for harnessing productivity potential of salt-affected soils mainly depends on the availability of Stvs to the farmers and including these practices in the state government's agricultural development mission so that the benefits can be extended to larger salt-affected areas.

Acknowledgements

The authors acknowledge the support of the EC-IFAD for supporting the development the Mmps for Stvs and disseminating through the STRASA project funded by the BMGF. We are thankful to the Director of the ICAR-CSSRI, Karnal, Haryana, India for providing facilities to carry out these studies.

Seaweed cultivation to harness the productivity of poorly drained saline lands

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Keywords: Seaweed, saline groundwater, degraded lands, soil salinity, water table

Description of the good practice

Seaweed crops could make currently degraded lands productive again using saline groundwater as a resource. Where saline groundwater has the equivalent concentration of the minerals necessary for seaweed growth, it could be helpful in the cropping of seaweeds. The cultivation, harvest, drying, and baling of seaweed is as easy as making hay. All farmers who face the high-water table salinity problems can use seaweed as a crop to maintain the sustainability of production on otherwise degraded lands. Seaweeds are large, multicellular algae. They are eaten raw, cooked, or processed, and their products (e.g. agars, carrageenans, and alginates) are essential ingredients in many cosmetic and pharmaceutical products. Also, seaweed cultivation enables carbon sequestration, breeding grounds for fish and shellfish, pollution abatement, and animal feed and fertilizers (NAAS 2003). Seaweeds are effective in mitigating eutrophication. Rising global demand for seafood has increased the demand for seaweed cultivation (Neoria *et al.*, 2004). Seaweed harvests could mitigate the costs of engineering investments and costs for salinity restoration programs. Farmers who currently have salinity problems and need a crop to substitute for the loss of traditional crops on their salt-degraded land can use seaweed as their primary crop.

Context of the practice

Seaweed cultivation assists those farmers disadvantaged by saline groundwater and enables them to consider these waters as a resource for a crop cultivated in saline water.

The positive impact of the practice in addressing soil salinity/sodicity

Seaweed sales could, at the minimum, mitigate the costs of land rehabilitation and drainage basin operations. Seaweed production can make productive, profitable, and sustainable use of salt-degraded land that is currently unproductive. Seaweeds also work as a soil additive and function as both fertilizer and soil conditioner.

Other benefits of the practice

It could increase the economic sustainability of farms through the use of currently non-productive land. Seaweed will soak up excess nutrients from irrigation drainage water and help to remove saltwater from the environment, and it helps in carbon sequestration. Cows fed certain seaweed species belch 58 percent less methane (Mernit, 2018).

Costs of the practice

Gracilaria, a type of seaweed dried and exported in bales, can generate at least $500-1000 per tonne to processors for the production of agar gel, which has a growing international market as an additive in the food and biotechnical industries and takes more than 35,000 tonnes of dried *Gracilaria* per annum (Cordover, 2007).

Challenges for scaling up the practice

Future research and development are required to understand the major practices required for its cultivation.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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Large-scale barren saline-alkali land amelioration with flue gas desulfurization gypsum in Northeast China

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Keywords: FGD gypsum, large-scale application, sodic soils, saline-alkali wasteland, paddy rice field, Songnen Plain

Description of the good practice

This practice was conducted from March to October 2017 in Minle village, Chagan town, Da'an city, Jilin Province, China. The geographic coordinates of the site are between 123°22′ and 123°26′ east longitude and 45°27′ and 45°29′ north latitude. The total area covered by different types of land use is 1404.7 ha (Table 1). Before amelioration, saline-alkali land accounted for more than half of the total area, with wasteland occupying the second largest land area. After amelioration, only a few areas, such as low-lying fields that are difficult to drain, still suffer from salinization or alkalinization. In general, after implementation, more than 80 percent of the land is paddy rice fields with good irrigation and drainage systems and field roads.

This practice was funded by the Natural Resources Bureau of Da'an city, Tsinghua University provided technical guidance and Tsinghua Agriculture Co., Ltd. was responsible for the technical implementation. Because the land mainly suffered from alkalinization, it was ameliorated by applying flue gas desulfurization (FGD) gypsum. In this case, it not only used a large amount of this resource but also ameliorated large areas of saline-alkali land. Referring to this example of best practices may result in a substantial increase in cultivated land and have considerable importance in China and in similar ecological areas.

Table 1. Changes in the area of different land-use types before and after amelioration.

Land-use type	Before amelioration			After amelioration		Net change (ha)
	Area (ha)	Proportion of the total area (%)		Area (ha)	Proportion of the total area (%)	
Saline-alkali land	789.5	56.2		6.7	0.5	-782.8
Wasteland	382.2	27.2		17.2	1.2	-365.0
Paddy rice land	0	0		1137.0	80.9	1137.0
Dry land	203.2	14.5		99.2	7.1	-104.0
Canals and ditches	16.5	1.2		88.8	6.3	72.3
Roads	13.3	0.9		55.8	4.0	42.5
Total	1404.7	100		1404.7	100	0

Context of the practice

This practice was carried out on the southwestern Songnen Plain, China, which has one of the three largest sodic soil distributions in the world. The area is characterized by a semi-humid to semi-arid continental monsoon climate. The annual mean air temperature is 4.3 °C and the mean annual precipitation is 400–500 mm. The topsoil (0–20 cm) is a silty clay and the groundwater table is 0.8–1.8 m. The procedures for ameliorating saline-alkali land are summarized below.

i. The land was divided into several permanent parcels and was then ploughed to a depth of 25–30 cm. The topsoil was pulverized and then levelled using a laser-equipped drag scraper. Thereafter, the surface height differences in the horizon for each parcel were less than 5 cm.
ii. The required rate of FGD gypsum application was applied evenly to the soil surface. The topsoil was then tilled twice with a reverse-rotational rotary tiller to fully incorporate the FGD gypsum into the soil.
iii. The parcels were flood-irrigated to a depth of approximately 10 cm and were then puddled and well levelled. After the mud settled, the water with salts that remained on the soil surface was completely drained out of the parcels. Thereafter, paddy rice was transplanted following local agronomic standards.

The positive impact of the practice in addressing soil salinity / sodicity

Soil salinity and sodicity levels in topsoil decreased remarkably after amelioration with FGD gypsum (Figure 1). Compared to the corresponding initial levels, the mean values of electrical conductivity (EC), pH and exchangeable sodium percentage (ESP) decreased by 34.4 percent, 21.1 percent and 64.9 percent, respectively, in the first year after paddy rice harvest. In addition, the mean yield of paddy rice was 7.1 Mg/ha, which was approximately 80 percent of the levels of nearby farmers' land. Moreover, the landscape changed notably two months after amelioration (Figure 2). Five years after amelioration, there were no significant differences in salinity and sodicity between the ameliorated and nearby farmer's lands (Table 2). However, the EC values were significantly higher in the ameliorated land than in the nearby farmers' land. The increases in ECs can be attributed to the significant increase in the concentration of Ca^{2+}, which dissolved from FGD gypsum. In addition, the paddy rice yield increased gradually with increasing planting years due to the reductions in soil salinity and soil quality and increases in soil quality.

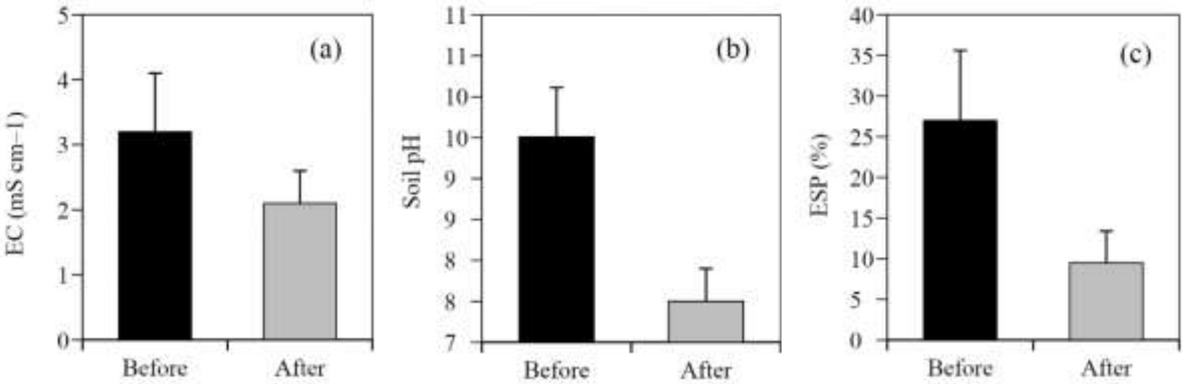

Figure 1. Electrical conductivity (EC), pH and exchangeable sodium percentage (ESP) in the 0–20 cm soil layer before (n=162) and after (n=114) amelioration in the first year

Table 2. Selected properties of topsoil in the ameliorated land after five years and nearby farmers' land

Sampling site	pH	EC (dS m^{-1})	ESP (%)	Soluble cations (mmol kg^{-1})			
				K^+	Na^+	Ca^{2+}	Mg^{2+}
Ameliorated land	7.9 a	0.5 a	8.9 a	0.2 a	6.5 a	0.9 a	0.3 a
Nearby farmers' land	7.8 a	0.2 b	7.1 a	0.2 a	6.7 a	0.5 b	0.3 a

Figure 2. Landscape changes before and after amelioration with flue gas desulfurization gypsum shown in satellite remote sensing images.

Other benefits of the practice

Other benefits of amelioration with FGD gypsum, in addition to the aforementioned positive effects on reducing soil salinity and sodicity, are highlighted below.

i. Increased grain production and capacity. The total yield of paddy rice in this practice was more than 8,073 tons per year. This suggests that the yielded grain can provide the annual rations of 41,252 people.
ii. Increased the income of local villagers and collectives. Each villager was allocated 1 ha of ameliorated land and the net return was ¥12,750 per year by planting paddy rice. The village committee rented the remaining 480 ha of paddy fields and received ¥17 million rent. The local county finance office received ¥840 million after 350 ha of ameliorated land was committed to the national arable land balance.
iii. Established a platform for the development of modern agriculture. The initial cultivated land was seriously fragmented, and it was difficult to carry out mechanized planting. Currently, the ameliorated land was suitable for the development of modern agriculture, including large-scale planting, standardized production and brand operation.
iv. Increased the quantity and quality of cultivated land. After amelioration, the paddy rice field area dramatically increased by 1137 ha. The increase in cultivated lands mainly comes from the transformation of saline-alkali land and wasteland as well as dry land with low soil quality.
v. Improved the regional environment. Before amelioration, most plants struggled to grow normally near the application site due to the toxicity of salt and alkali in the soil. After amelioration, the deserted patchy landscape has become a regular paddy field full of rice.

Costs of the practice

In this practice, the land was divided into five sodicity classes. Except for class I, the land was ameliorated with FGD gypsum, with the application rates increasing along with the sodicity classes. To ensure that the soil and FGD gypsum were fully mixed, rotary tillage was carried out twice in classes II–V. In addition, the puddling and drainage operations were carried out twice in classes III–V to leach out the dissolved salts in the soil after FGD gypsum application. Consequently, the mean costs increased as the sodicity class increased (Table 3). For the land with high sodicity (classes III–V), the costs associated with purchasing and applying FGD gypsum accounted for more than one-third of the total costs; in particular, these costs accounted for half or more of the total costs in the land with high ESPs (>15 percent).

Table 3. Amelioration costs of barren saline-alkali land into paddy rice field.

Land information and amelioration cost	Sodicity class					Total
	I	II	III	IV	V	
Initial soil property						
pH value	<8.5	<8.5	≥8.5	≥8.5	≥8.5	/
Exchangeable sodium percentage (%)	<10	≥10	≤15	15−30	≥30	/
Total area (ha)	105.0	509.2	297.1	135.3	90.4	1137.0
Application rate of FGD gypsum (Mg/ha)	0	3	7.5	15	30	/
Costs (¥/ha)						
FGD gypsum purchase	0	320,796	467,933	426,195	569,520	1,784,444
FGD gypsum application	0	458,280	297,100	148,830	108,480	1,012,690
Ploughing	47,250	229,140	133,695	60,885	40,680	511,650
Rotary tillage	42,000	407,360	237,680	108,240	72,320	867,600
Laser levelling	126,000	611,040	356,520	162,360	108,480	1,364,400
Puddling	63,000	305,520	356,520	162,360	108,480	995,880
Drainage	42,000	203,680	237,680	108,240	72,320	663,920
Others	27,825	134,938	78,732	35,855	23,956	301,305
Mean	3,315	5,245	7,290	8,965	12,215	/

Challenges for scaling up the practice

Presently, the Chinese government have issued the Program to Prevent Soil Pollution, which encouraged the amelioration of saline-alkali land with FGD gypsum. However, scaling up this approach remains a primary challenge.

i. Shortage of capital investment. It is difficult to recover all the costs in a short time if we rely only on the cultivation of crops after amelioration. Therefore, such projects require national or local government investment to ensure completion. Attracting enterprises to invest through preferential policies or other strategies may also help to solve this problem.
ii. The agricultural use of FGD gypsum has not been standardized. Given that FGD gypsum is a by-product from power plants, its potential hazard to soils and plants is a common concern worldwide. There is still debate regarding the use of FGD gypsum on agricultural lands. Thus, there is an urgent need to establish a standardized limit for the concentrations of harmful metals in FGD gypsum applied to agricultural lands.

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Biological improvement of saline-alkali land by planting two cultivated species of barnyard (*Echinochloa*)

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Keywords: saline-alkali land; biological amelioration; barnyard grass; Echinochloa fruntacea (Roxb.) link; Echinochloa crusgalli (L.) Beauv. Var. mitis (Pursh) Petermann

Description of the good practice

The conventional amelioration of saline-alkali land is engineering and chemical measures, establishing drainage systems or applying chemical modifiers in salinity affected land, which are costly or unsustainable. Planting salt tolerant forages in the medium and mild saline alkali lands which can decrease the soil salt content (so-called biological improvement of saline-alkali land), developing grass and livestock industry in saline alkali land, and producing high-quality livestock products realize the sustainable improvement and utilization of saline alkali land. Barnyard grass (*Echinochloa*) is a kind of herb with strong fecundity and wide ecological adaptability. It is widely distributed all over the world. Because it endangers the growth of many crops, barnyard grass was studied as a malignant weed in the past. However, many barnyard grass plants have high feeding value producing high-quality forages for the development of green livestock products. *Echinochloa fruntacea* (Roxb.) link and *Echinochloa crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann are high-quality gramineous forages with strong salt tolerance, which play an important role in the improvement of moderate and severe saline alkali land and the development of animal husbandry.

Echinochloa frumentacea (Roxb.) link, so-called Japanese millet has been selected and bred in Ningxia Hui Autonomous Region, China since the 1960s. Japanese millet (Picture. 1, left) has a stout stalk, 100–150 cm high and five-ten mm in diameter. The main shaft is thick and ribbed; spikelets ovate elliptic or elliptic, aweless. Chromosome 2n = 54. The flowering and fruiting period is from August to September. At maturity, the ears are yellowish green. *Echinochloa crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann is an annual barnyard grass of Gramineae, which has been domesticated from wild species for a long time. It (Picture 1, right) is lower than that of Japanese millet, with slightly thinner stems, loose arrangement of spikelets, gray brown ear color at maturity, early heading and flowering, and its growth period is about 1 month shorter than that of Japanese millet. In the 1980s, Japanese millet was introduced into the saline-alkali area in north of Ningxia. Since then, the two barnyard grasses have been grown together on the saline-alkali wasteland in northern area of Ningxia, playing an important ecological role. In practice, the sowing date of these barnyard grasses can be from the beginning of April to June with sowing rate being 37.5–45.0 kg/ha and the row spacing being 15–30 cm. After continuous planting for two–three years, the soil total water-soluble salt concentration can be decreased significantly and the crops with normal salt tolerance such as maize, wheat or alfalfa can be planted gaining reasonable yield. In the first two years, the stubbles are usually turned over into the soil in the autumn, and the hay can be harvested in the third year.

Figure 1. The difference in the characters of spike for the two barnyard grasses (Left : *Echinochloa fruntacea* (Roxb.) link; Right: *Echinochloa crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann) (Taken at August 2020 in Pinluo County, Ningxia, China)

The positive impact of the practice in addressing soil salinity / sodicity

The experiments conducted in 2019 and 2020 indicate that: one year after planting Japanes millet, the pH, total salt, alkalinity and bulk density of 0–20cm soil layer decreased by 0.75 percent, 21.02 percent, 6.55 percent and 3.80 percent respectively compared with bare land. Total nitrogen, alkali hydrolyzable nitrogen, alkaline phosphatase activity and soil urease activity increased in turn: 11.26 percent, 19.05 percent, 1.12 percent, 497.53 percent and 128.28 percent. The activities of alkaline phosphatase and soil urease were 22.96 percent and 6.13 percent higher than those of alfalfa. After two years of continuous cropping, the increased values of catalase activity and invertase activity in 0–20 cm and 20–40 cm soil layers of millet in Hunan Province were less than that of alfalfa, but higher than that of other forages.

Figure 2. The contrasted landscape at the emergence stage and the stage approaching maturation. The white colour in the left picture was the salt patch on the experimental land in spring while the barnyard forages grew well in summer on the same land (The photographs were taken at the same visual angle in March and June 2021 in Pingluo County, Ningxia, China)

Context of the practice

The climate of experimental site belongs to the semi-arid desert climate in the middle temperate zone, with sufficient annual light (2800–3200 h), 171 days of frost-free period, drought and little rain, large evaporation, annual average temperature of 9 ℃, annual average rainfall of 185 mm and annual average evaporation of 1825 mm. The soil is irrigated and silted soil with heavy soil viscosity. The improved mild saline alkali land is selected as the test site. The soil indexes are: total nitrogen 932 mg/kg, total phosphorus 0.076 percent, total potassium 1.73 percent, available potassium 88 mg/kg, Available phosphorus 12.0 mg/kg, Hydrolytic nitrogen 55.9 mg/kg, organic matter 17.2 g/kg, pH 8.65, total water-soluble salt 0.43 g/kg, alkalinity 7.50 percent.

Other benefits of the practice

The economic return by planting *E. fruntacea* and *E. crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann in is shown by Table 1.

Table 1. The income for planting *E. frumentacea*

Yield of hay（t/ha）	Unit-price of hay (CNY/t)	Income of hay(CNY/ha)	Yield of grain (kg/ha)	Unit price of grain (CNY/kg)		Total income (CNY/ha)
14.05	1000	14050	2395.8	5	11979	26029

The nutrients content in the stalks of the two cultivated species of barnyard grasses is shown in the Table 2, which indicates higher feeding value of the two species. The crude protein content in the stem of barnyard grasses is higher than or equal to those of paddy or wheat. The fiber content in the stem of the two barnyard grasses is higher than that of paddy or wheat. Therefore, the stalk of *E. fruntacea* and *E. crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann which is cut at heading stage can be used to feed animals.

Table 2. Comparison of nutrients in the stalks of *E. fruntacea* and *E. crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann harvested at the beginning of heading stage

Species	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Neutral detergent fibe (%)	Acid detergent fibe (%)	Acid detergent lignin (%)	Crude ash (%)	Calcium (%)	Energy (J/g)
E. fruntacea	9.44	1.48	34.6	68.1	39.0	14.7	10.0	0.63	15058
E. crusgalli (L.)	9.97	1.78	33.0	60.8	37.2	10.3	8.9	0.64	15832

As shown in the Table 3, grain of barnyard is also nutritious, its contents of crude protein and several amino acid are similar to or higher than those of sorghum and maize, which can be used as concentrated feed. The grain of barnyard is also edible with high value for nutrition and health care and can be used as the materials to ferment wine or alcohol.

Table 3. Comparison of nutrient components in the grains of barnyard grass, maize and sorghum (Yi & Peng, 1993)

Plant	Crude protein(%)	Lysine(%)	Methionine(%)	Histidine(%)	Arginine(%)
Barnyard grass	10.84	0.29	0.12	0.26	0.46
Maize	9.40	0.26	0.19	0.23	0.38
Sorghum	9.00	0.18	0.17	0.18	0.33

Costs of the practice

The cost of growing barnyard grasses includes seed, fertilizer, irrigation, herbicide, pesticide and so on with total investment around 16875 CNY (2615.6 USD) per hectare in Table 4.

Table 4. The investment for planting barnyard grasses

Seed(RMB/ha)	Fertilizer (CNY/ha)	Irrigation (CNY/ha)	Herbicide pesticide (CNY/ha)	Machine cultivation (CNY/ha)	Rent of land (R CNY/ha)	Total investment (CNY/ha)
225	3060	675	510	4155	8250	16875

Challenges for scaling up the practice

There are no risks on environment for planting barnyard grasses because they are nontoxic. To the contrary, the stems and grain of barnyard are nutritious and used for the feed of livestock or supplemental or healthy food for people. There is a little economic risk for planting barnyard grasses in the good quality land with higher rent. After all, the output value of hay and grain for barnyard grasses is relatively lower than that of such crops as maize, alfalfa, wheat or rice, etc. But the barnyard is usually used in the medium and severe saline-alkali lands where the crops such as maize, wheat or alfalfa cannot survive or poor yield is obtained. These lands with high total water-soluble salt concentration must be improved by planting barnyard grasses such as *E. fruntacea* and *E. crusgalli* (L.) Beauv. Var. mitis (Pursh) Petermann and then would be turned into the lands with higher productivity.

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