Food and Agriculture Organization of the United Nations

SYMPOSIUM WORKING DOCUMENTS

GLOBAL SYMPOSIUM ON SOIL EROSION

15-17 MAY 2019 - ROME, ITALY

GLOBAL SOIL PARTNERSHIP

itps INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

IAEA Joint FAO/IAEA Programme Nuclear Techniques in Food and Agriculture

UNCCD SPI Science - Policy Interface

GLOBAL SYMPOSIUM ON SOIL EROSION

Co-organized by

FAO
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GSP/ITPS
Global Soil Partnership
Intergovernmental Technical Panel on Soils

SPI/UNCCD
Science-Policy Interface of the United Nations Convention to Combat Desertification

Joint **FAO/IAEA** Programme of Nuclear Techniques in Food and Agriculture

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FAO Headquarters, Rome, Italy

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Summary

At its Sixth Session in June 2018, the Global Soil Partnership (GSP) Plenary Assembly (PA), upon request of its Intergovernmental Technical Panel on Soils (ITPS), voted to organize a Symposium on soil erosion "considering that this is the main threat affecting global soils". The Symposium aims to incentivize bottom-up global soil erosion assessments under the umbrella of the Food and Agriculture's (FAO) GSP.

The Global Symposium on Soil Erosion (GSER19) is organized around three key themes:

1. Soil erosion assessment tools and data: creation, consolidation and harmonization;
2. Best erosion management practices of the last 20 years and policy support to address human-induced erosion;
3. The economics of soil erosion

Although the three themes will be treated separately during the Symposium, they are inter-related.

Prior to the GSER19 and for each of the themes, working groups were set up with the objective of discussing the key topics to be tackled for each theme. The discussions held within each of the three working groups were then translated into working documents that are presented in this final document. The three theme working documents will eventually assist the GSP and its partners in planning upcoming actions to address soil erosion at the global, regional and local level. A revised version of this document will be included in the outcome c of the Symposium, which will be published after the event.

The working groups were composed of experts, members of the GSP's ITPS, and the Science-Policy Interface of the United Nations Convention to Combat Desertification (SPI-UNCCD), who participated on a voluntary basis.

Introduction

Soil erosion occurs naturally under all climatic conditions and on all continents. However, it is accelerated by human activities (up to 1 000 times) through intensive agriculture, deforestation and land uses that are not well matched to the land use capability.

The scientific community unanimously recognizes soil erosion as one of the most pressing environmental problems of our time because it decreases agricultural productivity, degrades ecosystem functions, amplifies hydrogeological risk and, in severe cases, leads to displacement of human populations. In the GSP's Voluntary Guidelines for Sustainable Soil Management (VGSSM)[1], soil erosion is formally recognized as the most significant threat to global soils and the ecosystem services they provide.

Adopting erosion-prevention, remediation and mitigation measures is directly linked to the achievement of many of the Sustainable Development Goals (SDGs). Indeed, as soil is a living ecosystem, from which over 95 percent of food is ultimately derived, avoiding the loss of fertile soil is fundamental to preserving soil fertility and producing healthy and nutritious food (necessary to achieve SDG 2 "Zero hunger" and SDG 3 "Good health and well-being"). Healthy soils also preserve water quality as the sediments produced by erosion pollute surface water with sediment and nutrients (SDG 3, SDG 14 "Life below water "and SDG 6 "Clean water and sanitation"). In addition, fighting soil erosion will help increase ecosystem resilience in a changing climate by avoiding soil carbon losses (SDG 13 "Climate Action") and by preserving life on Earth (SDG 15 "Life on land"). Implementing anti-erosive practices in the industry and production sectors will contribute to reach SDG 9 "Industry, innovation and infrastructure" and SDG 12 "Responsible production and consumption".

In 2015, the Voluntary Guidelines on Sustainable Soil Management (VGSSM) were endorsed by the FAO Council. The VGSSM provide guidance on the management needed to minimize soil erosion, e.g.:

- Land use changes such as **deforestation or improper grassland-to-cropland conversion** that cause removal of surface cover and loss of soil carbon should be **avoided or carefully planned and appropriately implemented if unavoidable**;
- A **cover of growing plants or other organic and non-organic residues** that protects the soil surface from erosion should be maintained through implementation of appropriate measures such as **mulching, minimum tillage, no-till by direct seeding** with attention to **reduced herbicide use, cover crops, agro-ecological approaches, controlled vehicle traffic, continuous plant cover and crop rotation, strip cropping, agroforestry, shelter belts, and appropriate stocking rates and grazing intensities**;
- Erosion by water on sloping and relatively steep lands should be minimized by measures that reduce runoff rates and velocity such as **strip cropping, contour planting, crop rotation, intercropping, agroforestry, cross slope barriers** (e.g. grass strips, contour bunds and stone lines), **terrace construction and maintenance, and grassed waterways or vegetated buffer strips**;Where appropriate, **riparian buffers, buffer strips, wetlands, water harvesting and cover crops** should be used/installed to minimize export of soil particles and associated nutrients and contaminants from the soil system and protect the downstream areas from damaging impacts; and,
- Erosion by wind, including **dust storms**, should be minimized and mitigated through **vegetative** (trees and shrubs) or **artificial** (stone walls) **wind breaks** to reduce wind velocity.

[1] FAO. 2017. Voluntary Guidelines for Sustainable Soil Management. 155th session of the FAO Council, Rome, Italy, 5th December 2016: 15. (also available at *http://www.fao.org/3/a-bl813e.pdf*).

Theme 1: Soil erosion assessment tools and data; creation, consolidation and harmonization

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Introduction to Theme 1

There has been much research carried out in recent decades to better understand the mechanics and spatial distribution of soil loss by water erosion, and to a lesser extent by wind and tillage erosion. The uneven distribution of studies and associated knowledge about these processes is evident by means of a simple keyword search in the International Scientific Indexing (ISI) database (*http://isiknowledge.com/*), which for the period 1990-2019 indicates 33 301 hits for the keyword 'water erosion', 7 169 hits for 'wind erosion' and 3 916 hits for 'tillage erosion'.

Although some significant progress has been made recently with regard to large-scale assessments of some water erosion processes (Van Oost *et al.*, 2007; Borrelli *et al.*, 2017), the lack of comprehensive information about global soil erosion dynamics forces both decision-makers and the scientific community to resort to pioneering studies carried out during the late 1980s and early 1990s such as the United Nations Environment Programme's (UNEP) project Global Assessment of Soil Degradation (GLASOD) (Oldeman, 1994).

The working group of theme 1 is composed of soil erosion experts, members of the ITPS and the International Network of Soil Information Institutions (INSII). After its creation, a discussion was initiated to explore opportunities regarding potential technical specifications for preparing a Global Soil Erosion Map (GSERmap).

Expected Theme 1 outcome

The specific outcome for theme 1 is to **propose a country driven process to produce the Global Soil Erosion Map (GSERmap) which will be** able to address (at least) the three major soil erosion processes (water, wind and tillage) following a multi-phased approach, with:

- **Phase 1**: Global scale products that are globally consistent, thus allowing for a comparison between geographic regions and for identifying hotspots
- **Phase 2**: National scale products that will follow a semi-standardized and uniform methodology allowing the incorporation of available national data
- **Phase 3**: National scale products based on field or on-screen visual interpretation of soil erosion signs achieved through monitoring programs

Challenges

In light of the experience gained during the preliminary working activity of the group and the present state-of-the-art concerning large-scale soil erosion assessments, this section presents the outcome of discussions and suggestions made by that group of erosion experts.

The participants of the working group of Theme 1 agreed that the task demanded by the GSP Plenary Assembly has a high degree of complexity. At the same time, they also recognized that a bottom-up approach to create a network and build local capacities to combat soil erosion, is the best way forward to generate new knowledge and incentives to combat soil erosion globally.

The output of the Global Symposium on Soil Erosion and mapping activities will constitute a tangible message that can lead to effective actions to support the implementation of the Voluntary Guidelines for Sustainable Soil Management (VGSSM) (FAO, 2017).

The development of global maps based on available national-scale information does not seem a viable option. Currently, only a limited number of countries have national-scale maps at their disposal, and most of those have used different approaches, input data and spatiotemporal resolutions. Accordingly, the global maps resulting from a collection of existing national information would not allow further regional and/ or global analysis and comparison between countries, regions or continents.

The working group of Theme 1 expressed a clear need to develop a methodology that allows for acknowledgement of different local expertise and data availability. In other words, the methodology should not be so simplistic to penalize countries that provide large data sets or detailed information on soil erosion, but also not so complex to exclude countries that cannot conform to the requirements.

The approach should also consider and eventually integrate existing information on soil erosion at national and/ or regional levels (e.g., monitoring networks, field observations and measurements).

The main limitation of a bottom-up approach would be the heterogeneity of the national datasets, which could lead to a country-specific and globally variable final product. Therefore, a multifactorial global soil erosion assessment using country-specific approaches to generate national soil erosion risk maps should be considered with caution, as this will result in methods-dependent results for developing geographical and transnational comparisons and for the identification of global high erosion risk areas, or 'hotspots.' The lack of harmonization could pose serious limitations to the use of the resulting global maps as a supporting tool for the SDGs (SDGs 2, 6, 13 and 15, among others).

Proposed methodology

Conceptual scheme

Understanding the importance of a harmonized initial product, the group proposes adopting a multi-phase mapping approach with a globally uniform method use for the first mapping level and nationally enriched data for the second and third levels. The idea behind this approach is to guarantee:

1. The development of products that are globally consistent, thus allowing for a comparison between geographic regions and for identifying hotspots useful to other GSP and UN global land degradation assessments/ mappings

2. National scale products that will follow a semi-standardized and uniform methodology will allow incorporation of available national data unique to each country or region. The aim of this map is to capture the intra-national variability in soil erosion rates and identify localized erosion hotspots. This, together with the acquisition of information on land use and management and policy and/ or activities of soil conservation, offers valuable information about the exposure of countries and regions to soil erosion

3. Additional national scale products based on field or on-screen visual interpretation of soil erosion signs and other spatial assessments, monitoring programs or measurements

4. A multi-phase approach fits well with the '*think globally, act locally*' adage. The aim of global products is to increase our understanding of the geography of soil erosion, combine the resulting global map with other global products (e.g., soil degradation, water resources, crop productivity), detect regions with lack of spatial information and define sets of best management practices in the different global regions. The semi-harmonized national maps (2nd phase) would primarily serve to respond to national and regional needs and actions. Furthermore, the comparison of the global harmonized approach with differing methods and tools of different countries, might lead to scientific progress and considerably knowledge gain on soil loss mapping and monitoring.

A multi-phase mapping approach

The development of a multi-phase approach to create new globally harmonized and semi-harmonized products at the national level is a viable solution. It could be organized as outlined below and graphically in Figure 1 and Figure 2.

First phase products: Development of global maps describing the potential land sensitivity to soil erosion by water, wind and tillage based on globally uniform datasets. These maps will explore the spatial pattern of potential soil erosion sensitivity globally, identifying possible hotspots and allowing comparisons among different geographical areas. For this map, only the natural driving forces will be considered (i.e., for water erosion: climate, soil properties and topography; for wind erosion: climate, soil properties and topography; for tillage erosion – topography). The most comprehensive globally readily-accessible datasets should be evaluated and used. Technology and data for this assessment already exists and will be made available by different research groups. The computational part will be facilitated using the Google Earth Engine.

Second phase products: National scale maps describing soil erosion risk to the best of the country's knowledge, available methods and input data. This can be done by combining the harmonized global soil erosion sensitivity maps with high detail national information on land use, land management practices, tillage operations (tillage intensity) and land use pressure indices derived by remote sensing data. The aim of this second level mapping activity is to enable the incorporation of national-scale information on the status of soil erosion within each country. The country-accessible information will allow for more refined spatial definition of the areas more vulnerable to erosion where the adoption of ad-hoc sustainable soil management would be more effective. National experts can develop second level products using the best information available at the national-scale. The GSP Secretariat and the Working Group of Theme 1 will provide a set of technical specifications in order to guarantee a certain minimum standardization for the national procedures. The adoption of land use maps associated with remote sensing techniques will enable the definition of the intensity and the timing of monthly/ seasonal plant developmental stages. Vegetation indices calculated in Google Earth Engine can provide further proxies of land use intensity and therefore erosion vulnerability. A combination of simple Geographic Information Systems (GIS) and remote sensing operations will allow spatial definition of the areas with elevated erosion vulnerability. The GSP Secretariat and the Working Group will assist national partners with technical documents and training.

Third phase products: While the first and second level products provide information useful for global- and national-scale analyses for eventually designing conservation practices, the third level product approach will generate new information on the occurrence of various soil erosion processes as well as innovative tools and methods. Temporary processes such as rill, inter-rill and shallow gully erosion are generally time dependent and their occurrence in cropland is highly dependent on crops being sown, time between tillage operations and rainfall events. Moreover, results of available soil erosion prediction models generally represent a fair proxy of their occurrence. By contrast, processes that are easily detectable but at the same time lead locally to large soil displacements and degradation (e.g., deep gullying, shallow landslides, piping and other forms of land degradation) are generally difficult to predict with existing models. Information about the occurrence of spatial susceptibility to gullying, shallow landslides and piping erosion are thus missing in large-scale assessments. The third level product could narrow this gap. A set of guidelines and technical specifications to monitor, identify and map the occurrence of visible soil erosion signs could be designed. These locations could be selected through a stratified random approach (defining an *n* observation point per *n* km^2). The sites can either be monitored through field observations or by using available aerial images (e.g., Google Earth and Bing imagery). Where countries already have such monitoring programs in operation, this information could be integrated. During this activity, validation of the acquired information could also be attempted (e.g., soil erosion occurrence, land use (change), detection of soil conservation activities). In addition, besides soil erosion processes and related features some further land information could be acquired from this monitoring activity, such as land use (change), farming activities, crop rotations, type of tillage, and the presence of evident soil conservation measures (e.g., conservation tillage, cover crops, mulching, contour cropping, grass buffer strips, grassed waterways, terraces).

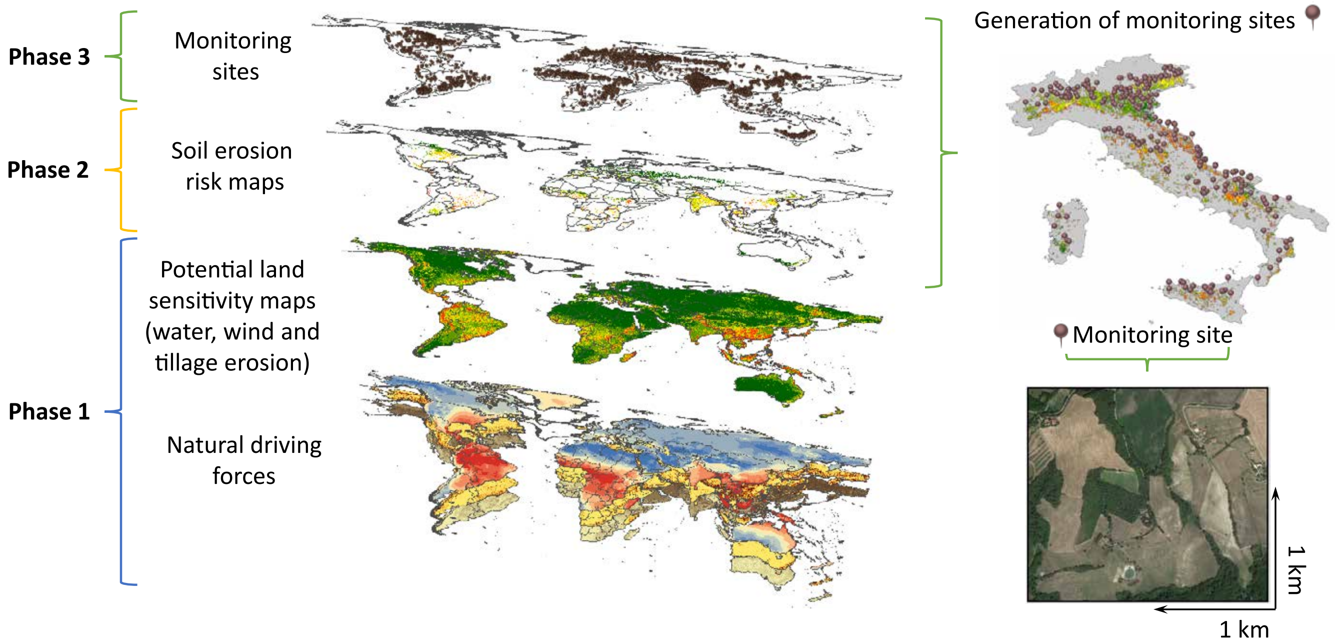

Figure 1. Synthetic representation of the multi-phase approach.

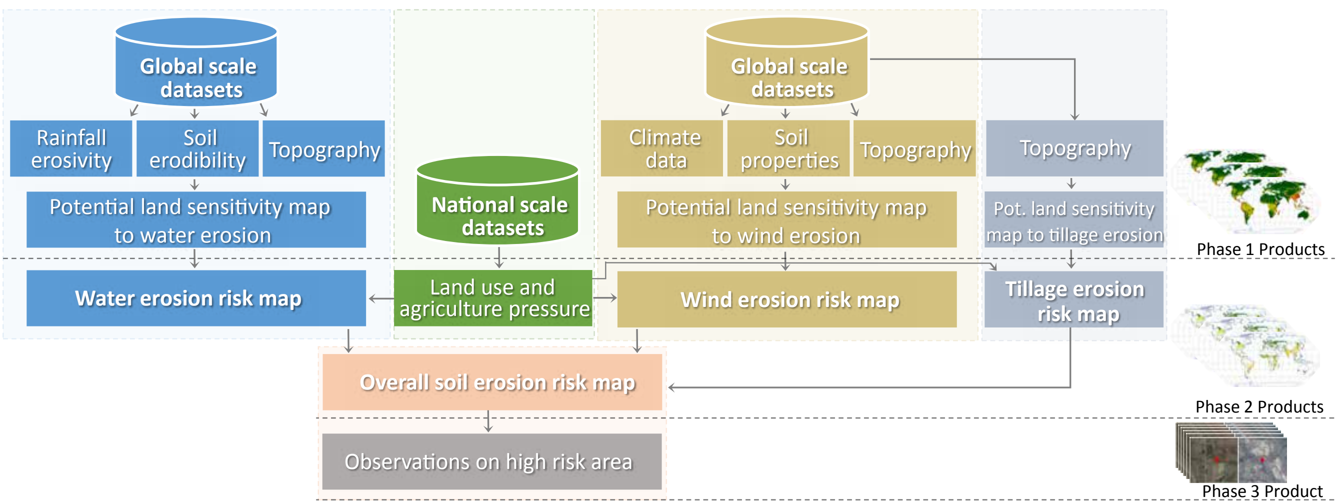

Figure 2. Synthetic workflow of the multi-phase approach.

Possible further assessments

Soil erosion includes a large set of complex geomorphic processes that often interact with each other. Although soil erosion by water, wind and tillage are the main causes of soil displacement, other natural or human-induced (subsurface erosion by piping and tunneling, among others) and fully anthropogenic (soil erosion due to crop harvesting (SLCH), land levelling, soil erosion by cattle trampling, among others) erosion processes exist. It's suggested to open a discussion with GSP actors and participants of GSER19 to identify further processes to consider, and to what extent, each of these processes can be incorporated in the GSERmap.

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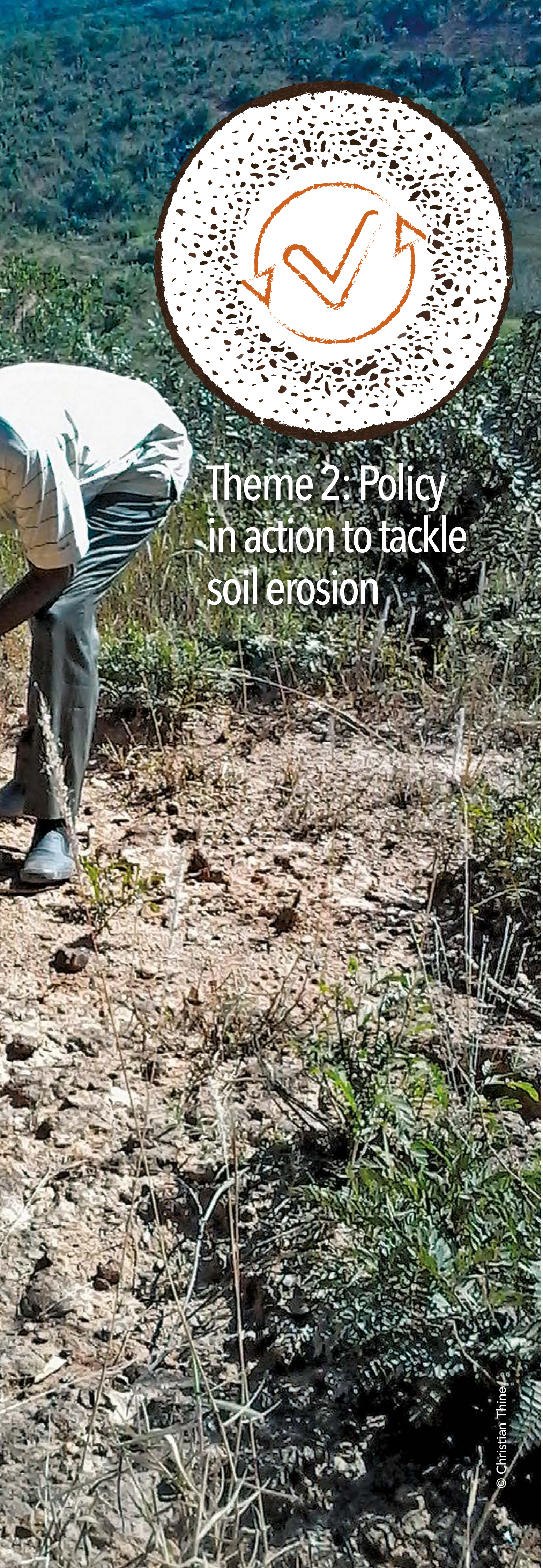

Introduction to Theme 2

This document was developed considering policy as the **principles (binding or not) adopted by governments or institutions that encourage, and possibly incentivize the prevention, minimization, remediation, or mitigation of human-induced soil erosion**.

At the international level, soil erosion is recognized as one of the biggest soil threats (FAO and ITPS, 2015). Likewise, soil erosion is addressed in the Voluntary Guidelines for Sustainable Soil Management (VGSSM) (FAO, 2017) and constitutes a sub-indicator to the SDG 2.4 (target 2.4.1, United Nations, 2015)[2]. At the national and regional levels, although policies exist to protect soils from erosion (e.g. in Brazil[3], the European Union[4], or Zambia[5]), these policies do not always prevent on-going accelerated human-induced soil erosion (FAO and ITPS, 2015; Montanarella *et al.*, 2016).

The GSP acknowledges the issue of soil-related policies and is establishing tools to improve access to the legal instruments and facilitate knowledge transfer across sectors involved. Leveraging the existence of the largest global database on legal instruments related to agriculture and natural resources management developed by FAOLEX[6], GSP is building SoiLEX, an online database that will present all existing legal instruments within FAOLEX directly related to soil grouped by relevant topics, including the soil threats. It is expected that the platform will be launched in mid-2019. Once online, SoiLEX will be a living participative tool that will allow external inputs from governmental bodies or institutions, and will serve as a tool for exchanging experiences between different countries around the world.

In order to foster the development and the implementation of legal instruments on soil erosion control, theme 2 intends to review the environmental policies focused on soil erosion prevention, remediation, or mitigation. During and after the GSER19, successful policies will be highlighted and integrated into a global framework for the development and implementation of effective soil erosion policies. Theme 2 will also outline policy gaps, lessons learned, and opportunities that policy development could give to the implementation of the VGSSM and the achievement of the SDGs.

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[2] Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

[3] Decree n° 9.414 of the 19 June 2018 on the Brazil's National Soils Program (Pronasolos)

[4] Common Agricultural Policy

[5] Environmental Management Act of 2011

[6] http://www.fao.org/faolex/en/

The theme will tackle the following core questions:

1. Which erosion control measures practices have proven to be effective?
2. Which policies are currently being implemented and used to enhance erosion prevention, remediation, or mitigation practices by land managers?
3. What are the current policy gaps, challenges and opportunities for the effective implementation of erosion prevention, remediation, or mitigation?
4. Where a lack of legislation is identified, which policies could be introduced to effectively implement soil erosion prevention, remediation, or mitigation measures?
5. What are the most useful means of converting erosion prevention, remediation, or mitigation policy into practical action?

Expected Theme 2 outcome

- Establishment of an action plan to support the formulation, implementation, and monitoring of soil erosion control policies
- Build a database on the best erosion control practices implemented according to regional contexts
- Provide SoiLEX with a collection of analyzed effective policies to control soil erosion
- Analyze major gaps on the development and implementation of soil erosion control policies at global, regional and national levels.

Actions to achieve the outcomes

GSER19 participants interested in Theme 2 will be given the opportunity to propose actions to achieve the expected outcomes. To facilitate the discussion, the following actions are proposed:

1) Database on the best erosion control practices

Discussion of case studies will provide an overview of the best practices used to control soil erosion. Data obtained will contribute to the creation of a database on the best practices for soil erosion control at the regional and local level, within the soil-climate context. Discussions should focus on finding the best indicators that can be used for scaling-up practices.

A technical group with experience in soil erosion will be established to identify the best available practices to control or minimize soil erosion, taking into account national and local characteristics. Information should be based on existing data (e.g. WOCAT). Practices should consider the social, economic and environmental impacts of soil erosion control.

2) Collection and evaluation of effective policies to control soil erosion

Policy instruments used to halt or control soil erosion will be discussed during the Symposium through the presentation of the case studies. Discussions will also raise the point of local socio-cultural issues that cannot be ignored in the implementation of soil erosion control policies (e.g. role of women, indigenous practices).

Policies may be related to education (e.g. farmers, land or forest managers, farm advisors, private land and forest owners), measures (e.g. subsidies, technical advice, access to equipment and materials, market product certification, the imposition of rules or requirements on land managers), compensation of farmers, foresters, and other private landowners for broader public good of erosion prevention, down-stream (including trans-national) effects of soil erosion, development of advisory services, development of sustainable land use planning systems at national and local levels, rules and enforcement (i.e. command and control), and any other related policies that are identified in the course of the research.

A dedicated working group will be set to continue the work at the regional level after the Symposium and to participate in adding data to SoiLEX.

3) Analysis of major gaps on the development and implementation of soil erosion control policies at global, regional and national levels.

Discussions during the Symposium will give an overview of gaps in efficient erosion control under varying conditions. A scientific document (paper, book, etc.) will be published containing an analysis of the status and gaps of policy development and implementation based on the Symposium's discussion, SoiLEX data, and inputs from experts.

In conclusion, a plan of action will be developed and presented at the 14th Meeting of the Conference of the Parties to the UN Convention to Combat Desertification (UNCCD COP 14, India, 7-18 October 2019). In addition to the actions herewith presented, the Plan of Action will build on the analysis of the case studies presented under Theme 2 and rely on countries' inputs. In this regard, the following steps are proposed:

1. Development and launch of a global questionnaire to assess legal instruments and management practices in countries. The data will enable identification of the needs and best actions to implement, based on national contexts.

2. Compilation of results and analysis of the regional situation.

3. Development of policy briefs, or any other relevant identified document, to raise awareness of the legal instruments and practices needed for each identified context or region,

4. Implementation of awareness-raising activities through training, workshops, and educational material, in collaboration with Regional Soil Partnerships (RSPs)

5. Development of legal instruments and application of adapted practices.

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Theme 3: The economics of soil erosion prevention, management and remediation

Introduction to Theme 3

Soil is a natural capital that provides a range of ecosystem services (Adhikari and Hartemink, 2016). The control of soil erosion directly affects the provision of agricultural and environmental benefits. Development of mitigation strategies to decrease soil erosion could avoid social costs and could increase the overall ability to provide agricultural soil services. Despite an increasing body of literature and evidence of the multi-faceted benefits of sustainable land/soil management, soil degradation still continues on a large scale (Montanarella *et al.*, 2016).

According to the Ecosystem Services Partnership[7], *"an important reason is that money spent on nature conservation, landscape restoration, and sustainable land management is still seen as a cost and not as an investment with a high return in benefits: ecological, social and economic"*. The characterization and quantification of the costs of soil erosion, and the costs and benefits of soil erosion prevention practices is therefore important to inform policy makers and to foster investments in anti-erosion projects. In this regard, policy and investment actions are tightly connected (reference is made to GSER19 Theme 2).

The GSP initiated a study on the economic impacts of Sustainable Soil Management (SSM), for which a concept note will be presented during the Seventh GSP Plenary Assembly (5-7 June 2019, FAO Headquarters, Rome). Theme 3, the economics of erosion prevention, management and remediation, links to investment and, more specifically, it aims to show which SSM practices give returns and which others do not, and why. The core questions to be tackled are the following:

1. What are the associated costs of soil erosion for agriculture, based on the cost of one ton of soil loss?
2. What are the direct costs associated with loss of soil (either qualitative of quantitative) for the supply of agricultural services and the indirect costs to the environment and human infrastructures?
3. Are the costs of implementing soil erosion control practices offset by current and future benefits of more, or more profitable, production?
4. What technologies, innovations or approaches exist to decrease the costs of implementing soil erosion control practices compared to that of conventional soil management?

Expected Theme 3 outcome

The expected specific outcome for Theme 3 is to **propose a cost-benefit analysis** of erosion and erosion prevention, remediation, and mitigation practices, following a 'tiered approach', with**:**

- **Tier 1**: Guidance for evaluating costs of erosion and economic assessment of soil erosion management practices as a flowchart;
- **Tier 2**: Erosion-specific template providing an on-line (and off-line) tool and guidance for people to calculate the cost-benefit of erosion management activities in their specific situation.

The methodology discussed during GSER will contribute to define the overall methodology of the economics of SSM, which still needs to be defined.

Proposed methodology

Handling cost-benefit analysis of soil conservation measures is a major challenge. Indeed, in the literature very variable values can be found, depending on the characteristics of the case studies, on the general approach used, on whether on-site or off-site impacts are assessed, and on the scale of the assessment. Estimates of the costs of soil erosion are highly dependent on the methodologies and assumptions made in the valuation (Adhikari and Nadella, 2011). Estimating the marginal benefits and costs of such changes would assist investment decision making. Theme 3 work will lead to a preliminary cost-benefit analysis of soil erosion management practices at a global level. The outcome will be reached following a two-step methodology:

1) Development of a flowchart and explanatory document

The document produced will consist of a flowchart and an explanatory document which could be seen as a "Tier 1 option", a non-quantified (or roughly quantified, using estimates) way of identifying possible alternatives. A draft of the flowchart is presented in Annex 1 of this document. It will be completed and improved during the Symposium. The explanatory document will aim to provide guidance on using the flowchart, explaining specific terms and giving more details or examples when needed. A draft of this explanation is proposed on Annex 2 of this document. The version presented at the beginning of the Symposium will be a draft to be improved during, and finalized after the event.

[7] *https://www.es-partnership.org/*

2) Erosion-specific template providing an on-line (and off-line) tool and guidance for people to calculate the cost-benefit of erosion management activities in their specific situation

This tool will be set-up based on case studies and will include guidance for evaluating the costs of erosion. The tool will contain more precise calculations than the previous flowchart. It would be a "Tier 2 option" when information is available at local scale. Some case examples of application of such a tool could be provided in a range of different situations, environments and practices.

A database compiling all available case studies following the flowchart should be compiled, referencing all the possible information available. Then, all the required information should be assembled, and the process automated in order to provide the cost-benefit analysis at a specific position.

Further discussions will have to focus on:

- The final shape of the tool (website, app, included on maps, etc.)
- The inclusion of the previous flowchart in the tool definition (how to translate the flowchart into a quantitative and local assessment, role of models, IT, etc.)
- Choice of indicators
- Further gaps to be identified

For Tier 2 outcome, the Symposium can be seen as a first step to start gathering case studies, referencing the relevant indicators and getting suggestions from participants on (i) the needs for such a tool and (ii) the resources needed.

Gaps and challenges

1) Choice of relevant indicators for Tier 1 and Tier 2 and valuation method to be used for each selected indicator

Most quantification and valuation models that tend to focus on a single resource or commodity are site-specific. This leads to a large variety of numbers, values, and claims in both the scientific and grey literature, depending on the metrics, models and approach used, and the scale or scope of the study (Adhikari and Nadella, 2011). The resulting cost/benefit estimates can be highly subjective and uncertain. Against this backdrop, it is essential to identify and use robust and reliable metrics, indicators and models that can capture the full range of performance and impact effects generated by soil erosion at farm, landscape or broader scale. For example, to this end, a comprehensive, an integrated assessment approach was presented at the Global Landscapes Forum (GLF) in December 2018 (GLF Bonn, 2018). This approach, developed by a coalition of partners called Integrated Ecosystem Assessment & Rating System, harvests data and indicators from multiple authoritative sources, and generates composite indices that are used to assess performance and impact across all sustainability dimensions. The system aims to guide the governance of ecosystems, their conservation, resilience to climate change, restoration and sustainable use, while optimizing values across all four dimensions of ecosystem services, as well as biodiversity. This approach could serve as a base to define the right indicators to be used to set up the cost-benefit analysis of soil erosion.

2) Time-frame of the cost-benefit assessment

The question of the time-frame must be asked and defined clearly before starting this type of analysis. The 'right' time scale for the assessment depends not only on the severity of the issue addressed and the project scale/scope, but also on which perspective is used, e.g. policymakers, investors, farmers, landowners, supply/value chain partners (Hastings, 2016). For the farmer the on-site effects of erosion are more important and shorter periods (three to five years) are more appropriate to evaluate the efficiency of the conservation measures, whilst longer periods (ten, 20, 50 years or even longer) are normally considered when evaluating the off-site effects of erosion control.

3) Role of policies and socio-economic factors in the economic assessment?

There is a huge variability between countries according to national wealth, and national philosophy of state-control vs non-interference from government. Specific circumstances – including laws, voluntary incentives, subsidies, penalties, etc., could be listed in the flow chart options.

To address this issue, the Ecosystem Services Partnership is currently working on the development of guidelines to assess, quantify and verify a series of returns on investment, comprising both financial and non-financial (e.g. environmental, socio-economic) returns (de Groot *et al.*, 2018). These guidelines could be taken into consideration in the development of Tier 2 decision-support tool.

4) Scope of analysis

The assessment is currently very agriculture-oriented. The possible addition of industry or urban erosion should be discussed.

5) Should examples of payment/compensation to farmers be added to the study?

For example, the EU Common Agricultural Policy (CAP) subsidizes EU farmers through rural development programmes which address sustainable land management. However, alternative approaches are not equally effective, efficient or affordable. Economic analysis could inform compensation design.

6) Taking into account interactions between different types of erosion

The actions to control one type of erosion may positively or negatively increase the others. This has implications for the cost-benefit analysis of soil erosion control practices.

Glossary[8]

Cost benefit analysis: Definition

Cost-benefit analysis is an important technique to systematically compare the streams of costs and benefits in order to determine the economic efficiency of a project or project worth. There are basically three measures using the same input data and assumption, as follows:

1. **Net present value or net present worth** (NPV or NPW): this measure is used to determine the difference between the present value of the stream of benefits and the present value of all the costs. A project (or certain component of a project) may only be accepted if this difference is zero or positive ($B - C \geq 0$).

2. **Benefit and cost ratio** (B/C ratio): Used to determine a ratio using present value of all the benefits in the numerator and the present value of the costs in the denominator. A project is considered to be economically sound or acceptable when the calculated value is larger than or at least equal to 1 ($B/C > 1$).

3. **Internal rate of return** (IRR): this is the discount rate, which, when applied to the stream of benefits and costs, produces an equal present value of both or a net present value of zero (A discount rate when $B = C$, or $B - C = 0$). This particular rate is called IRR and represents the average earning power of the project's investment to be compared with other investments.

Each measure has its pros and cons. NPV shows the magnitude of the net benefit of a project but indicates nothing about returns per unit. B/C ratio and IRR give no indication of the magnitude of net benefit. Since they use the same set of data, economists may use all three measures to obtain a complete picture.

[8] Terms and definitions taken from FAO, (1990) and OECD, (2008)

Cost and benefits: Economic methods of valuation

a) Based on reveal preferences

Contingent valuation: Method of valuation used in cost-benefit analysis and environmental accounting. It is conditional (contingent) on the construction of hypothetical markets, reflected in expressions of the willingness to pay for potential environmental benefits or for the avoidance of their loss.

b) Methods based on stated preferences

Set of pricing methods where people are asked how much they would agree to pay to avoid a degradation of the environment or, alternatively, how much they would ask as a compensation for the degradation. Alternatively, people can be asked to make tradeoffs among different alternatives, from which their willingness to pay can be estimated. The methods are referred to as stated preference methods, because they ask people to directly state their values, rather than inferring values from actual choices, as the revealed preference methods do. There are of three types: Production approach, shadow value and travel costs method.

Other definitions

Costs: Value in alternative uses of the factors of production used by a firm (labour costs, materials costs, capital costs). Costs may be fixed or variable.

- **Total costs** refer to the sum of fixed and variable costs.
- **Average costs** refer to total costs divided by output.
- **Marginal cost** is the increment to total cost that results from producing an additional unit of output. Marginal cost is a function of variable costs alone, since fixed costs do not vary with increases in output. Marginal cost has a particular importance in economic theory.

Opportunity cost: Commonly used in economics; it is measured by reference to the opportunities foregone at the time an asset or resource is used, as distinct from the costs incurred at some time in the past to acquire the asset, or the payments which could be realized by an alternative use of a resource (e.g. the use of labour in a voluntary capacity being valued at the wages which could have been earned in a paid job).

State indicator: A state indicator in the context of environmental indicators for agriculture is an indicator that expresses an actual resource condition, usually based on direct field measurement.

Valuation of the degradation of land and soil: The present value of the future rent on land that is foregone due to the degradation attributed to the period.

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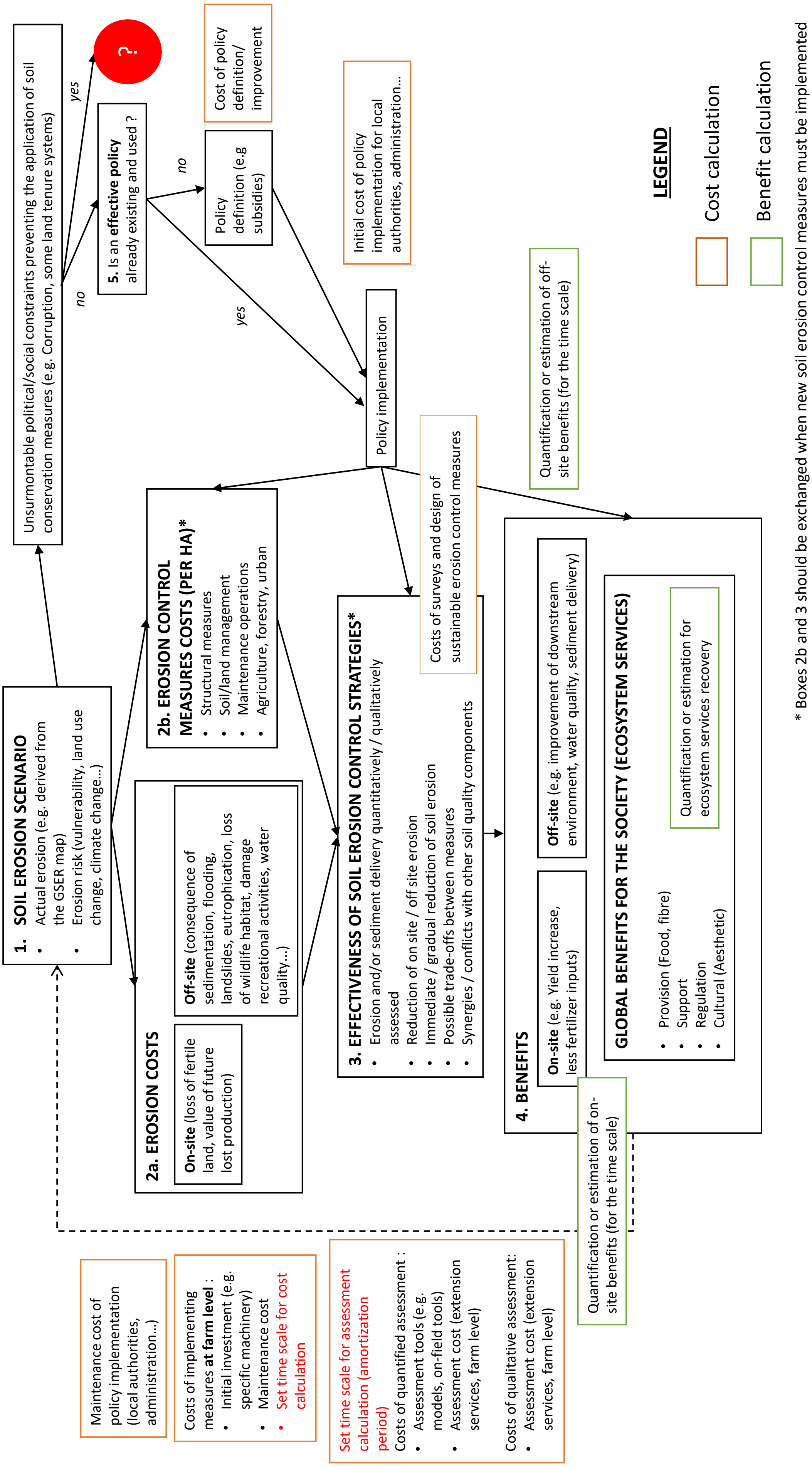
Annex 1: Draft of the flowchart



Annex 2: Draft of the explanatory document

The flowchart is an attempt to propose **a global cost-benefit analysis of soil erosion conservation measures**, either for actual erosion or for risks of future erosion under a number of assumptions. This document is structured according to the flowchart, raises gaps and further explains the methodology to be used to quantify the elements described in the flowchart. This document will need to be improved, and its development should support the definition of a clear methodology/ guideline that will eventually support the creation of the Tier 2 tool.

1. Vulnerability to soil erosion

The determination of the degrees, types and causes of **actual soil erosion** is a key question to make a correct diagnosis of the erosion problem, in order to solve / mitigate and to choose the appropriate soil conservation measures. The way to solve this question depends primarily on the scale: for large continental or regional surveys a useful tool is the Global Soil Erosion Map (output to Theme 1), which will give information on the level of exposure to soil erosion. At more detailed scales (as those used in Tier 2 assessments) specific sources such as local surveys, remote sensing and aerial photographs, field work, ad-hoc measurements and environmental analyses will be the base of the erosion diagnosis and the selection of sustainable erosion control strategies.

In the case of **vulnerability to soil erosion** under given future scenarios (e.g. after land use or soil management changes) a very detailed description, including the socio-economic environment will be needed.

Associated question:

Positioning climate change: erosion and the benefits from erosion control are likely to be impacted by climate change. There is room for economic analysis to more appropriately consider the interaction between climate change and soil erosion control.

2. Costs of soil erosion

On-site costs directly affect farming land. These are costs paid directly by farmers, through the loss of fertile land. The on-site costs include losses in production, yields, nutrients, damage to plantations and reduction of the available planting areas (Telles *et al.*, 2011). Different methods of accounting were proposed and were reviewed by Panagos *et al.*, (2018) erosion :

1. Cost-benefit analysis: cost of erosion control measures
2. Market price of soil: commercial price of soil
3. Crop productivity loss: decreased crop production due to soil erosion
4. Replacement cost: cost of fertilizers (N and P) to replace nutrient loss due to soil erosion
5. Macroeconomic models: estimate the cost represented by soil erosion loss (only in the agricultural sector)

Soil erosion generates **off-site costs** that are generally paid by the society and incurred away from the farm. They include the siltation in reservoirs, sediment impacts on fisheries, poorer water quality for irrigation or other uses (i.e. water eutrophication) downstream, loss of wildlife habitat and biodiversity, increased risk of flooding, damage of recreational activities, land abandonment and destruction of infrastructure such as roads, railways or other public assets (Telles *et al.*, 2011).

Although existing studies at national/regional level could be used to build the Tier 2 model, at global level, the methodology to estimate the cost of soil erosion needs to be defined.

3. Measures taken to face soil erosion

There is evidence that yields and other ecosystem functions and services increase with Sustainable Soil Management (SSM) in specific contexts and conditions. Generic best practices are already presented in the Voluntary Guidelines for Sustainable Management (FAO, 2017).

Some soil erosion control techniques may increase costs, practices such as terracing for example, or decrease yields, by using less intensive grazing practices. Some practices that prevent erosion may have also hidden, and uncertain, environmental costs, for example using herbicides in no-till cropping. Some erosion-prevention measures may have social impacts, for example removing vulnerable land from production.

Besides the costs of the assessment of the choice of the measures themselves, from the economical assessment point of view the following main distinctions may be done regarding the type of measures:

- Structural measures (e.g. terraces, waterways, detention ponds, check dams on gullies, windbreaks, plot layout) require initial investments and a periodical maintenance afterwards to ensure their efficiency.
- Land management and/or maintenance operations (e.g. cover crops, conservation tillage, organic amendments, conversion of arable land into forest/pasture) are

integrated in the current land management systems. Their costs have to be included in the yearly business accountancy.

- In the construction sector/cities: silt trapping, tree-planting, stabilizing the entrance of sites, bioengineering solutions, among others. They also involve both initial and maintenance costs.

Also, according to Kuhlman *et al*., (2010), each anti-erosion measure contains a number of different techniques or practices. The costs and benefits of each practice cannot simply be added up to the total impact of the measure as a whole. Kuhlman *et al*. (2010) proposed a framework to assess measures' costs for the European Union by:

1. Estimating the cost of one practice per hectare per year based on the value of the subsidies that farmers receive. Indeed, effective subsidies should compensate the difference between the cost and the benefit earned by the implementation of one given practice;
2. Aggregating the value of each practice into the measure as a whole, by weighting the cost of a practice to reflect its importance in erosion-control.

This methodology could be used when countries have sound policies based on subsidies, but how to assess the costs when we have no reference point to base our assessments on (when no subsidies are given)?

4. Assessment of the efficiency of soil erosion control measures

This step is necessary in order to ensure that the proposed measures sufficiently contribute to reduce erosion to acceptable levels. While some models exist to evaluate some types of erosion under different alternatives (e.g. RUSLE), most of the erosion processes do not count on a tool for a precise estimation of the erosion reduction, and for many of them only some broad estimations can be made. Another crucial aspect that is often overlooked is non-linear dynamics in ecosystem degradation (e.g. due to soil erosion) and restoration (Sietz *et al*., 2017).

Relevant aspects to take into account are:

- The erosion control practices should not adversely affect other soil quality components in the mid and long term
- Time scale: corresponds to the amortization period chosen to evaluate the profitability of the measures
- Soil erosion on site / sediment delivery off site: some measures have a direct effect on reducing erosion (soil removal) on site (e.g. cover crops), while others controlling concentrated runoff (e.g. check dams) act only reducing sediment concentration in runoff waters.
- Immediate reduction / gradual reduction of soil erosion: soil conservation practices have direct and fast response of erosion reduction (e.g. contour vs. non contour ploughing), while it is more gradual in others (e.g. organic amendments).

5. Benefits of soil erosion control measures

Erosion measures (tackling all types of erosion – wind, water and tillage) and the value of reduced erosion vary with biophysical factors (e.g. soil type, slope and climate) and with socio-economic factors (e.g. land use, education, population density), and benefits must be separated between on-site (at farm level) and off-site benefits.

Assessment of on-site and off-site benefits

According to Kuhlman *et al*., (2010) assessing the on-site benefits of conservation measures is similar to assessing the cost of erosion to the land user. Although there is no generally accepted model to estimate the benefits from erosion control measures on soil erosion rates, on-site benefits can be assessed based on the technical effects that erosion has (e.g. rooting depth, water retention capacity, nutrient loss).

To assess off-site benefits, Kuhlman *et al*., (2010) proposed to use the Sediment Delivery Ratio, e.g. the amount of erosion material that ends up in rivers, lakes, dams and settlements, expressed as a proportion of total erosion.

Assessment of ecosystem services

When the benefits at farm level are assessed and proven, it would be useful to provide a quantification of the ecosystem services provided to people, e.g. How much more food is produced? What are the socio-economic benefits ? Other items included in the 'assessment' and 'benefits at farm levels' could be expanded to also include other aspects linked to soil erosion that influence productivity and ecosystem/human wellbeing (e.g. nutrient cycling, C sequestration, pollination, biodiversity, habitats, recreational values, etc.). Indeed, this implies looking at both on-site and off-site cost/benefit effects, as rightly mentioned in the flowchart, but also at interdependencies, synergies and trade-offs (Vallet *et al*., 2018). For example, the cultural terraced landscapes of many Mediterranean areas are considered to be aesthetically attractive as well as providing increased productivity on hill lands with a lower risk of soil erosion. In these cases, agricultural landscapes provide intangible services, which may be evaluated: may be evaluated (UNESCO, 2018).

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