SUMMARY REPORT

THE STATE OF THE WORLD S LAND AND WATER RESOURCES FOR FOOD AND AGRICULTURE

Managing systems at risk

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2011

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PREFACE

FEEDING A GROWING POPULATION

Land and water resources and the way they are used are central to the challenge of improving food security across the world. Demographic pressures, climate change, and the increased competition for land and water are likely to increase vulnerability to food insecurity, particularly in Africa and Asia. The challenge of providing sufficient food for everyone worldwide has never been greater.

The world's population continues to rise. Today's population of around 7 billion is expected to increase to about 9 billion by 2050. By this time, another one billion tonnes of cereals and 200 million extra tonnes of livestock products will need to be produced every year. The imperative for such agricultural growth is strongest in developing countries, where the challenge is not just to produce food but to ensure that families have access that will bring them food security.

Today almost 1 billion people are undernourished, particularly in Sub-Saharan Africa (239 million) and Asia (578 million). In developing countries, even if agricultural production doubles by 2050, one person in twenty still risks being undernourished – equivalent to 370 million hungry people, most of whom will again be in Africa and Asia. Such growth would imply agriculture remaining an engine of growth, vital to economic development, environmental services and central to rural poverty reduction.

For nutrition to improve and for food insecurity and undernourishment to recede, future agricultural production will have to rise faster than population growth. This will have to occur largely on existing agricultural land. Improvements will thus have to come from sustainable intensification that makes effective use of land and water resources as well as not causing them harm.

The policies, practices and technologies needed to boost production and strengthen food security have long been discussed. Institutional mechanisms, the development of trade and markets and the financial facilities needed to raise productivity in a sustainable way have been negotiated at the international level. At national level, measures to raise output and strengthen food security are being put in place, including investment in pro-poor, market-friendly policies, institutions and incentives, as well as the infrastructure and services needed to improve productivity. Yet the challenge still remains.

INCREASED COMPETITION FOR LAND AND WATER

And there are warning signs. Rates of growth in agricultural production have been slowing, and are only half the 3 percent annual rate of growth seen in developing countries in the past. In 2007 and 2008, any complacency was jolted by food price shocks, as grain prices soared. Since then, the growing competition for land and water are now thrown into stark relief as sovereign and commercial investors begin to acquire tracts of farmland in developing countries. Production of feedstock for biofuels competes with food production on significant areas of prime cultivated land. A series of high profile floods, droughts and landslides further threaten the stability of land and water resources.

Deeper structural problems have also become apparent in the natural resource base. Water scarcity is growing. Salinization and pollution of water courses and bodies, and degradation of water-related ecosystems are rising. In many large rivers, only 5 percent of former water volumes remain in-stream, and some rivers such as the Huang He no longer reach the sea year-round. Large lakes and inland seas have shrunk, and half the wetlands of Europe and North America no longer exist. Runoff from eroding soils is filling reservoirs, reducing hydropower and water supply. Groundwater is being pumped intensively and aquifers are becoming increasingly polluted and salinized in some coastal areas. Large parts of all continents are experiencing high rates of ecosystem impairment, particularly reduced soil quality, biodiversity loss, and harm to amenity and cultural heritage values.

Agriculture is now a major contributor to greenhouse gases, accounting for 13.5 percent of global greenhouse gas emissions. At the same time, climate change brings an increase in risk and unpredictability for farmers – from warming and related aridity, from shifts in rainfall patterns, and from the growing incidence of extreme weather events. Poor farmers in low income countries are the most vulnerable and the least able to adapt to these changes.

The steady increase in inland aquaculture also contributes to the competition for land and water resources: the average annual per capita supply of food fish from aquaculture for human consumption has increased at an average rate of 6.6 percent per year between 1970 and 2008, leading to increase demand in feed, water and land for the construction of fish ponds.

The deteriorating trends in the capacities of ecosystems to provide vital goods and services are already affecting the production potential of important food-producing zones. If these continue, impacts on food security will be greatest in developing countries, where both water and soil nutrients are least abundant. Yet in some locations, better technology, management practices and policies (which take into consideration the need for appropriate tradeoffs between environmental needs and agricultural production) have arrested and reversed negative trends and thus indicate pathways towards models of sustainable intensification. The risks, however, are considerable. On present trends, a series of major land and water systems and the food outputs they produce are at risk.

SCOPE AND CONTENT OF THE FULL SOLAW REPORT

The *State of the World's Land and Water Resources for Food and Agriculture (SOLAW)* deals primarily with the issue of land and water for crops. It examines the kinds of production responses needed to meet demand. It also assesses the potential of the world's land and water resources to support these desired increases in output and productivity. Risks and tradeoffs are examined, and options reviewed for managing these without harm to the resource base.

While the use of land and water for forestry and livestock is briefly discussed in the report, these subjects have been addressed in greater detail in two earlier FAO reports to which the reader is referred: *The State of the World's Forests and The State of Food and Agriculture*. Similarly, more detailed analyses of trends and challenges on inland fisheries and aquaculture are provided in the recent FAO, report *The State of World Fisheries and Aquaculture*. These global reports are supplemented by comprehensive analysis of gender in agriculture in FAO and World Bank reports.

Chapter 1 of the SOLAW report analyses the current status of land and water resources together with trends. It assesses the biophysical and technical aspects of the resources and their use, and presents projections for the year 2050. Chapter 2 reviews current institutional arrangements, and assesses socio-economic and environmental impacts of current land and water management. Chapter 3 reviews current and future threats to land and water and their implications for a series of major systems at risk. Chapter 4 examines requirements and options to achieve the necessary levels of output and productivity required in a sustainable way. Chapter 5 assesses the institutional responses at local, national and international levels, with an analysis of lessons for the future. Finally, Chapter 6 draws conclusions and advances policy recommendations. These centre on the pragmatic step by step approaches towards a new paradigm of more sustainable, lower-carbon intensive agricultural production, based on more ecologically-sensitive management of land and water by farmers, supported by policies, institutions and incentives from national governments and the global community.

WHAT SOLAW SAYS

The world s cultivated area has grown by 12 percent over the last 50 years. The global irrigated area has doubled over the same period, accounting for most of the net increase in cultivated land. Meanwhile, agricultural production has grown between 2.5 and 3 times, thanks to significant increase in the yield of major crops.

However, global achievements in production in some regions have been associated with degradation of land and water resources, and the deterioration of related ecosystem goods and services. These, include biomass, carbon storage, soil health, water storage and supply, biodiversity, and social and cultural services. Agriculture already uses 11 percent of the world s land surface for crop production. It also makes use of 70 percent of all water withdrawn from aquifers, streams and lakes. Agricultural policies have primarily benefitted farmers with productive land and access to water, bypassing the majority of small-scale producers who are still locked in a poverty trap of high vulnerability, land degradation and climatic uncertainty.

Land and water institutions have not kept pace with the growing intensity of river basin development and the increasing degree of inter-dependence and competition over land and water resources. Much more adaptable and collaborative institutions are needed to respond effectively to natural resource scarcity and market opportunities.

Toward 2050, rising population and incomes are expected to call for 70 percent more food production globally, and up to 100 percent more in developing countries, relative to 2009 levels. Yet, the distribution of land and water resources does not favour those countries that need to

produce more in the future: the average availability of cultivated land per capita in low-income countries is less than half that of high-income countries, and the suitability of cultivated land for cropping is generally lower. Some countries with rapidly growing demand for food are also those that face high levels of land or water scarcity. The largest contribution to increases in agricultural output will most likely come from intensification of production on existing agricultural land. This will require widespread adoption of sustainable land management practices, and more efficient use of irrigation water through enhanced flexibility, reliability and timing of irrigation water delivery.

The prevailing patterns of agricultural production need to be critically reviewed. A series of land and water systems now face the risk of progressive breakdown of their productive capacity under a combination of excessive demographic pressure and unsustainable agricultural practices. The physical limits to land and water availability within these systems may be further exacerbated in places by external drivers, including climate change, competition with other sectors and socio-economic changes. These systems at risk warrant priority attention for remedial action simply because there are no substitutes.

The potential exists to expand production efficiently to address food security and poverty while limiting impacts on other ecosystem values. There is scope for governments and the private sector, including farmers, to be much more proactive in advancing the general adoption of sustainable land and water management practices. Actions include not just technical options to promote sustainable intensification and reduce production risks, they also comprise a set of conditions to remove constraints and build flexibility. These include (1) the removal of distortions in the incentives framework, (2) improvement of land tenure and access to resources, (3) strengthened and more collaborative land and water institutions, (4) efficient support services including knowledge exchange, adaptive research, and rural finance, and (5) better and more secured access to markets.

Widespread adoption of sustainable land and water management practices will also require the global community to have the political will to put in place the financial and institutional support to encourage widespread adoption of responsible agricultural practices. The negative trend in national budgets and official development assistance allocated to land and water needs to be reversed. Possible new financing options include payments for environmental services (PES) and the carbon market. Finally, there is a need for much more effective integration of international policies and initiatives dealing with land and water management. Only by these changes can the world feed its citizens through a sustainable agriculture that produces within environmental limits.

EXECUTIVE SUMMARY

In a crowded world with populations still rising and consumption patterns changing, humankind has not done enough to plan and manage the future development of land and water resources. After decades of underinvestment, poor management and lack of governance, the evidence is widely apparent. From dramatic mudslides on slopes too steep to bear human settlement to unprecedented inundation of whole river basins, the impact on human lives from extreme meteorological events makes the news. What does not, though, is the creeping degradation of the land and water systems that provide for global food security and rural livelihoods. In some regions, whole systems are now at risk. Urgent steps need to be taken to reverse trends in their degradation whilst maintaining their integrity and productivity.

There is no doubt that access to and management of land and water resources need to improve markedly. Projected demands for food and agriculture production have to be met, malnutrition and rural poverty still have to be addressed and competing demands for land and water reconciled with concerns over rapid degradation of natural systems. This calls for improved governance of land and water resources and a closer integration of policies, combined with increased and more strategic investment targeting food security and poverty alleviation.

The report presents the state of land and water resources for food production and analyses threats to food security and sustainable development. The threats result not just from the relative physical scarcity of land and water. Trends in population growth, changes in diets and climate present a complex set of challenges to which agricultural practices must adapt. The potential of the world's land and water systems to meet these challenges is examined in this context. Options for managing some of the 'systems at risk' to achieve sustainable levels of output are explored together with the attendant risks and trade-offs. The book discusses required institutional and policy changes, and technical approaches needed in the specific environments. The main findings and recommendations are presented below.

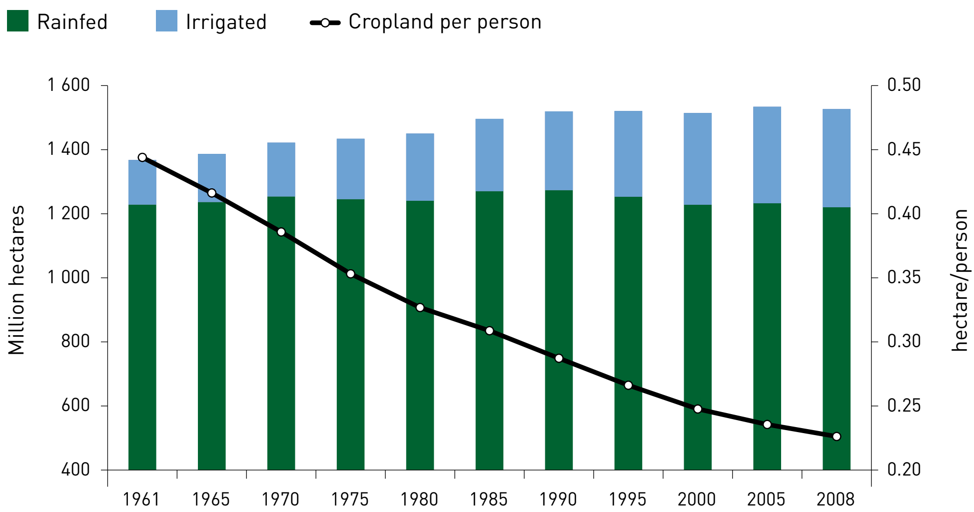
1 THE CHALLENGE OF LAND AND WATER

The availability of land and water to meet national and global demands for food and agriculture production have been put into sharp relief following the recent rise in commodity price levels (and associated volatility) and increased large-scale land acquisition. The social impacts of rapid food price inflation have hit the poorest hardest. The buffering capacity of global agricultural markets to absorb supply shocks and stabilize agricultural commodity prices is tied to the continued functioning of land and water systems. At the same time, climate change brings additional risks and further unpredictability of harvests for farmers – from warming and related aridity, shifts in rainfall patterns, and the frequency and duration of extreme events. While warming may extend the limit of agriculture in the northern hemisphere, it is anticipated that key agricultural systems in lower latitudes will need to cope with new temperature, humidity and water stresses.

STATUS AND TRENDS IN THE USE OF LAND AND WATER RESOURCES

Over the last 50 years, land and water management has met rapidly rising demands for food and fibre. In particular, input-intensive, mechanized agriculture and irrigation have contributed to rapid increases in productivity. The world's agricultural production has grown between 2.5 and 3 times over the period while the cultivated area has grown only by 12 percent (Figure 1; Table 1). More than 40 percent of the increase in food production came from irrigated areas, which have doubled in area. In the same period, the cultivated area of land per person gradually declined to less than 0.25 ha, a clear measure of successful agricultural intensification. Agriculture currently uses 11 percent of the world's land surface for crop production, and accounts for 70 percent of all water withdrawn from aquifers, streams and lakes (Map 1).

FIGURE 1: EVOLUTION OF LAND UNDER IRRIGATED AND RAINFED CROPPING (1961 2008)



Source: FAO (2010b)

TABLE 1: NET CHANGES IN MAJOR LAND USE (Mha)

	1961	2009	Net increase 1961 2009
Cultivated land	1 368	1 527	12%
• rainfed	1 229	1 226	−0.2%
• irrigated	139	301	117%

Sources: FAO (2010b,c)

The distribution of land suitable for cropping is skewed against those countries which have most need to raise production (Tables 2 and 3). Cultivated land area per person in low income countries is less than half that in high income countries, and its suitability for agriculture is generally lower. This is a troubling finding given that the growth of demand for food production, as a function of population and income, is expected to be concentrated in low income countries. The main implication is that a global adjustment of agricultural production will need to be anticipated in order to compensate for these facts of geography.

TABLE 2: REGIONAL DISTRIBUTION OF MAIN LAND USE CATEGORIES (2000)

Country category			Cultivated land		Forest land		Grassland and woodland ecosystems		Sparsely vegetated and barren land		Settlement and Infrastructure		Inland water bodies	
	Global share of land, %	Share of global population, %	Mha	%	Mha	%	Mha	%	Mha	%	Mha	%	Mha	%
Low-income	22	38	441	15	564	20	1 020	36	744	26	52	1.8	41	1.4
Middle-income	53	47	735	11	2 285	33	2 266	33	1 422	21	69	1	79	1
High-income	25	15	380	12	880	27	1 299	39	592	18	31	1	123	4

Source: adapted from Fischer et al. (2010)
Note: The extents of land cover classes were extracted from a dataset used for global agro-ecological modelling. Owing to different dates of data acquisitions, spatial resolutions, definitions and processing techniques, the estimates in this table may differ somewhat from those of other more recent sources. For example, the global extent of forest land is reported in FAO (2010d) as 4 billion ha versus approximately 3.7 billion ha reported here. See Annex A1 for the definition of regional and subregional country groupings.

TABLE 3: SHARE OF WORLD CULTIVATED LAND SUITABLE FOR CROPPING UNDER APPROPRIATE PRODUCTION SYSTEMS

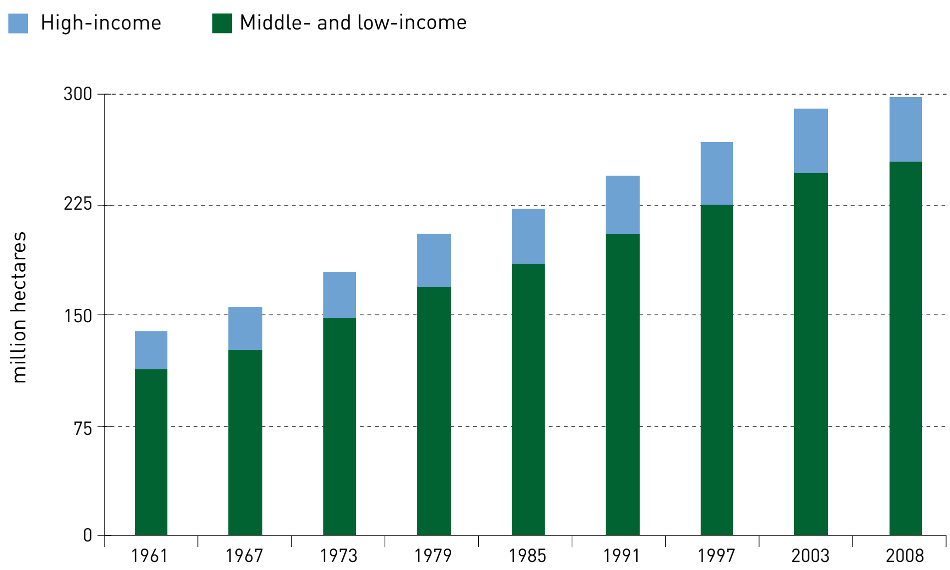
Regions	Cultivated land (Mha)	Population (million)	Cultivated land per capita (ha)	Rainfed crops (%)		
				Prime Land	Good Land	Marginal Land
Low-income countries	441	2 651	0.17	28	50	22
Middle-income countries	735	3 223	0.23	27	55	18
High-income countries	380	1 031	0.37	32	50	19
Total	1 556	6 905	0.23	29	52	19

Source: adapted from Fischer et al. (2010)

Rainfed agriculture is the world s predominant agricultural production system, but also hosts the majority of the rural poor. The large swathes of temperate cereal production in the northern hemisphere will continue to supply global markets and may even see a northward expansion, nudged by global warming. Instead, in the dry tropics and subtropics, rainfed production is held hostage by erratic precipitation. Unpredictable soil moisture availability over the course of a growing season reduces nutrient uptake and, consequently, yields. Taken with low soil fertility and carbon content of tropical soils, yields in rainfed systems are little more than half the achievable potential in many low-income countries. While improved land and nutrient management can result in higher yields, these can prove difficult to sustain if the threat of erratic rainfall remains. The rural poor on marginal lands with limited access to improved seed, fertilizer and information remain vulnerable.

The tendency to locate high-input agriculture on the most suitable lands for cropping relieves pressure on land expansion and limits encroachment on forests and other land uses. The steady trend toward precision agriculture and commercialization of all types of food and industrial crops is clear. Since 1961, while total cultivated land has shown a net increase of 12 percent to 2009, land under irrigation has more than doubled (Figure2; Map 2). While much of the prime agricultural land suitable for irrigation has been developed, the call for on-demand, just-in-time water services is rising and the global area equipped for irrigation continues to expand at a rate of 0.6 percent per year. Groundwater use in irrigation is expanding quickly, and almost 40 percent of the irrigated area is now reliant upon groundwater as either a primary source, or in

FIGURE 2: EVOLUTION OF AREA EQUIPPED FOR IRRIGATION



Source: FAO (2010b)

conjunction with surface water. This pattern of intensification, through a concentration of inputs, has offset expansion of rainfed cultivation for staple cereals and established guaranteed supply chains for a wide range of agricultural products into urban centres.

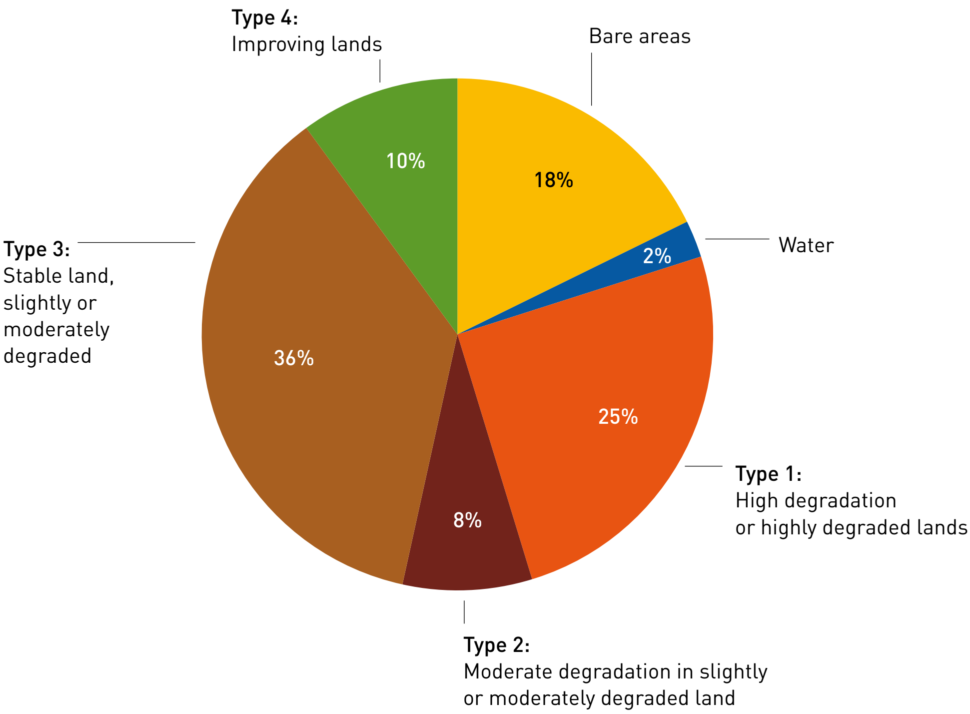
In too many places, however, achievements in production have been associated with management practices that have degraded the land and water systems upon which the production depends (Figure 3). In some of these areas, the accumulation of environmental impacts in key land and water systems has now reached the point where production and livelihoods are compromised. Intensive agricultural practice has, in some cases, resulted in serious environmental degradation, including the loss of biodiversity and surface and groundwater pollution from the improper use of fertilizers and pesticides.

Irrigation has had direct benefits in terms of production and incomes, and indirect benefits in terms of reduced incidence of downstream flood damage. However, there have also been associated impacts whose costs may at times outweigh the benefits of production. Impacts may include reduction in environmental flows, changes in downstream access to water, or reduction of the extent of wetlands which have important ecological functions of biodiversity, nutrient retention and flood control. The accumulation of environmental impacts in key land and water systems has reached the point where, in some cases, production and livelihoods are compromised.

While the intensive exploitation of land and water, particularly in large scale agriculture, has potential to protect forests by reducing pressure on land, it could also cause broader ecosystem deterioration, including loss of climatic buffering and carbon storage from forest biomass when cleared, loss of biodiversity, and loss of amenity, tourism and cultural heritage values. Unsustainable management practices on small scale farms could also cause degradation (e.g. nutrient mining, erosion) as well as contribute to greenhouse gas emissions. Often, such practices are the result of unfavourable socio-economic conditions (e.g. insecure land tenure, lack of incentives, lack of access to markets or appropriate technologies, use of marginal lands).

FIGURE 3: STATUS AND TRENDS IN GLOBAL LAND DEGRADATION

Typology of degradation of ecosystem benefits	Intervention options
Type 1 High degradation trend or highly degraded lands	Rehabilitate if economically feasible; mitigate where degrading trends are high
Type 2 Moderate degradation trend in slightly or moderately degraded land	Introduce measure to mitigate degradation
Type 3 Stable land, slightly or moderately degraded	Preventive interventions
Type 4 Improving lands	Reinforcement of enabling conditions which foster SLM



Source: this study

Water availability to agriculture is a growing constraint in areas where a high proportion of renewable water resources are already used, or where transboundary resource management cannot be negotiated. Overall, increasing water scarcity constrains irrigated production, particularly in the most highly stressed countries and areas (Map 3). In low to medium income countries with fast population growth, the demand for water is outstripping supply. Rising demand from both agriculture and other sectors is leading to competition for water resulting in environmental stress and socio-economic tension. Where rainfall is inadequate and new water development is not feasible, agricultural production is expected to be constrained more by water scarcity than land availability.

Groundwater abstraction has provided an invaluable source of ready irrigation water but has proved almost impossible to regulate. As a result, locally intensive groundwater withdrawals are exceeding rates of natural replenishment in key cereal producing locations – in high, middle and low income countries. Because of the dependence of many key food production areas on groundwater, declining aquifer levels and continued abstraction of non-renewable groundwater present a growing risk to local and global food production.

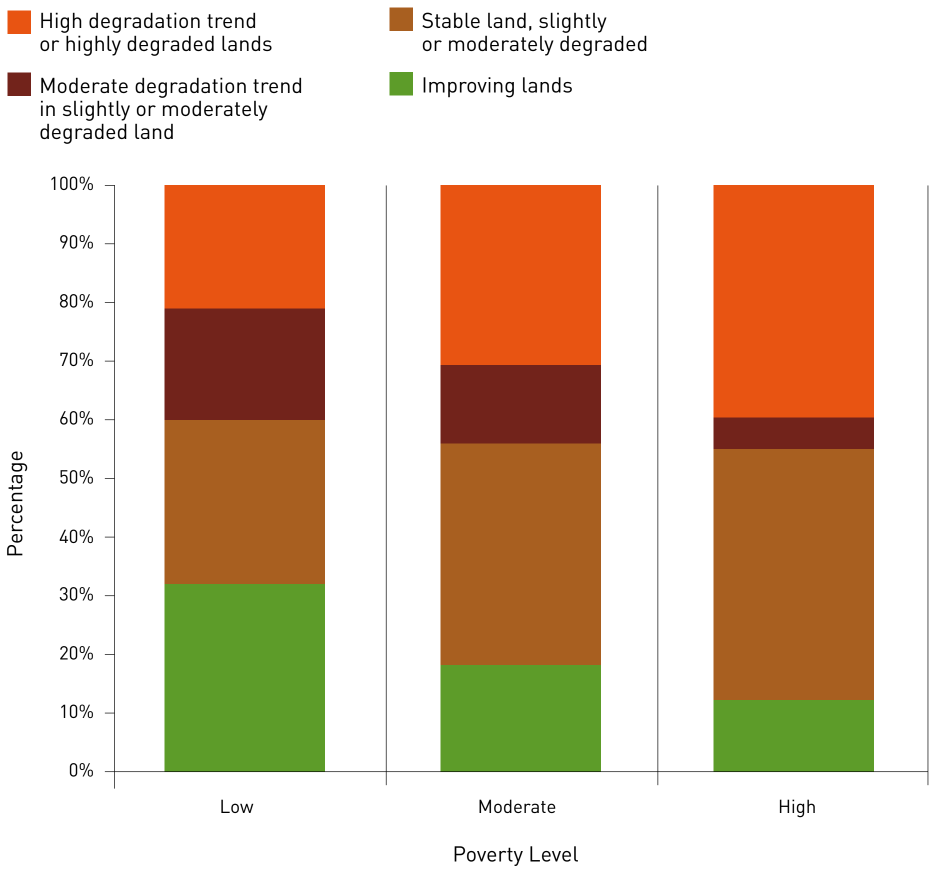
There is a strong linkage between poverty and the lack of access to land and water resource. Worldwide, the poorest (Map 4) have the least access to land and water and are locked in a poverty trap of small farms with poor quality soils and high vulnerability to land degradation and climatic uncertainty. Technologies and farming systems within reach of the poor are typically low management, low input systems that can contribute to land degradation or buffer rainfall variability. Highest trends in land degradation are associated with the poor (Figure 4).

POLICIES, INSTITUTIONS AND INVESTMENTS IN LAND AND WATER

The lack of clear and stable land and water rights as well as weak regulatory capacity and enforcement have contributed to conflict over land access and competition for water use. In particular, the systematic inclusion of customary and traditional use rights in national legislation is a necessary first step in order to protect rural livelihoods and provide incentives for responsible land and water use.

Agricultural development policies have tended to focus on investments in high-potential areas and on irrigation, mechanization and crop specialization (mono-cropping) for marketed commodities and export crops.

FIGURE 4: RELATION BETWEEN LAND DEGRADATION AND POVERTY



Data sources: FAO (2007a); LADA (2010a)

Their benefits have accrued to farmers with productive land and access to water, machinery and capital, largely bypassing the majority of smallholders who are constrained by generally poor and vulnerable soils under typically low-management, low-input systems. Such policies often prioritized short-term economic gains ignoring long-term resource degradation and impacts on ecosystem services. Rural livelihoods and cultures have also been impacted as these new agricultural systems have been adopted.

Land and water use in agriculture is caught in a policy trap. On one hand agricultural policies have been effective in responding to increasing demand but on the other hand they have resulted in a set of unintended consequences, including over-application of fertilizer and pesticides and depleted groundwater storage. Equally, water policies have driven expansion of water supply and storage, but in some water-short areas, this has created excess demand and 'constructed' scarcity. Low tariffs for irrigation water services have also encouraged its inefficient use.

In many river basins, the rate of socio-economic change and the accumulation of environmental problems have outpaced institutional responses. Environmental policy has had some influence in high-income countries, but has had far less effect so far on the development agenda of poorer countries.

Effective collaboration between land and water institutions has lagged behind patterns of use and consumption. Although land and water function as an integrated system, many institutions deal with them separately. While the legal decoupling of land and water is deliberate to avoid resource grabbing, the growing intensity of river basin development and the degree of inter-dependence and competition over land and water resources require more adaptable and collaborative institutions that can respond effectively to natural resource scarcity and changing market opportunities. Even institutions that are dedicated to integrated regional or basin management deal primarily with either land or water resources and their respective multiple uses, rather than with land and water jointly. National and local institutions regulating land and water use in many countries have come under growing pressure to arbitrate between different uses as competition for land and water has increased. The absence or weakness of transboundary cooperation frameworks (both within federated states and between riparian countries) have led to sub-optimal investment and tensions between upstream and downstream users.

Levels of public and private investment in basic agricultural infrastructure and institutions have declined over the past two decades. Agricultural infrastructure (rural roads, irrigation schemes, storage and marketing chains) has become increasingly unresponsive to changing markets and inefficient in delivering high quality produce. Renewed but smarter investment in modern agriculture is now seen as a vital component of global recovery to give more overall stability in food supply. The growing inter-dependence and competition over land and water resources in intensively used river basins indicates that this stability will not be achieved without more effective natural resource allocation and environmental regulation. Existing land and water systems that are threatened by depletion and degradation of natural resource endowments will be a priority target.

Large-scale land acquisitions are on the increase in parts of Africa, Asia and Latin America where land and water resources appear abundant and available. They are driven by concerns about food and energy security, but other factors such as business opportunities, demand for agricultural commodities for industry and recipient country are also at play. Although large-scale land acquisitions remain a small proportion of suitable land in any one country, contrary to widespread perceptions there is very little 'empty' land as most remaining suitable land is already used or claimed, often by local people. While they offer opportunities for development, there is a risk that the rural poor could be evicted or lose access to land, water and other related resources. Many countries do not have sufficient mechanisms to protect local rights and take account of local interests, livelihoods and welfare. A lack of transparency and of checks and balances in contract negotiations could promote deals that do not maximize the public interest. Insecure local land rights, inaccessible registration procedures, vaguely defined productive use requirements, legislative gaps and other factors too often undermine the position of local people.

PERSPECTIVES FOR LAND AND WATER USE TOWARDS 2050

By 2050, rising population and incomes are expected to result in a 70 percent increase in global demand for agricultural production. From a 2009 baseline this will need to be a 100 percent increase in low and middle income countries. This implies a global annual growth rate of 1 percentand up to 2 percent in low and middle income countries. Increased production is projected to come primarily from intensification on existing cultivated land. Expansion will still be possible in Sub-Saharan Africa and Latin America. In the longer run, climate change is expected to increase the potential for expansion in some temperate areas.

Both irrigated and rainfed agriculture will respond to rising demand. A doubling of current production could be derived from already developed land and water resources. Some further land and water resources could be diverted to crop production, but in most cases they already serve important environmental and economic functions. Possible conversion to crop production would require prior evaluation of the trade-off between production benefits and loss of their current ecological and socio-economic services.

Most of future growth in crop production in developing countries is likely to come from intensification, with irrigation playing an increasingly strategic role through improved water services, water-use efficiency improvements, yield growth and higher cropping intensities. Both irrigated area and agricultural water use are expected to expand rather slowly: land under irrigation will increase from 301 Mha in 2009 to 318 Mha in 2050, an increase of 6 percent. However, any expansion will require trade-offs, particularly over inter-sectoral water allocation and environmental impacts. Considerable growth of supplemental and pressurized irrigation is likely on private farms.

On the basis of existing trends in agricultural water use efficiency and yield gains, it is projected that agricultural withdrawals will need to increase to more than 2900 km^3/yr by 2030 and almost 3000 km^3/yr by 2050. This indicates a net increase of 10 percent between now and 2050.

As land and water resources scarcity becomes apparent, competition between municipal and industrial demands will intensify and intra-sectoral competition will become pervasive within agriculture – between livestock, staples and non-food crops, including liquid biofuels. Municipal and industrial water demands will be growing much faster than those of agriculture and can be expected to crowd out allocations to agriculture. Meanwhile, the levels of soil management and precision application of water will need to rise to meet agricultural productivity increases. This will involve intra-sectoral competition for scarce land and water and the ultimate source of naturally available freshwater - groundwater - will be hit hard.

Climate change is expected to alter the patterns of temperature, precipitations and river flows upon which agricultural systems depend.

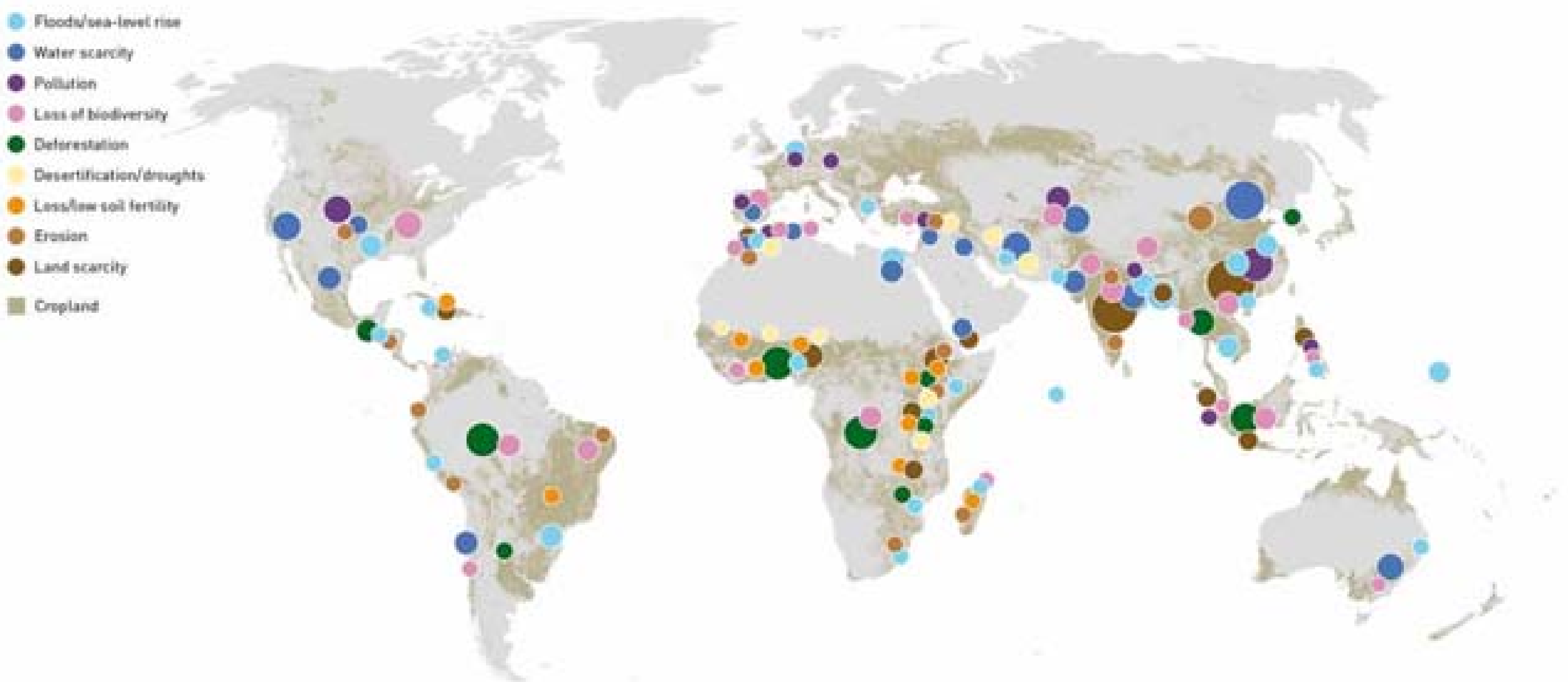
While some agricultural systems in higher latitudes may gain net benefits from temperature increases as more land becomes suitable for crop cultivation, lower latitudes are expected to take the brunt of the negative impacts. Global warming is expected to increase the frequency and intensity of droughts and flooding in subtropical areas. Deltas and coastal areas are expected to be impacted negatively by sea level rise. Mountain or highland systems and irrigated systems that rely on summer snowmelt are also expected to experience long-term changes in base flows. Adaptation and mitigation strategies should focus on increasing resilience of farming systems to reduce current and likely risks such as droughts, excessive rainfall and other extreme events. These strategies should also mitigate the negative impacts of climate change on agricultural production.

LAND AND WATER SYSTEMS AT RISK – WHAT AND WHERE

Across the world, a series of agricultural production systems are at risk due to a combination of excessive demographic pressure and unsustainable agricultural practices. Global figures on the rate of use and degradation of land and water resources hide large regional discrepancies in resource availability. Land and water constraints are expected to compromise the ability of key agricultural production systems to meet demand (Map 5). These physical constraints may be further exacerbated in places by external drivers, including climate change, competition with other sectors and socio-economic changes. These systems at risk warrant attention for remedial action since they cannot be replicated.

In SOLAW, a production system is considered 'at risk' where locally the current availability and access to suitable land and water resources are constrained. In addition, local scarcity of land and water resources may be further constrained by unsustainable agricultural practices, growing socio-economic pressures or climate change. Systems at risk occur within the nine major categories of global agricultural production systems mapped in SOLAW (Figure 5, Table 4).

FIGURE 5: GLOBAL DISTRIBUTION OF RISKS ASSOCIATED WITH MAIN AGRICULTURAL PRODUCTION SYSTEMS   A SCHEMATIC OVERVIEW



Source: this study

TABLE 4: MAJOR LAND AND WATER SYSTEMS AT RISK (A BROAD TYPOLOGY)

Global production systems	Cases or locations where systems are at risk	Risks
RAINFED CROPPING Highlands	Densely populated highlands in poor areas: Himalayas, Andes, Central American highlands, Rift Valley, Ethiopian plateau, Southern Africa.	Erosion, land degradation, reduced productivity of soil and water, increased intensity of flood events, accelerated out-migration, high prevalence of poverty and food insecurity.
RAINFED CROPPING Semi-arid tropics	Smallholder farming in Western, Eastern and Southern Africa savannah region and in Southern India; agro-pastoral systems in the Sahel, Horn of Africa and Western India.	Desertification, reduction of production potential, increased crop failures due to climate variability and temperatures, increased conflicts, high prevalence of poverty and food insecurity, out-migration.
RAINFED CROPPING Subtropical	Densely populated and intensively cultivated areas, concentrated mainly around the Mediterranean basin.	Desertification, reduction of production potential, increased crop failures, high prevalence of poverty and food insecurity, further land fragmentation, accelerated out-migration. Climate change is expected to affect these areas through reduced rainfall and river runoff, and increased occurrence of droughts and floods.
RAINFED CROPPING Temperate	Highly intensive agriculture in Western Europe.	Pollution of soils and aquifers leading to de-pollution costs, loss of biodiversity, degradation of freshwater ecosystems.
	Intensive farming in United States, Eastern China, Turkey, New Zealand, parts of India, Southern Africa, Brazil.	Pollution of soils and aquifers, loss of biodiversity, degradation of freshwater ecosystems, increased crop failure due to increased climate variability in places.
IRRIGATED Rice-based systems	Southeast and Eastern Asia.	Land abandonment, loss of buffer role of paddy land, increasing cost of land conservation, health hazards due to pollution, loss of cultural values of land.
	Sub-Saharan Africa, Madagascar, Western Africa, Eastern Africa.	Need for frequent rehabilitations, poor return on investment, stagnating productivity, large-scale land acquisition, land degradation.

Global production systems	Cases or locations where systems are at risk	Risks
IRRIGATED Other crops	RIVER BASINS Large contiguous irrigation systems from rivers in dry areas, including Colorado river, Murray-Darling, Krishna, Indo-Gangetic plains, Northern China, Central Asia, Northern Africa and Middle East.	Increased water scarcity, loss of biodiversity and environmental services, desertification, expected reduction in water availability and shift in seasonal flows due to climate change in several places.
	AQUIFERS Groundwater-dependent irrigation systems in interior arid plains: India, China, central USA, Australia, North Africa, Middle East and others.	Loss of buffer role of aquifers, loss of agriculture land, desertification, reduced recharge due to climate change in places.
RANGELANDS	Pastoral and grazing lands, including on fragile soils in Western Africa (Sahel), North Africa, parts of Asia.	Desertification, out-migration, land abandonment, food insecurity, extreme poverty, intensification of conflicts.
FORESTS	Tropical forest-cropland interface in Southeast Asia, the Amazon basin, Central Africa, and Himalayan forests.	Cropland encroachment, slash-and-burn, leading to loss of ecosystems services of forests, land degradation.
Other locally important subsystems	DELTAS AND COASTAL AREAS: Nile delta, Red River delta, Ganges/ Brahmaputra, Mekong, etc. and coastal alluvial plains: Arabian Peninsula, Eastern China, Bight of Benin, Gulf of Mexico.	Loss of agricultural land and groundwater, health-related problems, sea-level rise, higher frequency of cyclones (Eastern and Southeast Asia), increased incidence of floods and low flows.
	SMALL ISLANDS Including Caribbean, Pacific islands.	Total loss of freshwater aquifers, increased cost of freshwater production, increased climate-change related damages (hurricanes, sea-level rise, floods.
	PERI-URBAN agriculture	Pollution, health-related problems for consumers and producers, competition for land.

Source: this study

2 LAND AND WATER FOR SUSTAINABLE INTENSIFICATION

More than four-fifths of agricultural production growth to 2050 is expected to come from increased productivity on presently cultivated land. A variety of agronomic and technical approaches are available to achieve higher output, overcome constraints and manage risks. These will need to be accompanied and guided by increasingly effective and collaborative land and water institutions – public and private, formal and informal.

LAND AND WATER PRODUCTIVITY GAPS – AN UNTAPPED POTENTIAL

Land productivity is generally low on rainfed croplands, because of low inherent soil fertility, severe nutrient depletion, poor soil structure and inappropriate soil management practices (Map 6). This is particularly the case in sub-Saharan Africa, where yields are often below 1 t/ha. Sustainable land and water management techniques can increase productivity through integrated soil fertility management where rainfall is reliable.

Integrated rainfed production practices, such as conservation agriculture, agroforestry and integrated crop-livestock systems, or integrated irrigation and aquaculture combine best management practices adaptable to the local ecosystems, cultures and to market demand. Pesticide use and risks can be minimized by integrated pest management (IPM). Integrated soil fertility management, combined with rainwater harvesting and soil and water conservation on slopes could improve rainfed yields. By focusing on nitrogen and carbon cycles, these practices can also enhance carbon sequestration and mitigate GHG emissions.

These approaches have proven to be successful when they form part of a rural development and livelihoods improvement strategy which includes support services and better market access. Education, incentives and farmer field schools speed the transition to more productive and resilient land-use systems. However, risk and initial low profitability can inhibit the adoption of these techniques. Overall, feasibility and risk assessments are needed to evaluate socio-economic constraints and formulate effective incentive packages for farmers to adopt appropriate management approaches and adapt techniques and practices to their specific farming situation.

Most irrigation systems across the world perform below their capacity and are not adapted to the needs of today's agriculture. The low level of water productivity associated with their management translates into lost opportunities for resource use efficiency and economic returns. The scope for increase in water supply for irrigation is now limited in many water scarce regions. Some additional irrigation water is likely to come from large multi-purpose hydropower schemes. Small-scale water storage projects are also expected to boost supply, and some new groundwater development is anticipated. But water demand management will become increasingly important. A combination of improved irrigation scheme management, investment in modern technology, knowledge development and training can substantially increase water-use efficiency and improve supply to the often poor tail-end users. It can also improve water management where there is collective interest in maintaining aquifer function and services. The highest gains are possible in sub-Saharan Africa and parts of Asia.

To raise land and water productivity on larger irrigation schemes, an integrated modernization package of infrastructure upgrades and management system improvements is required, together with an economic environment providing undistorted incentives, manageable allocation of risk, and market access. There is also scope for improving irrigation efficiency and productivity in small-scale and informal irrigation. This requires mechanisms to ensure the availability of knowledge, technology and investment support, adapted to the local management practices and socio-economic context.

Recycling and re-use of water is another option, but only with effective regulation can water be safely derived from drainage, saline and treated wastewater. On-site and off-site risks from salinization (Map 7) and water-logging require careful drainage planning, investment and management in many irrigation projects . Salt and water balance studies and a regulatory and monitoring system are required.

NATIONAL SUPPORT FOR SUSTAINABLE LAND AND WATER MANAGEMENT

The world's farmers will continue to be the prime agents of change and their perspective has to count. Farmers are necessarily engaged in the planning and sustainable management of land and water, but many are forced into unsustainable practices by poverty and lack of aligned incentives; insecure land tenure and water-use rights; lack of adequate local organizations; and inefficient support services including rural credit and finance, markets and access to technology and knowledge. Here, public resources can be allocated more strategically. Together with mechanisms to engage private sector financing, both at the national level and through credit mechanisms at the local level. This should translate into a higher share of public investments in agriculture. Within countries, three principal areas of investment are vital: (1) At the national level, governments will need to invest in public goods such as roads, storage, land and water resource protection works and to facilitate private investment. (2) Investment is needed in the institutions that regulate and promote sustainable land and water management: research and development, incentives and regulatory systems; and land use planning and water management. (3) At basin or irrigation scheme level, an integrated planning approach is needed to drive a sequenced programme of land and water investments. For irrigation schemes, a focus on modernization of both infrastructure and institutional arrangements is needed.

Land and water administration institutions can be strengthened to improve systems for land and water rights where shortcomings inhibit improved productivity. Common-property systems can be adapted to provide secure land tenure by legal recognition and protection or by negotiated and legalized conversion to individual rights. Land markets can be promoted and regulated to improve allocation efficiency and equity.

Multi-level stakeholder participation across land and water systems can greatly enhance water productivity and reduce stress by improving allocation efficiency among sectors and by introducing technologies and a governance structure promoting efficient water use. Examples are participatory collective irrigation or groundwater management. Cooperation in transboundary water management, starting from the technical level, can promote optimal, multi-objective investment and basin-wide benefit-sharing. Future institutional development is likely to increasingly reflect participatory and pluralistic approaches, with growing devolution and accountability at local levels. Irrigation reforms would build on the movement of governments to decentralize control over irrigation and to seek greater responsibility from irrigating farmers. Basin management approaches reflect best practice in devolving land and water management to the lowest geographic unit and in involving stakeholders in planning and decision making.

In particular, the need to address trade-offs will centre on the level and modalities of intensification, protection and conservation, the balances between commercial farming and staple production and between growth and income distribution, the level of national food security, and the sharing of costs and benefits between urban and rural populations. What is vital is that the analysis should be explicit and decisions taken in the broader public interest. Participatory processes and transparency are thus important.

Improving the application of technology for sustainable land and water management requires the integration of knowledge from research with local diagnosis and adaptation. There is an extensive research basis for most land and water systems, but research and extension need to be equipped to offer adapted technology on demand, for example through outreach programmes such as Farmer Field Schools, in partnership with local farmer groups, NGOs and the private sector – the latter for example on product certification (ecological; fair trade) for value addition or pressurized irrigation technology.

The report has revealed a number of gaps and inconsistencies in existing data bases and information systems. These gaps should be filled by further inventories of land and water resources to help guide choices and implementation. Further research on the main existing farming systems will be essential to determine conservation and intensification strategies. Methods of assessing and valuing ecosystem services, including land and water audits should be developed to provide the tools that are needed to value development options and help making informed decision. Networks and modern media need to become more effective in exchanging and disseminating knowledge, and for identifying and filling knowledge gaps.

A first step to manage land and water more efficiently is removing distortions that encourage land and water degradation, such as cheap energy prices that drive inefficient, energy-intensive farming or groundwater depletion. An incentive structure including price incentives and regulatory measures can then be designed to promote better practice. Payments for environmental services (PES) may rebalance costs incurred by farmers and benefits to other sectors of society.

The recent trend in land acquisition needs to be addressed through appropriate regulations, and well-informed agricultural and food policies that take more account of land availability and access rights. Developing guidelines for land governance, or a code to regulate international investments backed up by capacity building at all levels, would be useful to improve decision-making and negotiations.

REQUIREMENTS FOR INTERNATIONAL COOPERATION AND INVESTMENT

There is an urgent need for better and more effective integration of international initiatives dealing with land and water management. International cooperation on sustainable land and water management has become a high priority in many institutions because of concerns about food security, poverty reduction, environmental protection and climate change. Several international agreements contain principles of conservation of natural resources, including land and water, but these have rarely been translated into substantive action on the ground or national codes of conduct or practice, and a consolidated agreement and framework for action on sustainable land and water management is not yet in place.

Several organizations and programmes, including the Global Environment Facility (GEF) have been raising awareness and prompting action on sustainable land and water management, and some have strengthened institutions and governance. However, different organizations often work in the same field, which reduces focus and impact, and approaches remain largely sectoral rather than integrated.

A number of recent initiatives and partnerships from civil society and the private sector such as fair-trade, environmental certification or organic labelling may also have positive effects on sustainable land and water management. They should be promoted and guided through better knowledge and monitoring mechanisms. Large scale agriculture, in particular, also has the potential to reduce transactions costs associated with carbon trading, thereby providing incentives for sustainable management.

Global investment in land and water management remains below the levels necessary to address persistent food insecurity and deal with natural resource scarcity. Gross investment requirements between 2007 and 2050 for irrigation development and management are estimated at almost US$1 trillion. Moreover land protection and development, soil conservation and flood control will require around US$160 billion. New financing options include PES and the carbon market. Global-level financing should complement public and private finance at the national level. To effectively attract and absorb these higher levels of investment, nations need to develop favourable policies, institutions and incentives, along with a strong monitoring and evaluation mechanism that addresses the social, economic and environmental dimensions of sustainability.

Financial resources to promote sustainable land and water management will need to be sourced and disbursed through existing funds and/or from private and market sources. A dedicated fund to support sustainable land and water management by smallholders could be set up within the context of global climate change negotiations over carbon sequestration financing, with a focus on the multiple benefits of raising soil carbon storage, reducing losses of soil nutrients and controlling runoff from farmer's fields. Programmes could then provide incentives to promote local level adoption of sustainable land and water management practices, and also to promote global goods such as reforestation and carbon capture, and to reduce negative environmental impacts. Programmes adopting the concept of PES could facilitate adoption of such initiatives by farmers.

Land and water management offers important opportunities for synergies between climate change adaptation and mitigation. Agriculture and deforestation together account for up to a third of total anthropogenic GHG emissions. At the same time, climate change is expected to impact patterns of land and water use for agriculture. However, many of the sustainable land and water management practices which are recommended to increase resilience and reduce vulnerability to climate change also contribute to mitigation, largely through carbon sequestration. In addition to its contribution as a carbon sink, increasing the storage of organic matter in the soil provides many further benefits, including improvement of soil water storage and retention of soil nutrients. These benefits can reduce fertilizers requirements and enhance their uptake. This contribution of improved land and water management to mitigating climate change may mean that developing countries should be able to attract financial support based on the carbon sequestration value of their sustainable land and water management.

3 MEETING THE CHALLENGES

The overriding challenges faced by agriculture are: to produce at least 70 percent more food by 2050; to improve food security and livelihoods of the rural poor; to maintain the necessary ecosystem services; and to reconcile the use of land and water resources among competing uses. All these challenges will need to be addressed together with the anticipated impacts of climate change where they have a net negative impact on agricultural production. These challenges will not be met *unless*:

- Existing agricultural practices can be transformed to reduce pressure on land and water systems.
- Negative impacts of intensive production systems are reduced markedly and increased food production is aligned with poverty alleviation, food and livelihood security diversification and the maintenance of ecosystem services.
- Negative impacts of smallholder agriculture associated with high population density, widespread poverty, and lack of secured access to land and water resources, are reduced.
- Agricultural systems at risk are addressed as a priority and progress in redressing risks is monitored.
- Investment, economic and trade policies favour sustainable agriculture and balanced rural development.
- Sustainable intensification can be implemented through integrated planning and management approaches that can be scaled up from local levels to address systems at risk and mainstream climate change mitigation and adaptation simultaneously.

The principles and practices around which major initiatives for sustainable land and water management can be built are:

- Broad adoption of participatory and pluralistic approaches to land and water management, with growing devolution and local accountability.
- Increasing investment for improvement of essential public good infrastructure related to the whole market chain from production to consumer.
- Appraisal of ecosystem services including land and water audits developed to frame planning and investment decisions.
- A review of the mandates and activities of existing global and regional organizations for land and water with the view to promote collaboration, if not integration.
- International trade agreements that favour a 'green economy' approach and contribute to sustainable agriculture overall.
- Cooperative frameworks and basin-wide management institutions that can work together to optimize economic value and ensure equitable benefit sharing in international river basins.
- A dedicated fund to support sustainable land and water management by smallholders. Incentive programmes such as PES for watershed management and clean water, biodiversity and sustainable production schemes could then promote adoption of sustainable land and water management practices capturing carbon and reducing negative environmental impacts.

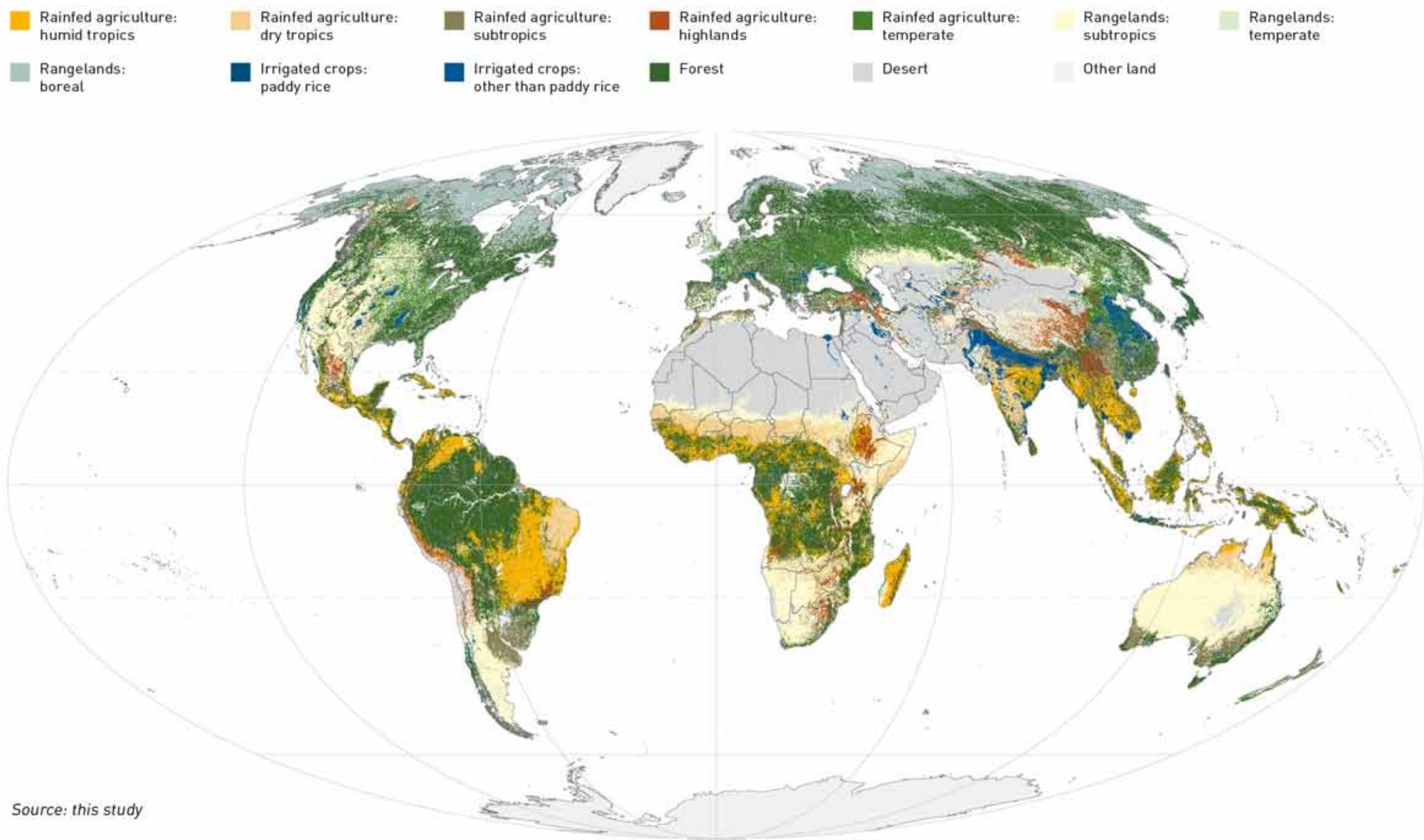
4 CONCLUSION

The land and water systems, underpinning many key food producing systems worldwide, are being stressed by unprecedented levels of demand. Climate change is expected to exacerbate these stresses in some key productive areas.

There is scope for governments and the private sector including farmers to be much more proactive in enabling and promoting the general adoption of more sustainable land and water management practices. These have the potential to expand production efficiently to address food insecurity while limiting impacts on other ecosystem values. However, this will require profound changes in the way land and water are managed. Global and national policies will need to be aligned and institutions transformed to become genuine collaborators in applying knowledge and in responsible regulation of the use of natural resources. Business as usual, with or without some marginal adjustments, will not be enough.

The status and trends of land and water resources for food and agriculture described in SOLAW provide a basis for designing and prioritizing regional programmes and financing to enhance sustainable management of land and water and address the systems at risk.

MAP 1: MAJOR AGRICULTURAL SYSTEMS



Source: this study

MAP 2: AREA EQUIPPED FOR IRRIGATION AS A PERCENTAGE OF LAND AREA

Source: Siebert et al. (2007)

MAP 3: GLOBAL DISTRIBUTION OF PHYSICAL WATER SCARCITY BY MAJOR RIVER BASIN

Source: this study

MAP 4: DENSITY DISTRIBUTION OF POOR PEOPLE, BASED ON STUNTING AMONG CHILDREN

Source: this study. Reference year: 2000

MAP 5: AGRICULTURAL SYSTEMS AT RISK: HUMAN PRESSURE ON LAND AND WATER

Source: this study

MAP 6: YIELD GAP FOR A COMBINATION OF MAJOR CROPS

Source: IIASA/FAO (2010)

MAP 7: PROPORTION OF LAND SALINIZED DUE TO IRRIGATION

Source: this study

SOLAW PREPARATION TEAM

Conceptualization and overall supervision: P. Koohafkan

Coordination: H. George

SOLAW Preparation core-group: H. George, J-M. Faurès, J. Burke, N. Forlano, F. Nachtergaele, P. Groppo, S. Bunning, P. Koohafkan and P. Steduto.

External reviewers and advisors: H. P. Binswanger, R. Conant, P. Mahler, R. Stewart and R. Brinkman.

Summary report writing team: C.S. Ward (independent consultant) and J. Pretty (University of Essex).

Preparation and review of thematic reports and SOLAW chapters: D. Bartley, C. Batello, M. Bernardi, R. Biancalani, H. P. Binswanger, J. Bonnal, J. Bruinsma, S. Bunning, J. Burke, C. Casarotto, N. Cenacchi, M. Cluff, R. Cumani, J. DelaCruz, C. De Young, O. Dubois, T. Facon, J. M. Faurès, N. Forlano, G. Franceschini, K. Frenken, T. Friedrich, A. Fynn, J. Gault, H. George, P. Gerber, P. Grassini, P. Groppo, T. Hofer, J. Hoogeveen, B. Huddleston, W. Klemm, P.K. Koohafkan, R. Lal, D. Lantieri, J. Latham, C. LiconaManzur, L. Lipper, M. Loyche-Wilkie, J. Mateo-Sagasta, P. Mathieu, G. Munoz, F. Nachtergaele, C. Neely, D. Palmer, M. Petri, T. Price, T. Robinson, S. Rose, M. Salman, V. Sadras, S. Schlingloff, P. Steduto, L. Stravato, P. Tallah, L. Thiombiano, J. Tranberg, F. Tubiello, J. Valbo-Jorgensen and M. van der Velde.

Institutions involved in the preparation of the thematic reports:

- IIASA (International Institute for Applied Systems Analysis) - G. Fischer, E. Hizsnyik, S. Prieler, and D. A. Wiberg.
- IFPRI (International Food Policy Research Institute) - R. Meinzen-Dick, E. Nkonya and C. Ringler
- IIED (International Institute for Environment and Development) – L. Cotula

- CDE (Centre for Development and Environment, University of Berne) – G. Schwilch, C. Hauert, and H. Liniger
- University of Bonn, Germany/ the University of Frankfurt – S. Siebert
- Geodata Institute (University of Southampton)
- AGTER (Association to contribute to improve the governance of land, water and natural resources)

Preparation of statistics and maps: K. Frenken, H. George, J.M. Faurès, J. Hoogeveen, L. Peiser, M. Marinelli, M. Petri, L. Simeone, with assistance from R. Biancalani, J. Latham and R. Cumani.

SOLAW website: N. Forlano, H. George, J. Morgan, G. Zanolli, L. Peiser and S. Giaccio, with assistance from G. Lanzarone, M. Fani, D. Lanzi, M. Marinelli, B. Mukunyora, F. Snijders and K. Sullivan.

Publishing arrangements and graphics design: N. Forlano, R. Tucker, J. Morgan and G. Zanolli.

Secretarial assistance: M. Finka.

MORE ABOUT THE REPORT

The *State of the World's Land and Water Resources for Food and Agriculture* report can be purchased at:
http://www.routledge.com/books/details/9781849713276/#description

For further information about the report and to access SOLAW Technical Background documents, visit the SOLAW web site at:
http://www.fao.org/nr/solaw/

All FAO publicly available georeferenced datasets are available at FAO's GeoNetwork metadata repository (**http://www.fao.org/geonetwork**)