







## Chapter 6

# CONCLUSIONS AND MAIN POLICY RECOMMENDATIONS

This book has traced three challenges facing the land and water resources upon which agriculture relies: to increase food production by almost 70 percent by 2050; to reduce hunger and improve livelihoods for the poorest; and to minimize or mitigate degradation of land and water and of the broader ecosystems. A range of technical and institutional solutions exist and have been discussed in previous chapters. They need to be adapted to local farming systems and socio-economic contexts. Improved planning, linked to smart incentive packages, can then establish a framework for investment that assigns agreed values to natural capital. On this basis, land and water management that is efficient, equitable and sustainable can be encouraged at all scales.



Movements towards this new 'green economy' have started. Increasingly, governments, civil society and the private sector are looking for technologies and approaches that can raise productivity while protecting the natural resource base and associated ecosystems. Packages for more sustainable farming are being adopted, and measures to overcome the technical and socio-economic constraints have been devised.

However, despite this progress, there remain considerable barriers to adoption. The proliferation of instruments, conferences and diverging commitments is time- and resource-consuming, with very little effect on the ground. Political commitment by nations and the international community to tackle issues in a synergetic manner is essential.

Moving to more sustainable pathways of intensification and ecological management will require additional efforts. Policies, institutions and implementation strategies will need adjustment at global, national and local levels to equip organizations and farmers with the knowledge, incentives and financial resources they need. With this support, farmers can raise productivity sustainably and strengthen the integration of their farming within local ecosystems, managing trade-offs to keep adverse effects to the minimum. A knowledge-rich engagement at local, national and global levels, focusing on land and water systems at risk, will ultimately spread socio-economic growth benefits far and wide, reducing food insecurity and associated poverty.

## Ensuring sustainable production in major land and water systems

Many major land and water systems are globally important and present substantial levels of risk, in terms of sustainability, productivity and capacity to address poverty and food security. This section summarizes how responses can be applied in the world's major land and water systems to promote expanded production within an ecologically sustainable framework, and with a focus on poverty reduction and food security.

### Major land and water systems at risk

Although productivity improvements, and in some cases expansion of the cropped area, are possible in many land and water systems, all systems are at risk of degradation and loss of productive capability. The status varies. Among rainfed systems outside the temperate zones, desertification and land degradation are significant risks. In temperate zones there is considerable scope for expanding production, but at the risk of pollution and other degradation of ecosystems. In the vast productive basins of Asia, systems are generally highly developed, but with water scarcity and land deterioration problems. Delta systems will also suffer risks from sea-level rise, as well as rising pollution; in many locations, new infrastructure may be needed to improve water security and productivity in the face of likely increased but more variable rainfall patterns. All systems using groundwater are at risk from aquifer depletion and degradation.

Priorities for action include the areas from which the bulk of extra production will have to come (notably irrigated systems and rainfed production in temperate zones). In addition, priority has to go to geographical areas that are poor and vulnerable to degradation, and where agriculture, including livestock and forestry, plays a predominant role in poverty reduction and food security. Tackling the problems of production systems particularly vulnerable to degradation in every region is also a priority: for example, marginal mountain systems, marginal grazing lands converted to rainfed farming, or forest converted to quick-return commercial farming.

### Options by major land and water system

Earlier chapters highlighted current problems and future risks in the world's major land and water systems as they face the challenge of greatly increasing output in the coming decades. This section summarizes the technical and institutional options that may be applied in each of these systems in order to manage the progress to higher levels of productivity and output, while minimizing negative impacts (Table 6.1).

**TABLE 6.1: TECHNICAL AND INSTITUTIONAL RESPONSES TO SUPPORT IMPROVED LAND AND WATER MANAGEMENT**

System	Technical responses to raise productivity through improved land and water management	Institutional responses to support sustainable improvements in land and water management
<b>Rainfed</b>		
Highlands	<ul style="list-style-type: none"> <li>• Soil and water conservation</li> <li>• Terracing</li> <li>• Flood protection</li> <li>• Reforestation</li> <li>• Conservation agriculture</li> </ul>	<ul style="list-style-type: none"> <li>• Payment for environmental services (PES) in watersheds</li> <li>• Promotion of tourism</li> <li>• Planned outmigration</li> <li>• Provision of basic services and infrastructure</li> </ul>
Semi-arid tropics	<ul style="list-style-type: none"> <li>• Better integration of agriculture–livestock</li> <li>• Investments in irrigation and water harvesting</li> <li>• Integrated plant nutrition</li> <li>• Plant breeding adapted to semi-arid conditions</li> <li>• Conservation agriculture</li> </ul>	<ul style="list-style-type: none"> <li>• Enhanced land tenure security</li> <li>• Land reform and consolidation where possible</li> <li>• Crop insurance</li> <li>• Improved governance and investments in infrastructure (markets, roads)</li> <li>• Planned out-migration</li> <li>• Solar energy production</li> <li>• Farmer field schools</li> </ul>
Subtropical	<ul style="list-style-type: none"> <li>• Climate change adaptation</li> <li>• Plant breeding adapted to semi-arid conditions</li> <li>• Improved soil and water conservation</li> <li>• Integrated plant nutrition</li> <li>• Conservation agriculture</li> </ul>	<ul style="list-style-type: none"> <li>• Land reform and consolidation</li> <li>• Crop insurance</li> <li>• investments in rural infrastructure and services</li> <li>• Planned out-migration</li> </ul>
Temperate	<p><b>Western Europe:</b></p> <ul style="list-style-type: none"> <li>• Pollution control and mitigation</li> <li>• Conservation agriculture</li> <li>• Integrated plant nutrition and pest management</li> </ul> <p><b>Elsewhere:</b></p> <ul style="list-style-type: none"> <li>• Pollution control and mitigation</li> <li>• Integrated plant nutrition and pest management</li> <li>• Conservation agriculture</li> </ul>	<ul style="list-style-type: none"> <li>• Participatory planning for expansion and intensification</li> </ul>

Options need to be adapted to both problems and opportunities. For land, changes in crop and land use, crop diversification, and measures to improve soil quality, such as soil fertility management and conservation agriculture, are needed to enhance productivity, sustainability and resilience of agricultural systems. Better-informed agronomic techniques are needed everywhere: minimum tillage, use of cover crops and nitrogen fixers in rotation cycles, managed application of fertilizers and organic amendments, soil water management improvements to irrigation and drainage, and a switch to improved varieties with higher water productivity. For water, a combination of supply-side measures coupled with demand management is needed to adjust

System	Technical responses to raise productivity through improved land and water management	Institutional responses to support sustainable improvements in land and water management
<b>Irrigated</b>		
Rice-based (Asia)	<ul style="list-style-type: none"> <li>Improved storage</li> <li>Diversification (introduction of fish and vegetables)</li> <li>Pollution control</li> </ul>	<ul style="list-style-type: none"> <li>Payment for environmental services (PES)</li> <li>Farmer field schools</li> </ul>
(Africa)	<ul style="list-style-type: none"> <li>System of rice intensification (SRI)</li> </ul>	<ul style="list-style-type: none"> <li>Better incentives, markets, access to inputs and improved varieties</li> <li>Improved governance management and infrastructure</li> <li>Farmer field schools</li> </ul>
River basin systems	<ul style="list-style-type: none"> <li>Modernization of irrigation schemes (infrastructure and governance) to improve water service, increasing flexibility and reliability in water supply to support diversification</li> <li>Prepare and implement climate change adaptation plans</li> </ul>	<ul style="list-style-type: none"> <li>Develop incentives for efficient use of water</li> </ul>
Aquifer-based systems	<ul style="list-style-type: none"> <li>Enhanced water productivity</li> </ul>	<ul style="list-style-type: none"> <li>Regulation of groundwater use</li> <li>More effective water allocation</li> </ul>
<b>Other</b>		
Deltas and coastal areas	<ul style="list-style-type: none"> <li>Climate change adaptation plans</li> <li>Flood control</li> <li>Pollution control</li> <li>Mitigation of arsenic contamination through improved irrigation practices</li> </ul>	<ul style="list-style-type: none"> <li>Land-use planning</li> <li>Control of groundwater depletion</li> </ul>
Peri-urban agriculture	<ul style="list-style-type: none"> <li>Pollution control</li> </ul>	<ul style="list-style-type: none"> <li>Secured access to land and water</li> <li>Better integration of peri-urban agriculture into urban planning</li> </ul>

storage capacity and improve supply management, reduce the rate of groundwater depletion, promote more efficient conjunctive use and raise water productivity.

**Rainfed systems in highland areas** are particularly at risk in terms of impacts on poverty and food security. There will be a need to combat negative effects of erosion and desertification through soil and water conservation, terracing, flood protection measures, and tree planting. This will require outside support, as the areas are typically poor, and there are downstream benefits from these investments. PES schemes are very appropriate for these systems, where the conservation of landscape values will also generate tourism.

**Rainfed systems in semi-arid areas** can improve productivity through better integration of agriculture and livestock, and cropping productivity may be raised by integrated plant nutrition, better varieties and improved water control, employing supplementary irrigation or water harvesting. Institutional measures to improve land tenure and, in some cases, effect land reform and consolidation, combined with research, technology transfer and investment in rural infrastructure, are needed to help raise incomes and stem out-migration.

**Rainfed systems in subtropical areas** can exploit potential for intensification through soil and water conservation measures, integrated plant nutrition, and use of new, better adapted crop cultivars. Institutional support measures required include land reform and consolidation, and investment in rural infrastructure.

**Temperate zone rainfed systems** in some areas do have potential for both further intensification and expansion, but pollution risks need to be carefully regulated and managed, and integrated approaches to both plant nutrient and pest management are priorities. Institutional support measures should include research, regulatory mechanisms, and planning for orderly expansion of the cultivated area.

The irrigated systems are generally a higher risk. In the Asian **rice-based systems**, priorities are improved storage for water control and flood prevention, diversification into higher value crops and multifunctional systems (e.g. rice/fish), and control of downstream pollution impacts. For **irrigated systems in Africa**, the key will be improved market access, combined with improved governance and management of irrigation.

Across **river basin systems**, modernization of infrastructure and institutions can improve water service and support intensification and diversification. Incentive structures will need adjustment to promote water-use efficiency. Climate change adaptation planning will be required. **Groundwater systems** can continue to support intensification, but only if users can be encouraged to moderate demand to within the limits of aquifer replenishment. The at-risk **delta and coastal plain systems** will need to give high priority to climate change adaptation and related strategies and investments for adaptation and flood control. Technical and institutional measures for control of pollution will also be a high priority to restore degraded systems and prevent further impact. Finally, **peri-urban agriculture** will require a regulatory framework for re-use of wastewater.



## Policies and strategies for sustainable land and water management

The systems at risk present regional and global targets, but the real work of fixing them through better land and water management starts at local and national levels, where sovereign policies and investment can be applied. Bearing these overall system targets in mind, what practical steps can be taken at national level to structure support and implement more effective management?

### The macro-policy setting

At the national level, governments have a role to ensure an enabling environment that is favourable to sustainable, efficient and equitable agricultural development. This includes the framework set by trade and price policy, fiscal policy and budget allocations, legislation and institutional set-ups for land and water administration, and producer services. Ideally, policy frameworks are developed by transparent, participatory processes of shared analysis, and result in policies and institutions that are efficient, pro-poor and favourable to ecosystem sustainability.

One key task is to encourage the multiple synergies and decide upon the trade-offs involved in intensification of production or in expansion of the cultivated area – synergies between sustainable production systems and food security, conservation and sustainable use of biodiversity, and climate change adaptation and mitigation. Trade-offs to consider include those between the short term and the longer term, between production and the conservation of existing ecosystem services, between food crops and biofuel feedstocks, between commercial farming and smallholder farming, between resource allocation to agriculture or to urban and industrial sectors, and between local benefits and global goods.

### Setting the incentive framework

Programmes to encourage sustainable management have to be technically appropriate, and the knowledge, financing and markets need to be in place. Most importantly, incentives, investment support or subsidies will need to be pitched at levels that encourage farmers to choose sustainable practices over the less sustainable.

A supportive incentive structure is vital, but it needs to be match to user interests. Incentives are often quite different at local, national and global levels, and equitable and fair distribution of costs and benefits is essential for sustainable land and water management. Some form of smart subsidy to farmers who bear costs but do not receive benefits may need to be designed, for example through PES contracts. Incentives may also need to be built in to compensate farmers for the lag between invest-



ment and the arrival of benefits. Care needs to be taken to ensure that any subsidies are targeted to policy objectives, environmental conservation and are pro-poor.

### **Securing access to land and water resources**

Farmers adopt new measures and technologies if they are assured stable engagement with land and water resources. Hence systems of land tenure and water-use rights that can allow farmers to exploit comparative advantage in food staples and cash crops are foundational, and require analysis and adjustment at the outset. Promotion of rural credit and finance that suits specific agricultural systems is also a necessary precondition, but needs to be based not only on annual production credits but also longer-term finance for investment in land and water resources. These initiatives will have to be complemented by dissemination of technology and good practices, and thus require adequate levels of public investment.

### **National strategies for sustainable land and water management**

Assuming the necessary enabling policy environment is in place, local and national agendas for sustainable land and water management need to be translated into strategies and investment programmes. These would need to be supported by sound cost-benefit analyses to identify strategic investments that will facilitate adoption of best practices in land and water management. Box 6.1 summarizes steps involved in the preparation of a national strategy for sustainable land and water management. Such planning has to be done with the full participation of local people.

### **Institutional support**

Sustainable land and water management requires strong institutional support, with sustained budget allocation to regulate natural resource use in the public interest. Institutions need to be adaptable to take into account changing needs, and to have access to the knowledge resources essential to the task. Institutional reforms that may be required at the country level to support sustainable land and water management include:

- Reform of land and water institutions to support more equitable tenure and responsible management. Stable access to land and water, incentives for responsible management, and obligations not to pollute are key.
- Development and strengthening of institutions for integrated land and water management at the project or scheme level, including programmes for modernization of irrigation institutions and infrastructure, with full participation of users in decision-making and financing.
- Where regional development agencies or river basin authorities exist, the adoption of programmes that tightly integrate land and water management across regions or basins. Watershed management programmes may be

**Diagnostic.** An in-depth participatory diagnostic and situation analysis is needed as a reference point for developing the strategies.

**Implementation strategy.** The strategy would spell out how the shared vision for sustainable land and water management can be implemented. The strategy would have tangible milestones, human and financial resource requirements, and detailed roles and responsibilities of the various actors (public, community organizations, NGOs and private).

**Strong and adaptable institutional support for implementation.** Cooperation for sustainable land and water management requires strong institutions with sustained budgetary support, strong monitoring and evaluation, conflict resolution mechanisms, and other mechanisms for accountability. Good databases and knowledge-sharing mechanisms on land and water are essential. Institutions also need to be adaptable in order to take into account changing needs.

**Taking to scale – use of investment frameworks.** The investment framework would be supported by a sound cost–benefit analysis, and would identify strategic investments that will lead to a rapidly increasing adoption of best sustainable land and water management practices. Investment frameworks in land and water management can be used to target beneficiaries and structure support.

**Disseminating knowledge.** Knowledge sharing and dissemination is a key element in a strategy for sustainable land and water management. It must make best use of local knowledge, complemented with research, and exchanges at regional and international levels. Global catalogues can play an important role when adapted to local situations, in partnership with local people, and consistent with national objectives and policies.

**Monitoring and evaluation.** Implementation strategies and investment frameworks need to be accompanied by a simple, comprehensive and transparent monitoring and evaluation (M&E) framework that focuses on both performance and impact aspects of the strategy.

required, and these need to be implemented over long timeframes, with good monitoring and evaluation to measure changes in the complex upstream–downstream interactions.

- Framework conditions put in place for the efficient working of competitive input and output markets.
- Research and extension packages, and outreach programmes such as Farmer Field Schools, working in partnership with local farmer groups, NGOs and the private sector.

Also important are community and farmer organizations that can work with the local administration, technical agencies, NGOs and the private sector on a partnership approach to local sustainable resource management.

### **Taking to scale – delivering investments where they are most needed**

A combination of public and private finance is needed at the national level, strengthened through strategic international financial support. Recent increases in resource allocation to agriculture by some African countries have been encouraging, but policy-level commitments to sustainable land and water management would need to be matched by increased and more strategic allocation of public resources, along with mechanisms to engage private sector financing. The investment framework approach elaborated in Chapter 5 can be used to programme public and private financial resources to achieve a well-structured agricultural sector that is responsive to both national development objectives and changing demand for production and environmental services.

Three areas of investment can be identified in countries. At the national level, government investments can be geared to local markets so that they can become effective in meeting local demands and contribute to growing regional markets. This will require investment in public goods such as roads and storage, but will also involve a large role for private investment. In addition, governments need to invest in the institutions that regulate and promote sustainable land and water management: context-specific research and development on good practices for sustainable intensification of crop, livestock and aquatic systems; integrated nutrient management (INM) and integrated pest management (IPM); incentives and regulatory systems that promote sustainable intensification; and land-use planning and water management, including negotiating cooperative agreements on transboundary water resources, where appropriate.

At basin or irrigation scheme level, an integrated planning approach will drive a sequenced programme of land and water investments. For irrigation schemes, a focus on modernization of infrastructure and institutional arrangements is needed to improve productivity of individual schemes and reduce resource degradation and externalities. To encourage local management and ease pressure on limited public finance, the development of WUAs, operational cost recovery and progressive irrigation management transfer will be a priority. These institutional fixes would be as important as investment in more water efficient technology and husbandry, but they are more likely to succeed if they are clustered and context-specific.

At the local level, support can put in place the knowledge, incentives and resources (including credit) to enable farmers and pastoralists to adopt sustainable management practices, but in the end land users will decide. Any package has to be

tailored to fit the environmental and socio-economic context, and its adoption and modifications have to be monitored and adjustments made if needed.

### **Application of knowledge**

Translating principles and finance into action needs knowledge development and transfer. A wealth of information exists on technologies and approaches for sustainable land and water management, including local knowledge, but there is insufficient sharing of experiences among stakeholders at all levels, and between countries or regions. Key steps in putting in place an enabling environment will therefore be to strengthen, through better synergy, the existing networks and media for exchanging and disseminating knowledge, and for identifying and filling knowledge gaps.

Farming systems research will be essential to determine strategies, looking not only at production technology and data but also at socio-economic factors such as farm size, family size, food security, and access to capital and markets. If rainfed production is to be stabilized with a contribution from enhanced soil moisture storage, the physical and socio-economic circumstances under which this can occur need to be well identified.

### **Monitoring and evaluation**

The progressive impact of institutional reform and investment need to be monitored and evaluated carefully. This can be done as part of an investment framework. Indicators to be measured would draw from the inventory on supply and demand of land and water, and could include: status and changes of land use, land cover and land degradation; changes in water and soil health; indicators of biodiversity and carbon stocks below and above ground; changes in access to land and water by the poor; changes in agricultural productivity; changes in rural poverty; and rates of adoption of sustainable land and water management practices. The GEF and the UNCCD have developed sets of standard indicators that could be adapted for use at the country programme level.

## **Reforming international cooperation in land and water management**

### **Agreement on principles and approaches**

There is so far no agreed framework at international level for the sustainable management of land and water. However, the vision and strategies developed by several global programmes could form building blocks for principles and practices around which major initiatives for sustainable land and water management could be aligned.



Such an agreement could include definition of common priorities and broad development objectives and strategies to be addressed by sustainable land and water management in the context of systems at risk. This could cover enhanced food security, improved rural livelihoods, sustainable conservation, improvement of ecosystem services, carbon sequestration and reduction of agricultural greenhouse gas emissions. A shared vision agreed at the international level could then be reflected in institutions, policies and programmes at the national and local levels.

To move from shared vision to action, agreement would need to be accompanied by a multisector strategy and investment framework, setting out how the shared vision for sustainable land and water management could be made operational, with tangible milestones, human and financial resource requirements, and detailed roles and responsibilities of the various actors: public bodies, international organizations, non-governmental organizations, community organizations and the private sector.

### **New entry points for international cooperation**

The potential for international cooperation has increased recently as a result of several drivers, including concern over climate change, the recent food price crisis and the world recession, as well as global moves towards a greener economy. All these factors have raised awareness of the need for cooperation and heightened interest in the mechanisms of cooperation. There are many areas of current and emerging international cooperation on land and water. Some of these may represent entry points for increasing cooperation and scaling up support to the adoption and implementation of sustainable land and water management approaches (Box 6.2).

### **Financing**

While it is clear that considerable financial resources will be needed for sustainable land and water management, it is the quality of investment that will count. Attention will be required on the most efficient mechanisms for financing increased levels of investment, whether through existing funds such as GEF or the International Development Association (IDA), or private and market sources. Financing would have to be consistent with the principles of the Paris Declaration on Aid Effectiveness and, for Africa, the Accra Agenda for Action. The possibility of a dedicated fund to support sustainable smallholder land and water management might be evaluated, possibly within the context of global climate change negotiations over adaptation or carbon sequestration financing. Mechanisms to provide incentives for farmers (and particularly for enabling smallholders and poorer farmers to adopt sustainable management practices) need to be built into financing arrangements.

Programmes in support of sustainable land and water management need to be designed and financed with incentives and mechanisms to promote local-level, pro-poor adoption, to promote global goods such as reforestation and carbon capture,

Many of the current and emerging cooperative activities on land and water represent entry points for scaling up. These include:

- Private sector partnership opportunities such as Fairtrade, green and organic labels and certifications, ecotourism.
- Partnerships with international foundations such as the Ford, Rockefeller and Gates foundations.
- PES for watershed services, biodiversity conservation, benefit-sharing in trans-boundary river basins and reduction of carbon emissions.
- Concerns over climate change: the technical, institutional and financial support mobilized around this issue and that may be available globally, regionally and at country level could have large positive spill-over effects for the land and water agenda (for example, in the shape of carbon credits).
- Financing for the new 'green economy': global thinking is moving towards support for 'green economy' approaches, and this is receiving impetus from the Rio+20 programme. Green economy rationales may thus strengthen the case for sustainable land and water practices to access a range of funding sources, and may also lead to the setting up of new facilities from which land and water management improvements might benefit.
- Foreign direct investment (FDI) in developing country agriculture brings both risks and opportunities. There is scope for international cooperation to establish 'rules of engagement' to ensure that foreign investments are beneficial to the host countries, and that small farmers and the poor have access to *increased* economic opportunity as a result. Cooperation through international law and government policies, and the involvement of civil society, the media and local communities, would help ensure that these win-win outcomes are reached.

and to reduce negative environmental impacts, including GHG emissions. Adopting the concept of PES would help to improve the balance of incentives in favour of ecological management, and could facilitate adoption by farmers otherwise unable or unwilling to implement sustainable management approaches.

Acknowledging the important role played by foreign direct investments and their rapid increase in the past decade, it will be fundamental to establish rules of engagement in order to ensure that foreign investments are beneficial to the host countries and the land users.

### Knowledge

A key element for the implementation of international cooperation for land and water could be an Inventory of the World's Land and Water Systems, with focus on systems at risk, and a capacity for regular monitoring and reporting on their status

### BOX 6.3: MONITORING LAND AND WATER SYSTEMS AT RISK

Considerable investment of intellectual and financial capital has gone into the development and dissemination of knowledge instruments on land and water. These need to be brought together and articulated in an Inventory of the World's Land and Water Systems. Such an inventory would include: (1) a shared **diagnostic** between cooperative partners on the situation and status of land and water resources in major farming systems; (2) an **inventory** of the demand for goods and services derived from land and water; and (3) an **analysis of constraints and opportunities** for the adoption of sustainable land and water management technologies at institutional, budgetary and policy level. It should be simple, transparent and scientifically validated, and should serve as a reference and platform for knowledge exchange and international cooperation.

To complement the inventory and to equip governments, planners and practitioners with best practice tools, existing catalogues of approaches for sustainable land and water management should be enhanced and disseminated. They would include best practice knowledge on solutions, options and lessons for sustainable land and water management, including what works, where and how, as well as conditions for success, bottlenecks for uptake and scaling up, best approaches (landscape, participative, watershed management), best-bet basket of technologies (conservation agriculture, agroforestry, organic farming, crop-livestock integration), new opportunities and promising technological developments, together with benefit and risk assessment.

and trends (Box 6.3). The global inventory could guide choices at the international, regional and national levels, help setting principles and approaches, and assist countries and their partners in priority setting. Existing catalogues of best practices, success stories and approaches for sustainable land and water management could be enhanced and more widely disseminated. Knowledge synthesis done at the international level can be adapted for use at the level of farming systems, and at national and local levels.

Further work is needed on the issue of ecosystem services valuation in the framework of natural resources accounting. Although considerable research is under way, particularly in complex rainforest systems, no agreed method of assessing and valuing ecosystem services has yet emerged, and tools to classify the priority of land for conversion or protection and to assess and validate outcomes are still lacking. Building on the global Inventory of Land and Water Systems at Risk, a monitoring framework needs to be developed for tracking of degradation and SLM trajectories and pace, together with methodologies for valuation of ecosystem goods and services. These methodologies would measure and cost direct relationships such as those between soil health and production. They would also quantify and cost externalities, and would assess the overall costs and benefits, and the synergies

and trade-offs of degradation, and of measures to prevent, mitigate or reverse it. Governments and the global community will need to pursue this research agenda, which will then provide the means to make these difficult assessments of trade-offs and evaluate externalities.

## Institutions

Current approaches of global and regional organizations tend to be sectoral, focusing only on specific aspects of land or water management. Several conventions and initiatives of direct relevance to land and water management provide a more integrated framework for action, but the synergies between them need to be strengthened to avoid duplications of efforts and make tangible impact. An international agreement on sustainable land and water management would indicate pathways for more integrated approaches and lend impetus to these needed changes.

For international river basins, cooperative frameworks and basin-wide management institutions will continue to optimize economic value and ensure negotiated, equitable benefit-sharing. For major basins under threat, concerted economic, institutional and agro-engineering plans will need to be developed and implemented to slow or reverse trends in land and water degradation and overcome constructed scarcity. Private and market-based institutions to promote sustainable land and water management, such as Fairtrade and ecological labelling, should be encouraged, and global trade agreements should favour sustainable agricultural practice.

## Looking ahead

The challenges facing agriculture and the land and water resources upon which they depend are clear and multiple: to produce at least 70 percent more food by 2050, reconcile the use of land and water resources with the conservation of the broader ecosystem, and improve food security and the livelihood of the rural poor; all this in the context of a changing climate and associated risks.

This book has set out the evidence that large parts of the world's land and water resources are under stress or vulnerable from current and emerging patterns of agricultural practice. There is a risk, as demand rises, that current trends will deteriorate further, with consequent threats to local food security and the resource base on which production and livelihoods depend. The possible repercussions for global food security are not negligible. The risk for the world's poor is acute. This book has therefore proposed accelerated uptake of more sustainable land and water management that can expand production efficiently while limiting impacts upon the ecosystems on which the world depends.

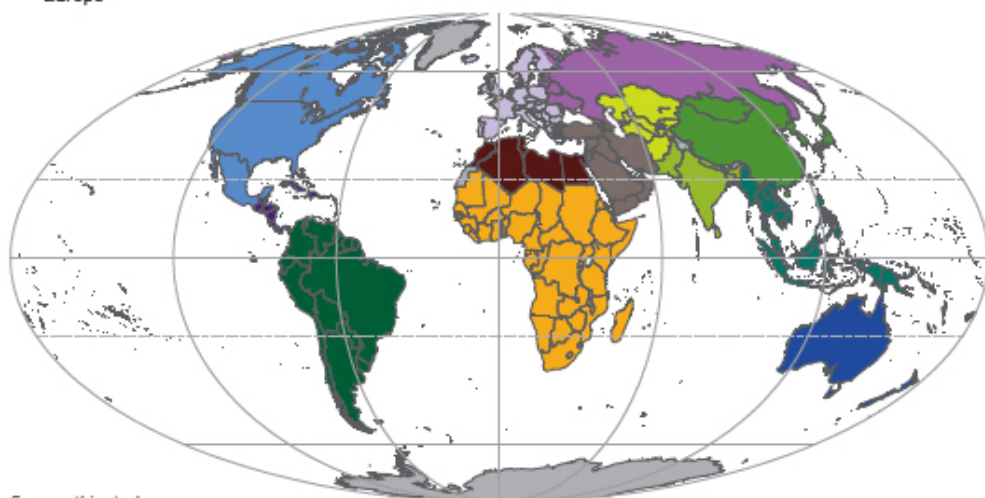
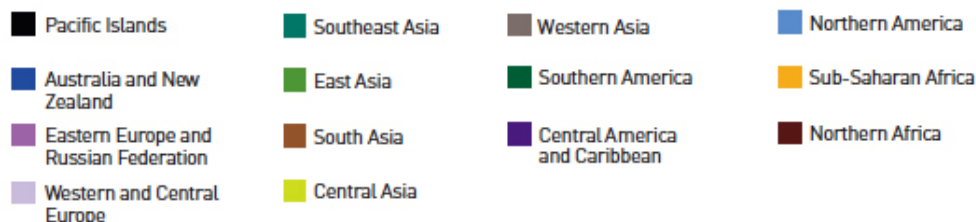


This will require adjustments in policies, institutions, incentives, programmes, financing and knowledge at national and global levels. Above all, it will require the world's farmers to acknowledge that many current intensification patterns and practices of extending the cultivated area are unsustainable, and need to change for their own long-term benefit. Promoting such a shift will require the global community and all nations to have the political will to adopt paths to sustainable intensification and to put in place the necessary institutional and financial support. Only by these changes can the world feed its citizens in the short and long term, through a sustainable agriculture that supports, not harms, the ecosystems on which it depends, and that ensures fair and equitable access to resources to those who manage it.

# Annexes

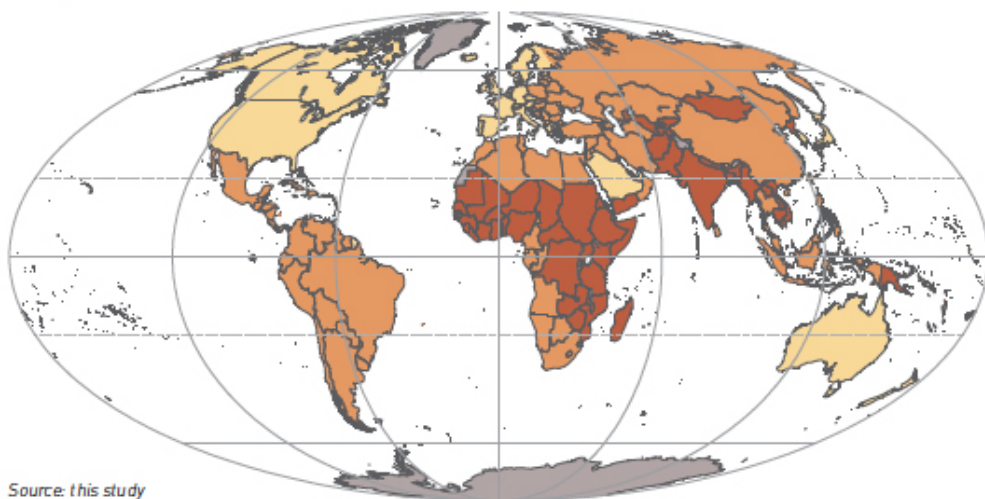
## A1 – Country groupings used

### BY REGION



Source: this study

### BY INCOME



Source: this study

## A1-1: Subregional country groupings

Continent Regions	Sub-region	Countries	
Africa		Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	
	Northern Africa	Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Tunisia	
	Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	
		Sudano-Sahelian	Burkina Faso, Cape Verde, Chad, Djibouti, Eritrea, Gambia, Mali, Mauritania, Niger, Senegal, Somalia, Sudan
		Gulf of Guinea	Benin, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone, Togo
		Central Africa	Angola, Cameroon, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Sao Tome and Principe
		Eastern Africa	Burundi, Ethiopia, Kenya, Rwanda, Uganda, United Republic of Tanzania
	Southern Africa	Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe	
	Indian Ocean Islands	Comoros, Madagascar, Mauritius, Seychelles	
Americas		Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia (Plurinational State of), Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana (France), Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico (United States of America), Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, United States of America, Uruguay, Venezuela (Bolivarian Republic of)	

(Continued)

Continent Regions	Sub-region	Countries
Northern America		Canada, United States of America
	Northern America	Canada, Mexico, United States of America
	Mexico	Mexico
Central America and Caribbean		Antigua and Barbuda, Bahamas, Barbados, Belize, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Puerto Rico (United States of America), Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago
	Central America	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
	Greater Antilles	Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico (United States of America)
	Lesser Antilles and Bahamas	Antigua and Barbuda, Bahamas, Barbados, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago
Southern America		Argentina, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Ecuador, French Guiana (France), Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela (Bolivarian Republic of)
	Guyana	French Guiana (France), Guyana, Suriname
	Andean	Bolivia (Plurinational State of), Colombia, Ecuador, Peru, Venezuela (Bolivarian Republic of)
	Brazil	Brazil
	Southern America	Argentina, Chile, Paraguay, Uruguay
Asia		Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, Georgia, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Occupied Palestinian Territory, Oman, Pakistan, Papua New Guinea, Philippines, Qatar, Republic of Korea, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, Timor-Leste, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Viet Nam, Yemen
Middle East – Western Asia		Armenia, Azerbaijan, Bahrain, Georgia, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates, Yemen

(Continued)



Continent Regions	Sub-region	Countries
	Arabian Peninsula	Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen
	Caucasus	Armenia, Azerbaijan, Georgia
	Islamic Republic of Iran	Iran (Islamic Republic of)
	Near East	Iraq, Israel, Jordan, Lebanon, Occupied Palestinian Territory, Syrian Arab Republic, Turkey
Central Asia		Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
Southern and Eastern Asia		Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, India, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand, Timor-Leste, Viet Nam
	South Asia	Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
	East Asia	China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea
	Southeast Asia	Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Thailand, Timor-Leste Viet Nam
Europe		Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, France, Germany, Greece, Holy See, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Ukraine, United Kingdom
Western and Central Europe		Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Faroe Islands, Finland, France, Germany, Greece, Holy See, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, United Kingdom
	Northern Europe	Denmark, Faroe Islands, Finland, Iceland, Norway, Sweden
	Western Europe	Andorra, Austria, Belgium, France, Germany, Ireland, Liechtenstein, Luxembourg, Netherlands, Switzerland, United Kingdom
	Central Europe	Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia
	Mediterranean Europe	Albania, Cyprus, Greece, Holy See, Italy, Malta, Monaco, Portugal, San Marino, Spain, The former Yugoslav Republic of Macedonia

(Continued)

Continent Regions	Sub-region	Countries
Eastern Europe		Belarus, Estonia, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
	Eastern Europe	Belarus, Estonia, Latvia, Lithuania, Republic of Moldova, Ukraine
	Russian Federation	Russian Federation
<b>Oceania</b>		Australia, Cook Islands, Fiji, Kiribati, Micronesia (Federated States of), Nauru, New Zealand, Niue, Palau, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
Australia and New Zealand		Australia, New Zealand
Pacific Islands		Cook Islands, Fiji, Kiribati, Micronesia (Federated States of), Nauru, Niue, Palau, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
<b>World</b>		Afghanistan, Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia (Plurinational State of), Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Cook Islands, Costa Rica, Côte d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Democratic People's Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Faroe Islands, Fiji, Finland, France, French Guiana (France), Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Holy See, Honduras, Hungary, Iceland, India, Indonesia, Iran (Islamic Republic of), Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Latvia, Lebanon, Lesotho, Liberia, Libyan Arab Jamahiriya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Micronesia (Federated States of), Monaco, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Niue, Norway, Occupied Palestinian Territory, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico (USA), Qatar, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Rwanda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Samoa, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, The former Yugoslav Republic of Macedonia, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom, United Republic of Tanzania, United States of America, Uruguay, Uzbekistan, Vanuatu, Venezuela (Bolivarian Republic of), Viet Nam, Yemen, Zambia, Zimbabwe

## Low-income food-deficit countries (LIFDC)

An FAO classification of a country, based on: (1) whether the per capita income is below the 'historical' ceiling used by the World Bank to determine eligibility for international development assistance; (2) the net (i.e. gross imports less gross exports) food trade position; and (3) whether a country specifically requests FAO not to be included in the LIFDC category.

### *Africa:*

Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe

### *Asia:*

Afghanistan, Armenia, Azerbaijan, Bangladesh, Bhutan, Cambodia, China, Democratic People's Republic of Korea, Georgia, India, Indonesia, Iraq, Kyrgyzstan, Lao People's Democratic Republic, Mongolia, Nepal, Pakistan, Philippines, Sri Lanka, Syrian Arab Republic, Tajikistan, Timor-Leste, Turkmenistan, Uzbekistan, Yemen

### *Europe:*

Republic of Moldova

### *America:*

Haiti, Honduras, Nicaragua

### *Oceania:*

Kiribati, Papua New Guinea, Solomon Islands, Tuvalu, Vanuatu

## More-, less- and least-developed countries or regions

- (a) More-developed regions comprise Europe, Northern America, Australia/New Zealand and Japan.
- (b) Less-developed regions comprise all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean, plus Melanesia, Micronesia and Polynesia.
- (c) The group of least-developed countries, as defined by the United Nations General Assembly in its resolutions (59/209, 59/210 and 60/33) in 2007, comprises 49 countries, of which 33 are in Africa, 10 in Asia, 1 in Latin America and the Caribbean, and 5 in Oceania.
- (d) Other less-developed countries comprise the less-developed regions, excluding the least-developed countries.

*Source: United Nations (2009)*

## A2 – Environmental externalities associated with irrigated agriculture

Cause	Location	Nature of externality
Depletion of stream flow by crop water use in irrigation system	In-stream, downstream	<ul style="list-style-type: none"> <li>• Reduced flow</li> <li>• Changed flow pattern, especially low flows</li> <li>• Possibly resulting in: anoxic conditions, high temperature, salt accumulation</li> <li>• Loss of habitat, flora and fauna: fish stocks → livelihoods</li> </ul>
	Riparian zone	<ul style="list-style-type: none"> <li>• Loss of riparian vegetation, wetlands, billabongs</li> <li>• Increased bank erosion and sediment inflow from adjacent land</li> <li>• Loss of near-bank fauna</li> <li>• Loss of buffering capacity of riparian zone</li> <li>• Salinization of banks and adjacent water bodies</li> </ul>
	Wetlands	<ul style="list-style-type: none"> <li>• Changed wetting patterns and reduced inflow</li> <li>• Loss of wetland area and associated livelihoods</li> <li>• Loss of tree and vegetation – amount and species composition</li> </ul>
	Flood Plain	<ul style="list-style-type: none"> <li>• Loss of stream power → poor definition of natural channels and floodways</li> <li>• Channel sedimentation</li> <li>• Loss of groundwater recharge</li> </ul>
	Estuary	<ul style="list-style-type: none"> <li>• Loss of inflow, and changed habitat; changed pattern and range of saline intrusion</li> </ul>
Additional impacts of storage of stream flow or runoff in dams or reservoirs	In-stream	<ul style="list-style-type: none"> <li>• Loss of low and medium frequency flood flows → reduced flushing of river</li> <li>• Loss of sediment (deposited in dam) → downstream erosion (higher erosive capacity)</li> <li>• Flow reversal: higher than natural flows in irrigation season (dry season) and lower flows in wet season</li> </ul>
	Upstream–downstream	<ul style="list-style-type: none"> <li>• Barrier to fish migration for spawning → population decline</li> </ul>
	Estuary	<ul style="list-style-type: none"> <li>• Radically changed habitat flows and sediment</li> </ul>
Upper catchment development	Downstream waterways, existing storages and diversions	<ul style="list-style-type: none"> <li>• Reduced runoff and water availability</li> <li>• Possible reductions in groundwater recharge</li> </ul>
Groundwater mining (average extraction exceeds average recharge)	Across aquifer	<ul style="list-style-type: none"> <li>• Declining water table → increased pumping cost</li> <li>• Where latent, emergence of arsenic and fluoride contamination</li> <li>• Where relevant, mixing of saline and fresh aquifer water</li> <li>• Land subsidence</li> <li>• Loss of groundwater-dependent wetland area</li> <li>• Loss of tree cover, where dependent on water table</li> </ul>
	Downstream	<ul style="list-style-type: none"> <li>• Reduced baseflow in rivers</li> <li>• Increased seepage from river system to shallow aquifer (streamflow 'loss')</li> </ul>



Cause	Location	Nature of externality
Irrigation in areas with saline soils or saline groundwater close to soil surface	Within irrigation system	<ul style="list-style-type: none"> <li>Severe salinization requiring remediation, drainage and leaching</li> <li>Yield penalty</li> <li>Soil structure damage</li> <li>Loss of biodiversity (excepting salt tolerant plants)</li> </ul>
	Downstream	<ul style="list-style-type: none"> <li>Regional salinization (soil and water)</li> <li>Episodic saline flushes in river network (typically after heavy rainfall) → loss of flora and fauna</li> <li>Salinization of riparian vegetation, wetlands etc.</li> <li>Loss of trees in landscape</li> <li>Degraded quality of water for irrigation downstream</li> </ul>
Development of irrigated land	Various	<ul style="list-style-type: none"> <li>In flood plain (dyking, levees, polders) – loss of flood function</li> <li>Loss of wetlands (drainage) – loss of livelihoods</li> <li>Rice paddies have limited flood mitigation function, but rice will not survive submergence for more than 4–5 days</li> <li>Loss of native fauna, trees and habitat</li> </ul>
Irrigation when annual $ET_0 > \text{rainfall}$ on non-saline soils	Within irrigation system	<ul style="list-style-type: none"> <li>Salt accumulation</li> <li>Potential salinization</li> <li>Restricted yield and crop pattern choice</li> <li>Manageable by leaching and limited drainage</li> </ul>
Irrigation of sodic soils	Coastal zones	<ul style="list-style-type: none"> <li>Soil dispersion and sediment export → degradation of coastal ecosystems, such as coral reefs, especially if accompanied by adsorbed phosphate</li> </ul>
Excess or inefficient N fertilizer application	Within irrigation system	<ul style="list-style-type: none"> <li>Long term soil acidification (rice soils with ammonium compounds: dryland soils with a range of compounds)</li> </ul>
	Downstream	<ul style="list-style-type: none"> <li>Nitrate contamination of waterways and water bodies → eutrophication, predisposition to (toxic) algal blooms</li> <li>Excessive aquatic weed growth (e.g. water hyacinth)</li> </ul>
	Groundwater	<ul style="list-style-type: none"> <li>Nitrate contamination of potable water (public health), especially in shallow wells; possible eutrophication</li> </ul>
Excess or inefficient P fertilizer application	Downstream	<ul style="list-style-type: none"> <li>Episodic phosphate flushes associated with vegetation changes (weed control, senescence) in sediment in drains and rivers</li> <li>Eutrophication and predisposition to toxic algal blooms</li> </ul>
	Groundwater	<ul style="list-style-type: none"> <li>Rarely documented, but occurs through preferential flows and soluble phosphate; consequences uncertain</li> </ul>
Herbicide application	Groundwater	<ul style="list-style-type: none"> <li>Long term contamination of groundwater – limits abstraction for drinking water (e.g. Atrazine in the USA)</li> </ul>
Poorly managed Insecticide use	Landscape	<ul style="list-style-type: none"> <li>Loss of biodiversity, and natural predators</li> <li>Accidental death or chronic illness</li> <li>Accumulation in food chain (now rare)</li> </ul>
	Stream network and groundwater	<ul style="list-style-type: none"> <li>Fish and fauna loss</li> <li>Contamination of drinking water (streams, groundwater, shallow wells)</li> </ul>

Cause	Location	Nature of externality
Application of organic wastes and partially treated wastewater	Locality	<ul style="list-style-type: none"> <li>• Smell</li> <li>• Faecal coliform contamination of produce and encysted parasites – public health</li> <li>• Heavy metal accumulation (typically copper from intensive pig production)</li> <li>• Groundwater contamination – faecal coliforms, encysted parasites</li> </ul>
Long term monoculture	Landscape	<ul style="list-style-type: none"> <li>• Progressive loss of biodiversity: loss of pollinators</li> <li>• Episodic insect and plant disease epidemics due to progressive loss of natural predators</li> <li>• Accelerated soil nutrient and micro-nutrient depletion</li> </ul>
Poor cultivation and livestock management	Wet soils	<ul style="list-style-type: none"> <li>• Loss of structure, aeration</li> <li>• Pugging</li> <li>• Reduced productivity</li> </ul>
Excess water application through poor irrigation (technology/management)	Within system, shallow groundwater, streams	<ul style="list-style-type: none"> <li>• Perched water table</li> <li>• Salinization (if connected to deeper saline groundwater)</li> <li>• Water logging and crop loss</li> <li>• Drainage flows that transport pollutants to streams</li> </ul>
Excessive flow rate or slope furrow irrigation	On farm and downstream	<ul style="list-style-type: none"> <li>• Erosion, sediment export, topsoil loss at site</li> </ul>

## A3 – Country programmes for sustainable land management

Country SLM programmes can be built through a series of steps: (1) stakeholder engagement and partnerships; (2) stocktaking and diagnostics; (3) prioritization and programming; (4) investment formulation; and (5) implementation and M&E. These steps are presented below. The steps are not intended as a blueprint, but as a ‘template’ of actions that can be adapted to each country and local situation (TerrAfrica, 2009).

The five steps are designed to build an ‘**SLM investment framework**’, which will specify the principles, policies and institutional approaches involved, as well as the priorities, the investment and financing programme, and implementation arrangements.

Usually, SLM activities fit within existing programmes and are implemented through on-going programmes and instruments by mandated agencies and bodies (public, communal and private) at national or local level. SLM is thus not treated

as a separate 'sector' of activity but as a complement to the policy, institutional and implementation structures already in place.

### **Step 1: Stakeholder engagement and partnerships**

Under step 1 the aim is to set up a broad-based SLM coalition and platform, including central and local-level public agencies, civil society, donors and – most importantly – the land users themselves. Such a coalition, which could be associated in a 'country SLM team', should operate in a flexible manner, avoid excessive formality and provide the basis for implementing the following activities:

- Development of a common vision on SLM among technical ministries (e.g. agriculture, environment, energy, local government, finance and planning), the donor community, the private sector and NGOs/civil society organizations (including farmer organizations and WUAs), and land users' representatives. The involvement of civil society and a range of private sector representatives is key, as dominance of government representatives may weaken the partnership approach.
- Ensuring effective and long-term political commitment to SLM, from the highest level (e.g. president, prime minister, cabinet).
- Raising awareness of the need of a programmatic approach to SLM.
- Developing better coordination, harmonization and alignment between partners. Agreed practices might be summarized in a 'code of conduct on SLM'.

### **Step 2: Stocktaking and diagnostics**

A wide-ranging participatory **diagnostic study** would need to be implemented to identify existing programmes and activities across all sectors and to identify the main bottlenecks and opportunities for scaling up and mainstreaming SLM. This diagnostic is structured around five different components:

**Technical component:** through a review and assessment of the past SLM experiences and lessons learnt, this component identifies best practices that can be recommended for scaling up, with options for different land-use types and geographical areas.

**Ecosystem/spatial component:** through an assessment of the main agro-ecological and land uses, this component identifies bottlenecks and opportunities for improving productivity and sustaining or improving other ecosystem services (including reversing land degradation), and highlights options for introducing or scaling up SLM.

**Policy and incentive framework component:** based on a review of constraints and opportunities in sectoral and cross-sectoral policies and strategies related to land and water resources, this component would place SLM within national policies and identify changes that would facilitate the introduction and scaling

up of SLM. A key element here will be analysis of the incentive framework driving land and water management practices, and of the opportunities for recalibrating the incentives to favour the adoption of SLM.

**Institutional component:** through analysis of relevant private and public institutions at national and subregional level concerned by land and water issues, this component would identify agencies responsible for land and water and associated areas, identify what is or could be their role in SLM delivery, assess gaps and weaknesses, and propose recommendations for strengthening and streamlining.

**Financial component:** through an assessment of existing funding for SLM, this component would identify the main existing and potential financing mechanisms, bottlenecks and opportunities for scaling up. The objective would be to ensure that financing is in place that would promote SLM adoption at the farmer level. The component would cover local-level financing mechanisms (e.g. through credit schemes), national-level programmes and global programmes such as carbon credits.

On the basis of the diagnostic study, the country SLM team might prepare a **'strategy note'** that identifies main **SLM priorities** (technologies, areas, partners), as well as the main thrusts of the SLM investment framework that will be developed (see step 3). The strategy note should be prepared in a fully participatory way, ensuring that the perspectives of land users and civil society are fully integrated.

### **Step 3: Programming and the investment framework: decision on priorities**

The main thrusts identified by the diagnostic study (and captured in the strategy note) should be assessed against national development priorities for synergies, gaps, contradictions and links. They should then be ranked according to which offer the highest synergies and complementarities. Based on the results, a preliminary investment framework is then prepared. Through a series of consultations, validation workshops and the assessment of any pilot projects or other catalytic field activities under way, the investment framework can then be finalized. This step should include some negotiation with land users and communities, to make sure that their needs and priorities are well taken into account, in particular as far as land tenure and territorial issues are concerned.

### **Step 4: Investment formulation and costing**

This phase includes detailed formulation of SLM activities and investments with the participation of all the beneficiaries, and in coordination with the development partners and donors. The investment proposals will be matched to financing sources, ideally within long-term national programmes with sustained external financing, rather than through short-term and one-off projects.

### **Step 5: Implementation and M&E**

When possible, first investments should be those that can be implemented rapidly and demonstrate quick results – for example, where local demand is strong, there are champions, and the agro-economic and land and water situation favours success. Early demonstrations of success will feed back lessons into the programme and prepare the ground for rolling out SLM on a wider scale.

Monitoring and evaluation should concern both performance and impact indicators, collected preferably through simple, cost-effective and rapid assessment, using multimedia technologies (combination of ground photos, global positioning system, data sheets, georeferenced on maps).

### **Timescale and cost**

Overall, it is expected that the preparation of an investment framework (steps 1 to 3) may take between six and twelve months and cost between US\$100 000 and US\$200 000. This cost is small 'seed money' for a programme that can contribute to the achievement of multiple national and household-level objectives through the adoption of SLM on a large scale.

## A4 – Core land and water indicators by country or region

### A4-1: Arable land in use, cropping intensities and harvested land

Continent Regions	Year	Total land in use			Rainfed use			Irrigated use*		
		A	CI (%)	H	A	CI (%)	H	A	CI (%)	H
Africa	2009	251	85	214	239	83	199	12	131	15
	2050	342	79	270	326	77	250	15	129	20
Northern Africa	2009	28	74	21	22	54	12	6	149	9
	2050	27	92	25	19	70	13	7	149	11
Sub-Saharan Africa	2009	223	87	194	217	86	187	6	112	6
	2050	315	78	245	307	77	237	8	111	9
Americas	2009	395	69	273	356	66	233	40	102	40
	2050	468	82	384	427	80	340	41	106	44
Northern America	2009	253	58	146	224	52	117	29	100	29
	2050	241	80	192	214	77	165	27	100	27
Central America and Caribbean	2009	15	64	10	14	56	8	1	162	2
	2050	15	80	12	13	73	9	2	120	3
Southern America	2009	127	93	118	118	92	108	10	100	10
	2050	213	85	181	200	83	166	12	117	14
Asia	2009	542	109	588	357	94	335	185	137	253
	2050	541	118	641	340	101	344	201	148	297
Western Asia	2009	64	66	43	47	47	22	18	117	21
	2050	55	93	52	31	80	24	25	110	27
Central Asia	2009	39	69	27	28	56	15	12	100	12
	2050	33	94	31	20	90	18	13	100	13
South Asia	2009	204	113	232	126	108	136	78	122	95
	2050	212	115	243	135	97	131	77	145	112
East Asia	2009	133	133	176	74	99	74	58	175	102
	2050	133	144	191	67	116	77	66	172	114
Southeast Asia	2009	101	109	111	82	107	88	19	118	23
	2050	107	115	124	88	106	93	19	156	30



Continent Regions	Year	Total land in use			Rainfed use			Irrigated use*		
		A	CI (%)	H	A	CI (%)	H	A	CI (%)	H
Europe	2009	293	63	184	280	60	168	13	119	16
	2050	264	83	219	245	82	200	19	100	19
Western and Central Europe	2009	125	76	94	113	73	83	12	100	12
	2050	125	89	111	111	87	97	14	100	14
Eastern Europe and Russian Federation	2009	168	53	89	167	51	85	2	249	4
	2050	139	78	108	134	77	103	5	100	5
Oceania	2009	46	57	26	42	52	22	3	100	3
	2050	58	83	48	55	82	45	2	101	2
Australia and New Zealand	2009	45	56	25	42	53	22	3	100	3
	2050	58	83	48	55	82	45	2	101	2
Pacific Islands	2009	1	70	0.4	1	-	-	0.004	-	-
	2050	-	-	-	-	-	-	-	-	-
World	2009	1527	84	1286	1274	75	958	253	130	327
	2050	1673	93	1562	1393	85	1179	279	137	382
High-income	2009	368	61	225	326	56	182	42	102	43
	2050	353	86	302	314	83	261	39	108	42
Middle-income	2009	444	136	603	331	132	436	114	147	167
	2050	769	95	728	628	84	528	141	142	200
Low-income	2009	714	64	458	617	55	341	97	121	117
	2050	551	97	532	451	87	391	100	141	140
Low-income food-deficit	2009	642	107	685	476	95	453	167	139	232
	2050	766	104	794	587	89	524	179	151	270
Least-developed	2009	173	94	163	159	92	146	14	118	17
	2050	227	82	187	211	78	164	16	145	24

A = cultivated area (million ha); CI = cropping intensity (percent); H = harvested land (million ha).

\* Refers to around 2006.

Source: FAO (2010a,b)

## A4-2: Per capita land by major current land cover type for years 2000 and 2050 populations (ha/person)

Regions	Cultivated land		Grassland and woodland		Forest land		Sparsely vegetated and barren land		Settlement and infrastructure	
	2000	2050	2000	2050	2000	2050	2000	2050	2000	2050
Northern Africa	0.13	0.08	0.23	0.13	0.04	0.02	3.36	1.99	0.02	0.01
Sub-Saharan Africa	0.33	0.13	1.61	0.62	0.77	0.29	0.80	0.31	0.03	0.01
Northern America	0.62	0.45	1.77	1.28	1.61	1.17	0.66	0.48	0.04	0.03
Central America and Caribbean	0.21	0.13	0.33	0.20	0.40	0.25	0.01	0.01	0.02	0.01
Southern America	0.37	0.27	1.89	1.36	2.45	1.76	0.28	0.20	0.03	0.02
Western Asia	0.24	0.13	0.39	0.21	0.07	0.04	1.66	0.91	0.02	0.01
Central Asia	0.60	0.30	1.82	0.90	0.07	0.04	3.44	1.71	0.03	0.02
South Asia	0.15	0.09	0.04	0.03	0.06	0.03	0.03	0.02	0.02	0.01
East Asia	0.10	0.09	0.26	0.24	0.15	0.14	0.24	0.22	0.02	0.02
Southeast Asia	0.19	0.13	0.24	0.16	0.46	0.31	0.00	0.00	0.02	0.01
Western and Central Europe	0.26	0.25	0.30	0.28	0.33	0.31	0.02	0.01	0.03	0.03
Eastern Europe and Russian Federation	0.80	1.03	2.71	3.52	3.84	4.99	0.65	0.85	0.03	0.04
Australia and New Zealand	2.21	1.49	22.14	14.97	4.24	2.87	5.53	3.74	0.05	0.04
Pacific Islands	0.32	0.19	0.55	0.32	2.26	1.32	0.04	0.03	0.03	0.02

Source: adapted from Fischer et al. (2010)

### A4-3: Share of currently cultivated land suitable for cropping under appropriate production systems

Regions	Prime (Mha)	Good (Mha)	Marginal (Mha)	Total (Mha)
Northern Africa	3	9	7	19
Sub-Saharan Africa	71	128	26	225
Northern America	94	136	28	257
Central America and Caribbean	7	8	2	16
Southern America	41	77	10	129
Western Asia	4	34	23	61
Central Asia	0.3	32	13	46
South Asia	57	84	60	201
East Asia	25	72	53	150
Southeast Asia	28	54	16	98
Western and Central Europe	50	54	27	131
Eastern Europe and Russian Federation	59	102	12	173
Australia and New Zealand	4	26	21	51
Pacific Islands	0	0	0	0
<b>Total (Mha)</b>	<b>442</b>	<b>816</b>	<b>298</b>	<b>1 556</b>
<b>Total (%)</b>	<b>28</b>	<b>53</b>	<b>19</b>	<b>100</b>

The columns shown as 'Marginal' include both marginal land and land not suitable for crop production.

Source: adapted from Fischer et al. (2010)

**A4-4: Soil and terrain constraints for low-input farming of current cultivated land (as a percentage share of region)**

Regions	No or slight constraints	Soil nutrients	Soil depth	Soil drainage	Salinity/sodicity	Calcium carbonate/gypsum	Soil workability	Terrain slopes	Perma-frost
Northern Africa	57	13	5	5	2	1	7	9	0
Sub-Saharan Africa	41	37	3	6	1	0	9	2	0
Northern America	64	14	2	13	2	0	2	2	1
Central America and Caribbean	47	18	1	3	0	1	17	14	0
Southern America	36	42	2	6	2	0	8	4	0
Western Asia	49	7	16	3	4	4	4	14	0
Central Asia	68	12	2	5	6	3	0	4	0
South Asia	49	12	3	6	6	1	20	3	0
East Asia	41	22	6	14	2	1	2	12	0
Southeast Asia	20	46	5	17	0	0	6	6	0
Western and Central Europe	47	16	14	12	1	2	5	3	0
Eastern Europe and Russian Federation	73	15	2	7	3	0	0	0	1
Australia and New Zealand	41	20	1	17	17	0	3	1	0
Pacific Islands	58	8	15	1	0	0	0	18	0
Low-income countries	44	24	3	7	3	1	14	3	0
Middle-income countries	49	24	4	9	2	1	4	6	0
High-income countries	56	17	6	13	3	1	2	1	0

Note:   Highest values are highlighted.

Source: adapted from Fischer et al. (2010)



# Glossary of terms and definitions used in this report

**Adsorption:** Process whereby molecules are attracted and retained on the surface of a substance (liquid or solid).

**Agricultural land:** Land used primarily for agricultural purposes. FAOSTAT defines agricultural area as the sum of areas under (a) arable land, (b) permanent crops (land cultivated with long-term crops that do not have to be replanted for several years), and (c) permanent meadows and pastures.

**Agroforestry:** Land-use systems or practices in which trees are deliberately integrated with crops and/or animals on the same land management unit.

**Alkalinization:** A net increase of alkali salts in the (top) soil, leading to a decline in agricultural productivity.

**Anthropogenic activities:** Activities related to human beings.

**Arable land:** Land under temporary agricultural crops, temporary meadows for mowing or pasture, market and kitchen gardens, and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for 'arable land' are not meant to indicate the amount of land that is potentially cultivable.

**Baseflow:** Part of streamflow, which results predominantly from groundwater discharged into a stream.

**Carbon sequestration:** The process of removing carbon from the atmosphere and depositing it in reservoirs such as oceans, forests or soils through physical or biological processes.

**Conjunctive use (of surface water and groundwater):** The coordinated management of surface water and groundwater supplies to maximize overall water yield.

**Conservation agriculture (CA):** An approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security, while preserving and enhancing the resource base and the environment. CA is character-



ized by three principles: continuous minimum mechanical soil disturbance; permanent organic soil cover; and diversification of crop species grown in sequences or associations.

**Conservation tillage:** An approach to soil management that excludes conventional tillage operations that invert the soil and bury crop residues. Five types of conservation tillage systems: no-tillage (slot planting), mulch tillage, strip or zonal tillage, ridge till (including no-till on ridges), and reduced or minimum tillage.

**Consumptive use of water:** The part of water withdrawn from its source for use in agriculture, industry or domestic purposes that has evaporated, transpired, or been incorporated into products. The part of water withdrawn that is not consumed is called return flow.

**Cropland (or cultivated land):** In SOLAW, the term cropland is used to indicate land which is under agricultural crops. In statistical terms, cropland is the sum of arable land (see definition above) and permanent crops.

**Desertification:** The degradation of land in arid semi-arid, and dry subhumid areas due to various factors, including climatic variations and human activities.

**Drylands:** Arid, semi-arid and dry subhumid areas (other than polar and subpolar regions) in which the ratio of mean annual precipitation to mean annual reference evapotranspiration ranges from 0.05 to 0.65.

**Ecosystem:** A dynamic complex of plant, animal and microorganism communities, and the nonliving physical components of the environment (such as air, soil, water and sunlight), interacting as a functional unit.

**Ecosystem services (or environmental services):** The benefits people obtain from ecosystems. These include provisioning services (such as food and water), regulating services (such as regulation of floods, drought, land degradation and disease), supporting services (such as soil formation and nutrient cycling) and cultural services (such as recreational, spiritual, religious and other non-material benefits).

**Eutrophication:** The enrichment of freshwater bodies by inorganic nutrients (e.g. nitrate, phosphate), typically leading to excessive growth of algae.

**Evapotranspiration:** The combination of evaporation from the soil surface and transpiration from the plants.

**Externality:** A consequence (positive or negative) arising from the production and/or consumption of goods and services that is experienced by unrelated third parties and for which no appropriate compensation is paid.

**Fertigation:** The application of fertilizer with irrigation water.

**Freshwater:** Naturally occurring water on the Earth's surface in lakes and rivers, and underground in aquifers. Its key feature is a low concentration of dissolved salts. In this report, when not otherwise specified, the term *water* is used as synonym of freshwater.

**High-level inputs/advanced management:** Under the high input, advanced management GAEZ scenario (IIASA/FAO, 2010), the farming system is mainly market-oriented. Commercial production is a management objective. Production is based on improved high-yielding varieties, is fully mechanized with low-labour intensity, and uses optimum applications of nutrients and chemical pest, disease and weed control.

**Integrated nutrient management (INM):** (or integrated plant nutrition management, IPNS). Approach by which plant nutrition is obtained by optimizing the benefits from all possible sources of nutrients. The basic objectives are to reduce the inorganic fertilizer requirement, to restore organic matter in soil, to enhance nutrient-use efficiency, and to maintain soil quality in terms of physical, chemical and biological properties.

**Integrated pest management (IPM):** An ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops while minimizing the use of pesticides.

**Intermediate-level inputs/improved management:** Under the intermediate input, improved management GAEZ scenario (IIASA/FAO, 2010), the farming system is partly market-oriented. Production for subsistence plus commercial sale is a management objective. Production is based on improved varieties, on manual labour with hand tools and/or animal traction, and some mechanization. It is moderately labour intensive, and uses some fertilizer application and chemical pest, disease and weed control, adequate fallows and some conservation measures.

**Internal renewable water resources (IRWR):** The conventional measure of freshwater available to a nation (surface water and groundwater), comprising resources deriving from the rainfall within a nation's boundaries. It excludes transboundary and fossil water resources.

**Land degradation:** The reduction in the capacity of the land to provide ecosystem goods and services over a period of time for its beneficiaries.

**Low-level inputs/traditional management:** Under the low-input, traditional management GAEZ scenario (IIASA/FAO, 2010), the farming system is largely subsistence-based and not necessarily market-oriented. Production is based on the use of traditional cultivars (if improved cultivars are used, they are treated in the same way as local cultivars), labour-intensive techniques, no application of nutrients, no use of chemicals for pest and disease control, and minimum conservation measures.

**Mixed level of inputs:** Under the GAEZ scenario of mixed level of inputs (IIASA/FAO, 2010), only the best land is assumed to be used for high-level input farming; moderately suitable and marginal lands are assumed to be used at intermediate- or low-level input and management circumstances.

**Modernization:** In irrigation, modernization is defined as a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, if required, with the objective to improve resource utilization (labour, water economics, environment) and water delivery service to farms.

**Mycorrhiza:** Fungus that forms a symbiotic association with the roots of particular plants and through which these plants benefit from greater availability of nutrients.

**Organochlorines:** Chemicals characterized by carbon and chlorine components. Some environmentally persistent pesticides (like DDT) are organochlorines.

**Payment for environmental services (PES):** A voluntary transaction whereby a service provider is paid by (or on behalf of) beneficiaries for land-use practices that are expected to result in continued or improved environmental service provision beyond what would have been provided without the payment.

**Qanat:** Excavated underground channels tapping groundwater from upslope aquifers.

**Rangeland:** Land on which the indigenous vegetation (climax or subclimax) is predominantly grasses, grass-like plants, forbs or shrubs that are grazed or have the potential to be grazed, and which is used as a natural ecosystem for the production of grazing livestock and wildlife.

**Riparian:** Relating to land adjoining a stream or river.

**Runoff:** Part of the water from precipitation or irrigation that flows over the land surface in stream flow and is not absorbed into the ground.

**Salinization:** The process by which salt accumulates in or on the soil. Human-induced salinization is mostly associated with poor irrigation practices.

**Shaduf:** An irrigation tool, consisting of a pole with a bucket at one end and a weight at the other end.

**Silvopastoralism:** Land-use systems and practices in which trees and pastures are deliberately integrated with livestock components.

**Sodic soil:** A soil that contains sufficient sodium to adversely affect the growth of most crop plants (sodic soils are defined as those soils which have an exchangeable sodium percentage of more than 15).

**System of rice intensification (SRI):** An integrated rice production system where yield increase is obtained through changes in management practices rather than by increasing inputs. Central to the principles of SRI are soil moisture management (no use of continuously saturated soils), single planting and optimal spacing, and transplantation within 15 days after germination.

**Vertisols:** Dark-coloured clay-rich soils with characteristic shrinking and swelling properties.

**Wadi:** The bed or valley of a seasonal stream in arid or semi-arid areas that is usually dry except for a short time after spate flow events (a few hours to a few days).

**Water accounting:** A systematic method of organizing and presenting information relating to the physical volumes and flows of water in the environment, as well as the economic aspects of water supply and use.

**Water audit:** A systematic study of the current status and future trends in both water supply and demand, with a particular focus on issues relating to accessibility, uncertainty and governance in a given spatial domain.

**Water demand management:** A set of actions consisting in controlling water demand, either by raising the efficiency of its use (see definition below) or operating intra- and intersectoral reallocation of water resources.

**Water harvesting:** A technology by which rainwater is collected, and either directly applied to the cropped area and stored in the soil profile for immediate uptake by

the crop (runoff irrigation), or stored in a water reservoir for future productive use (for example used for supplementary irrigation).

**Water productivity:** The amount or value of output (including services) provided by water, in relation to the volume of water used. Crop water productivity refers to the ratio between crop yield and water supply. Economic water productivity is expressed as the ratio between added value of a product and water supply.

**Water resources assessment:** Water resources assessment focuses on the supply side of water accounting and provides a systematic assessment of water resources, including their variability and trends. See also water accounting.

**Water right:** In its legal sense, a legal right to abstract or divert and use water from a given natural source; to impound or store a specified quantity of water in a natural source behind a dam or other hydraulic structure; or to use or maintain water in a natural state (ecological flow in a river, and water for recreation, religious/spiritual practices, drinking, washing, bathing or animal watering).

**Water-use efficiency:** The ratio of the amount of water actually used for a specific purpose to the amount of water withdrawn or diverted from its source to serve that use.

**Water withdrawal:** Water abstracted from streams, aquifers or lakes for any purpose (e.g. irrigation, industrial, domestic, commercial).

**Waterlogging:** State of land in which the water table is located at or near the soil surface, affecting crop yields.

# Explanatory note for the global maps presented in this report

SOLAW contains a limited set of carefully selected global maps, which support the main messages of the report. While some of these maps have been previously published, several have been prepared specifically for first publication in SOLAW. These notes provides brief methodological explanations on the newly prepared maps as well as references for those previously published. Detailed documentation is available on the SOLAW website: <http://www.fao.org/nr/solaw/>.

## **Map 1.1: Dominant land cover and use**

This map shows a global distribution of major land cover classes, which includes elements of land use in which cropland has been separated from natural grass and shrub categories. It is extracted from the Global Agro-Ecological Zones (GAEZ v3.0) database maintained by FAO and IIASA, and used as a basis for agricultural perspective studies.

*Source: IIASA/FAO, 2010.*

## **Map 1.2: Global distribution of physical water scarcity by major river basin**

This map provides a representation of levels of water scarcity by major river basin, expressed in terms of the ratio between irrigation water that is consumed by plants through evapotranspiration and renewable fresh water resources. In contrast to earlier water scarcity maps, this map uses consumptive use of water rather than water withdrawal. Renewable freshwater resources, as well as net irrigation water requirements in the river basin, are calculated through a water balance model, using data on climate, soils and irrigated agriculture as inputs.

*Source: this study*

## **Map 1.3: Major agricultural systems**

This map, which builds upon work done by Dixon *et al.* (2001) in mapping major farming systems, is used as the basis for the analysis of SOLAW's systems at risk. The map is based on an interpretation of global land cover data, as well as thematic datasets showing irrigated land and the extent of paddy rice.

*Source: this study*

## **Map 1.4: Dominant soil and terrain constraints for low-input farming**

This map shows dominant soil and terrain constraints for low input farming conditions. The map is part of the IIASA/FAO Global Agro-Ecological Zones version 3.0.

Constraining soil and terrain-slope conditions are accounted for and factored into the analysis by means of soil quality ratings.

*Source: IIASA/FAO, 2010.*

### **Map 1.5: Yield gap for a combination of major crops**

This map presents, for a combination of major crops, the ratio between actual crop production in the year 2000 and that potentially achievable under advanced farming in current cultivated land. It represents the productivity gap due to low levels of inputs and management, or the potential gains that could be obtained when moving from current to advanced farming.

*Source: IIASA/FAO, 2010.*

### **Map 1.6: Area equipped for irrigation as a percentage of land area**

This map shows the extent of land area equipped for irrigation around the turn of the 20th century according to the Global Map of Irrigation Areas (version 4.0.1), together with areas of rainfed agriculture obtained from Map 1.3.

*Source: Siebert et al., 2007*

### **Map 1.7: Percentage of irrigated area serviced by groundwater**

Most irrigation systems in the world are serviced either by surface water, by groundwater or by a combination of the two (conjunctive use of water). This map is based on a combination of Map 1.6 and a global dataset of groundwater irrigation. Both areas serviced by groundwater and areas under conjunctive use of surface water and groundwater are represented.

*Source: Siebert et al., 2010*

### **Map 2.1: Prevalence of stunting among children**

This map is adapted from a global GIS database maintained by FAO on food insecurity, poverty and the environment. It is based on stunting data among children under 5 years of age, around the year 2000.

*Source: FAO, 2007c.*

### **Map 2.2: Distribution of poor population in developing countries, based on stunting among children**

Stunting among children is used by FAO as an indicator of food insecurity and poverty. By overlaying stunting rate (Map 2.1) and population density, this map shows the density distribution of poor populations in developing countries.

*Source: this study*



### **Map 3.1: Proportion of land salinized due to irrigation**

This map represents the spatial distribution of land under irrigation that is affected by some degree of salinization. It was produced by combining FAO AQUASTAT country statistics regarding irrigated areas affected by salinization with spatial information on irrigated areas where precipitation is not sufficient to leach away salt residues that have built up in the soil due to irrigation.

*Source: this study*

### **Map 3.2: Agricultural systems at risk: human pressure on land and water**

This map shows the extent to which rainfed and irrigated agricultural systems, as identified on Map 1.3, are constrained by land and/or water scarcity. Land scarcity in rainfed agriculture was assessed by comparing the rural population density with the suitability for rainfed crops, assigning a distinctive population carrying capacity to each suitability class. Water scarcity in irrigated areas was assessed by combining Map 1.2 with the global map of irrigation areas. Land-scarce areas in dry climates are considered both land- and water-scarce.

*Source: this study*

All FAO publicly available input datasets, including references, are available at FAO's GeoNetwork metadata repository (<http://www.fao.org/geonetwork>).

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# THE STATE OF THE WORLD'S LAND AND WATER RESOURCES FOR FOOD AND AGRICULTURE (SOLAW)

Managing systems at risk

*Food and Agriculture Organization of the United Nations*

By 2050, food production is projected to increase by about 70 percent globally and nearly 100 percent in developing countries. This incremental demand for food, together with demand from other competing uses, will place unprecedented pressure on many agricultural production systems across the world. These 'systems at risk' are facing growing competition for land and water resources and they are often constrained by unsustainable agricultural practices. They therefore require particular attention and specific remedial action.

The State of the World's Land and Water Resources for Food and Agriculture (SOLAW) analyses a variety of options for overcoming constraints and improving resource management in these areas of heightened risk. In each location, a mix of changes in institutional and policy measures will have to be combined with greater access to technologies for better management of land and water resources. Increased investments; access to novel financing mechanisms; and international cooperation and development assistance will also help overcome these constraints.

This first issue of SOLAW, which complements other "State of the world" reports published regularly by FAO, is intended to inform public debate and policy-making at national and international levels.



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