Risks proliferate: *Pressures on land and water resources come from within agriculture and the wider food system from food losses and waste, coupled with the uncertainty of climate forcing the proliferation of emerging pollutants in soils and water.* *(See map on page 32.)*

Some key findings in this section...

- **Risks run deep:** The slow-onset risks of human-induced land degradation, soil erosion, salinization and groundwater pollution are not perceived as urgent risks, but they run deep and are persistent.

- **Land degradation is reversible:** remedial land management is possible but only under much- reformed land and water governance. Planning a way out of this downward spiral of land degradation offers promise when combined with forward-looking climate finance for mitigation and adaptation.

- **Food security is threatened by water scarcity:** Groundwater depletion affects vulnerable rural populations and national food security.

- **Risk awareness is key:** Farmers and resource managers need to be much more risk aware and work together with planners in setting their responses and contingency planning.

The risk to human-induced land degradation primarily affects cropland. Almost a third of rainfed cropland and nearly a half of irrigated land are subject to risk from human-induced land degradation.

3 CHALLENGES RUN DEEP

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3.1 Land and water systems are at breaking point

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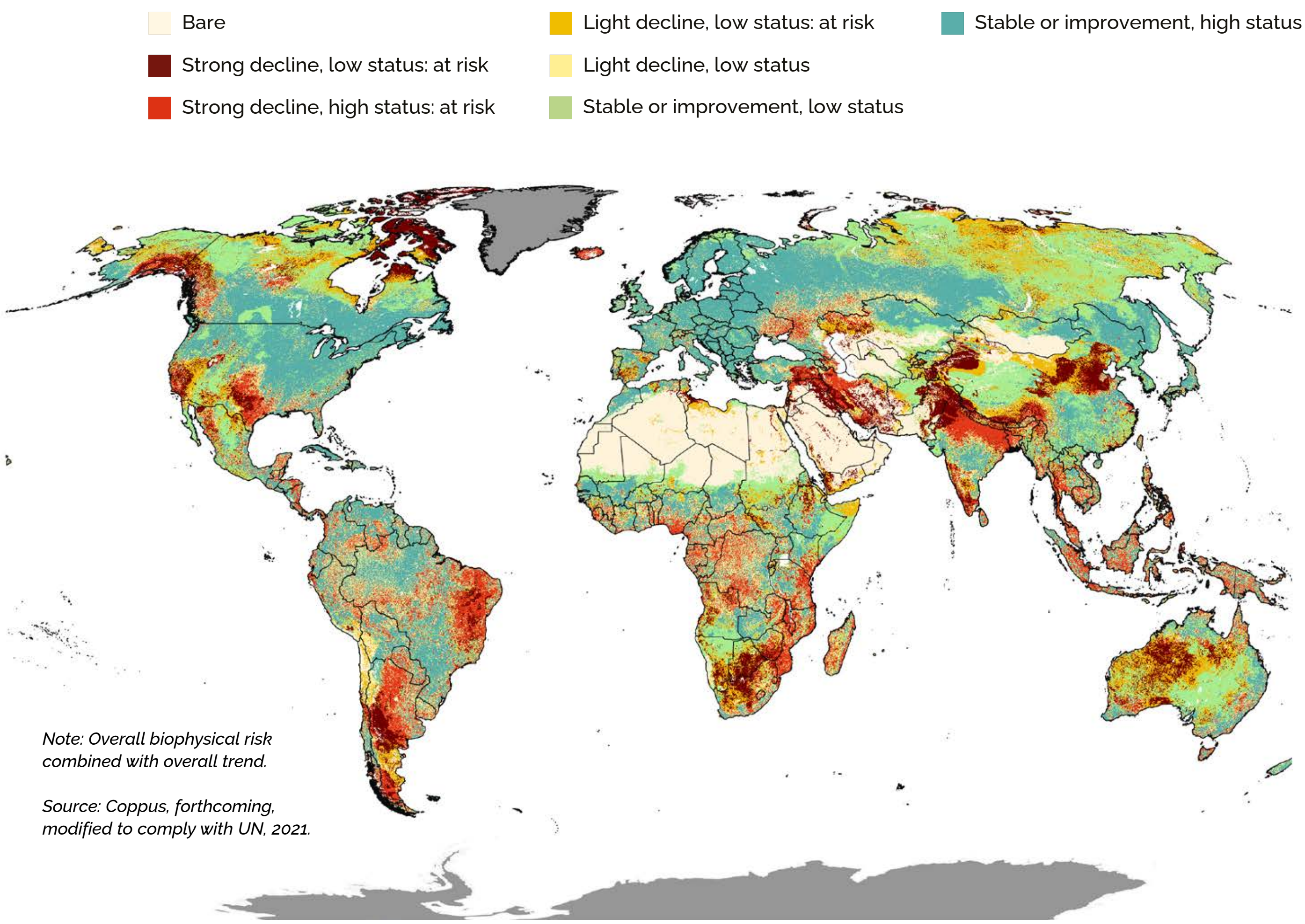
Pressures on land and water systems are compromising agricultural productivity. This is occurring precisely at times and in places where growth is most needed to meet sustainable global food targets. Human-induced land degradation and water scarcity raise risk levels for agricultural production and ecosystem services (Map S.12). Climate change adds uncertainty to the agroclimatic risks facing producers, particularly those who are least able to buffer shocks and who are food insecure. Climate volatility and extreme hydrological and meteorological events will affect all producers, but risks are greater in areas with minimal resource endowments, growing populations and limited economic powers to adapt local food systems or find substitutes.

MAP S.12 REGIONS AT RISK BASED ON STATUS AND TRENDS OF LAND RESOURCES, 2015



Note: Overall biophysical risk combined with overall trend.

Source: Coppus, forthcoming, modified to comply with UN, 2021.

The scale and intensity of current land and water use for agriculture are not sustainable at many local levels. In some cases, this extends to the global level when just-in-time supply can break down, particularly if unforeseen drought drastically reduces crop production.

Projections under climate change illustrate how temperature changes can exacerbate production risks. Competition for land and access to water is evident, particularly as it affects impoverished communities, whose food security and livelihoods depend directly upon land and water. Forced migration resulting from conflict pushes demand into fragile economies where resources are limited and rapidly exhausted.

The risk to human-induced land degradation primarily affects cropland. Almost a third of rainfed cropland and nearly a half of irrigated land are subject to risk from human-induced land degradation (Table S.5).

Croplands at risk tend to be areas recently brought into production. They are subject to limited freshwater availability and increasing population density. The historical drought frequency on rainfed cropland reflects this concentration of drought risk on land associated with high population densities (Map S.13).

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Most grasslands at risk are exposed to decreasing freshwater availability. There are exceptions in Southern America and sub-Saharan Africa, where decreasing land productivity and soil protection account for declining ecosystem services. In Asia, increasing water stress contributes to grasslands at risk. In sub-Saharan Africa, grasslands are prone to frequent and intense fire.

Forest land is prone to deforestation, and in sub-Saharan Africa also to frequent and severe fire. The biophysical status of most regions at risk is characterized by low soil organic matter and low plant species biodiversity, which are influenced by water cycles. Soil salinity is estimated to take 0.3–1.5 million ha of farmland out of production each year and reduce productivity on a further 20–46 million ha. According to the United States Department of Agriculture, approximately 10 million ha of arable land annually drops out of agricultural use due to salinization, sodification and desertification.

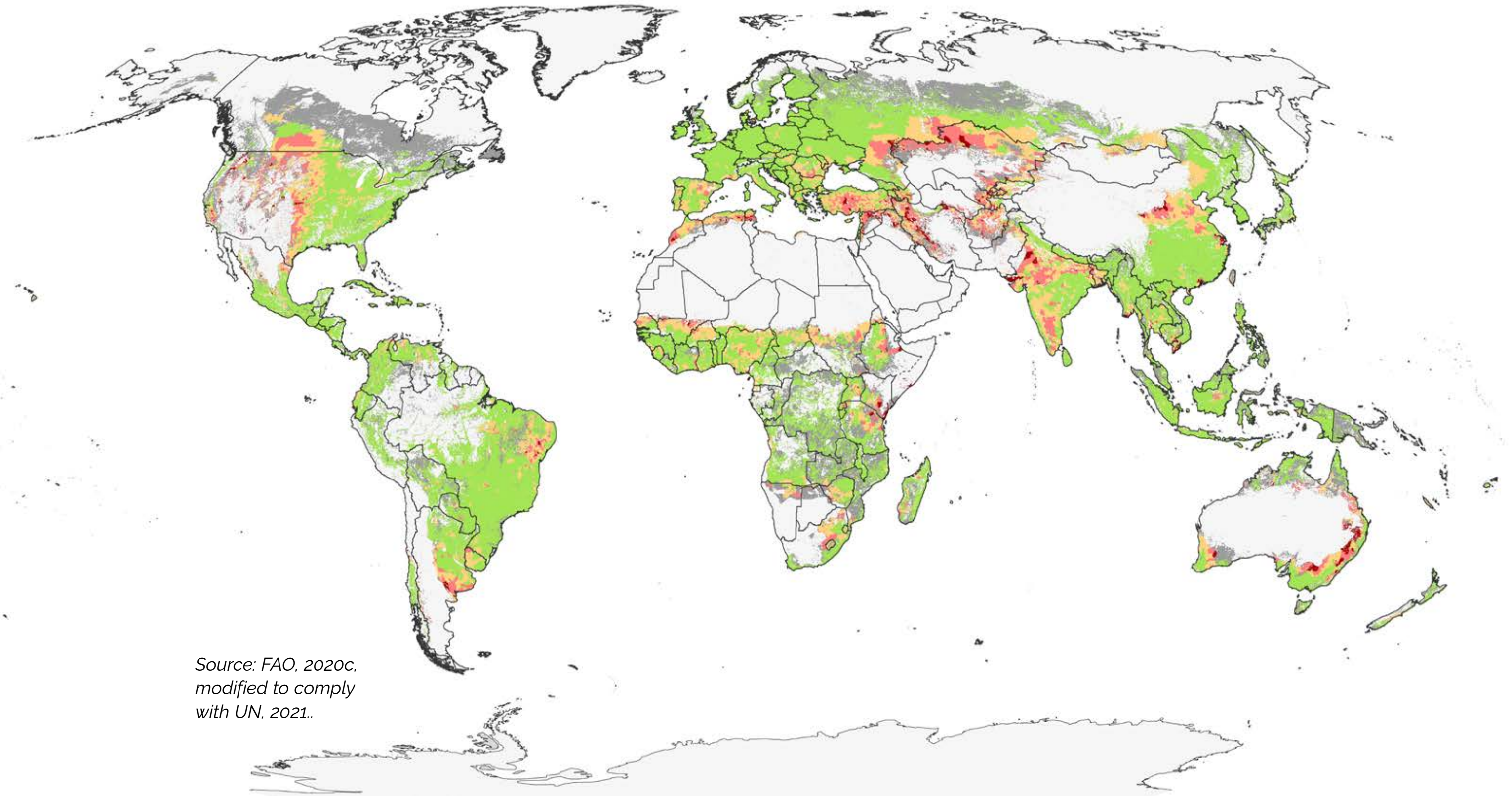
TABLE S.5 PRODUCTIVE LAND AT RISK FROM LAND DEGRADATION, 2015

LAND COVER	TOTAL AREA (MILLION ha)	AREA AT RISK (MILLION ha)	AREA AT RISK (%)
Cropland	1 527	472	31
Rainfed	1 212	322	27
Irrigated	315	151	48
Grassland	1 910	660	35
Forest land	4 335	1 112	26

Note: The term degradation refers to high pressures from anthropogenic drivers. All other declines in biophysical status are defined as deterioration.

Source: Coppus, forthcoming.

MAP S.13 HISTORICAL DROUGHT FREQUENCY ON RAINFED CROPLAND, 1984–2018



Source: FAO, 2020c, modified to comply with UN, 2021..

3.2 Looking to the future

FAO estimates that by 2050, agriculture will need to produce almost 50 percent more food, fibre and biofuel than in 2012. Agricultural production in South Asia and sub-Saharan Africa will need to more than double (increase of 112 percent) to meet estimated calorific requirements. The rest of the world will need to produce at least 30 percent more. Achieving this will mean increasing crop yields and cropping intensities as well as diversifying crop varieties. There will be trade-offs among nutritional value, crop productivity and climate resilience because there are limited options for expanding the cultivated area.

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The SOLAW 2011 report identified a wide range of risks to the overall performance of productive land and water systems. The main focus in the SOLAW 2021 report is on the most-prominent risks: land and soil degradation, water scarcity associated with agricultural withdrawals and pollution from land.

The FAO future of food and agriculture (FOFA) foresight scenarios for cropland apply a set of technical improvements and climate change drivers to arrive at harvested areas of crop production to satisfy food balance sheets by 2030 and 2050. The projections for harvested areas on rainfed and irrigated land generate demand for land and water resources under three scenarios (Box S.2).


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When harvested area projections for irrigated and rainfed production are converted to arable land requirements, the cultivated area under the BAU scenario would need to grow from 1 567 million ha in 2012 to 1 690 million ha by 2030 and 1 732 million ha by 2050. Based on expected yield growth and cropping intensities, satisfying the food balance sheets would require the cropland area to expand by 165 million ha by 2050. The BAU scenario projects irrigated harvested areas to increase by 91 million ha by 2050 (Table S.6), indicating an annual growth rate of only 0.14 percent. This represents a significant slowdown, compared to the period 1961–2009, when the global area under irrigation grew at an annual rate of 1.6 percent and more than 2 percent in the poorest countries. Most expansion of irrigated land is likely to take place in low-income countries. Under the BAU scenario, irrigated areas would need to increase their contribution to total production value from 42 percent in 2012 to 46 percent by 2050.

TABLE S.6 **BASELINE (2012) AND PROJECTIONS (2050) FOR IRRIGATED HARVESTED AREAS AND INCREMENTAL EVAPOTRANSPIRATION DUE TO IRRIGATION (INCLUDING EVAPOTRANSPIRATION) ON IRRIGATED HARVESTED AREAS UNDER FAO FOFA FORESIGHT SCENARIOS**

	2012 BASELINE		2050 FOFA PROJECTION		
FOFA SCENARIO	IRRIGATED HARVESTED AREAS (MILLION ha)	INCLUDING ET IRRIGATION (km³)	IRRIGATED HARVESTED AREAS (MILLION ha)	INCLUDING ET IRRIGATION (km³)	INCLUDING ET AND CC IRRIGATION (km³)
BAU (SSP 2/3 – middle of the road) Climate futures RCP 6.0	408	1 285	499	1 540	1 730
TSS (SSP 1 – the green road) Climate futures RCP 4.5	408	1 285	477	1 424	1 594
SSS (SSP 4 – a road divided) Climate futures RCP 8.5	408	1 285	499	1 530	1 771

Note: CC = climate change; ET = evapotranspiration; RCP = representative concentration pathway; SSP = shared socio-economic pathway; SSS = stratified societies; TSS = towards sustainability.

Source: SOLAW 2021 background studies.

BOX S.2

FAO FORESIGHT SCENARIOS FROM A LAND- AND WATER-USE PERSPECTIVE

Business as usual (BAU): Climate futures, RCP 6.0 and SSP 2/3 ("middle of the road")

Arable land (the physical area under temporary and permanent agricultural crops) expands at faster annual rates than in the last decades, and land degradation is only partially addressed. Land intensity, the quantity of land per unit of output, decreases as crop and animal yields increase, but these achievements require the progressive use of chemicals. Deforestation and unsustainable raw material extraction continue while water efficiency improves, but the lack of significant changes in technology leads to the emergence of more water-stressed countries.

Towards sustainability (TSS): Climate futures, RCP 4.5 and SSP 1 ("green road")

Low-input processes lead water intensity to decrease substantially and energy intensity to substantially improve against the levels seen under the BAU scenario. Land-use intensity, the quantity of land per unit of output, drops compared to current levels, thanks to sustainable agricultural intensification and other practices to improve resource efficiency. This helps to preserve soil quality and restore degraded and eroded land. Agricultural land is no longer substantially expanded, and land degradation is addressed. Water abstraction is limited to a smaller fraction of available water resources.

Stratified societies (SSS): Climate futures, RCP 8.5 and SSP 4 ("a road divided")

The world suffers further deforestation. New agricultural land is used to compensate for increased degradation and satisfy additional agricultural demand, which is left unmanaged. The quantity of land per unit of output decreases for commercial agriculture but remains stable or increases for family farmers, who increasingly suffer from crop losses fuelled by extreme climate events. Water use is not sustainable in many regions, and there is little investment towards water-use efficiency. Climate change exacerbates water and land constraints.

Notes

Harvested areas and yield differentials for each cropping system (irrigated and rainfed)

Data on harvested areas are used to calculate the shares of irrigated and rainfed production systems by crop and yield differentials between the two systems in the base year. The FAO and the International Institute for Applied Systems Analysis Global Agro-Ecological Zones (GAEZ) data portal includes geospatial data sets consistent with country-level FAO statistical database (FAOSTAT) data on harvested areas, yields and crop production. These are derived by disaggregating ("downscaling") country-level FAOSTAT production data for the period 2009–2011 to pixel level using an iterative rebalancing approach that ensures matching country totals. The assignment of crops and crop systems to each pixel is based on the FAO Global Land Cover Share, which provides high-resolution land-cover data, geospatial data on land equipped for irrigation (Global Map of Irrigated Areas, available at www.fao.org/nr/water/aquastat/irrigationmap/index.stm) and other data sets.

Land areas

Data on land cover are used to estimate the amount of suitable land available in the future under alternative climate scenarios. The GAEZ data portal includes pixel-level data on protected areas, based on a recent version of the World Database of Protected Areas, a comprehensive global data set of marine and terrestrial protected areas that includes those under the International Union for the Conservation of Nature such as nature reserves and national parks, protected areas with an international designation status, such as World Heritage and Ramsar Wetland areas, and those with national protection status. The land-suitability assessment does not account for land productivity changing over time due to natural or human-induced degradation and may overestimate potential land availability.

Source: FAO, 2018.


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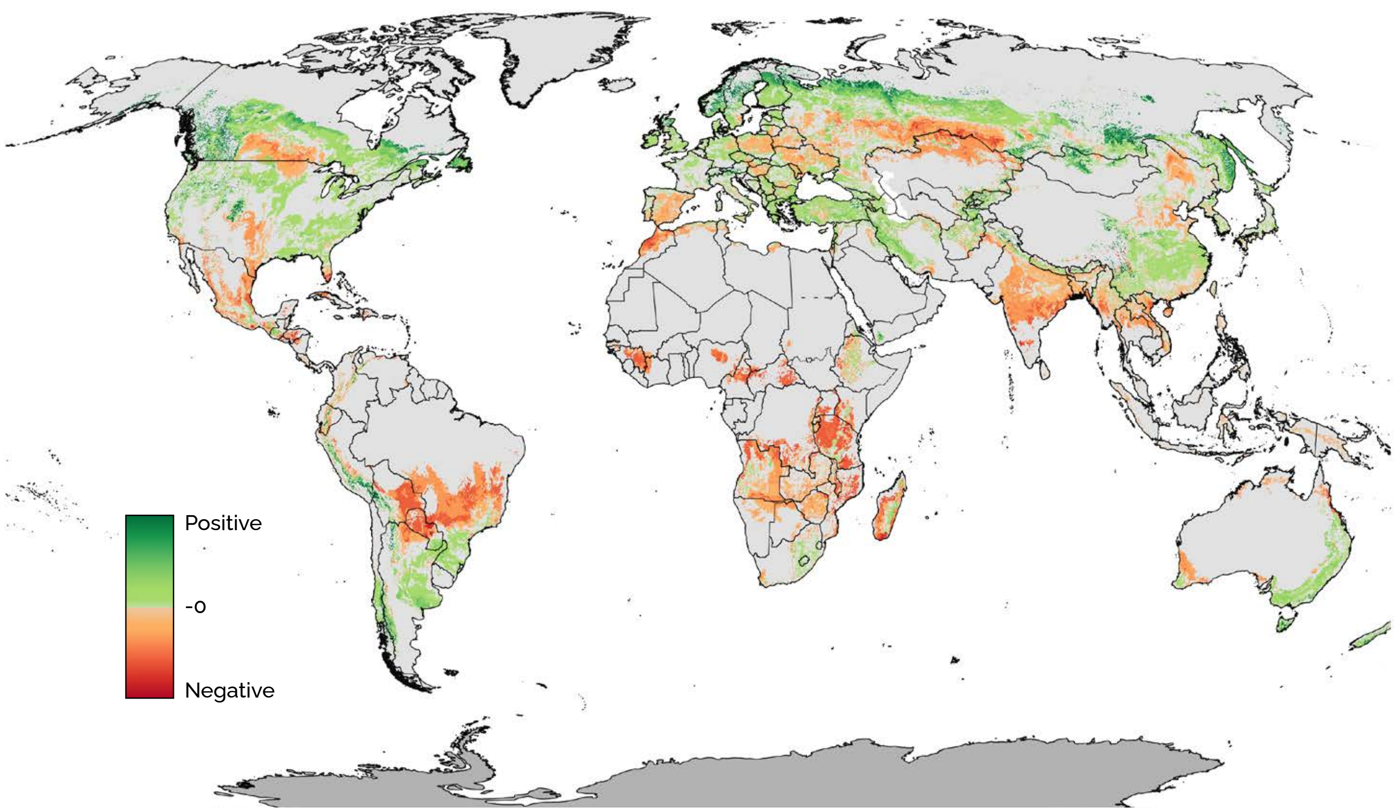
3.3 From climate risk to rainfed production – shifting land suitability

The water resource implications for this growth have been modelled for the SOLAW 2021 report. They indicate evapotranspiration would increase from 1 285 km^3 in 2012 to 1 540 km^3 by 2050 without climate change and to 1 730 km^3 with climate change (Table S.6). Taking account of water requirements for land preparation and leaching, plus conveyance losses from withdrawal to consumption, would push annual gross agricultural withdrawals towards 3 500 km^3.

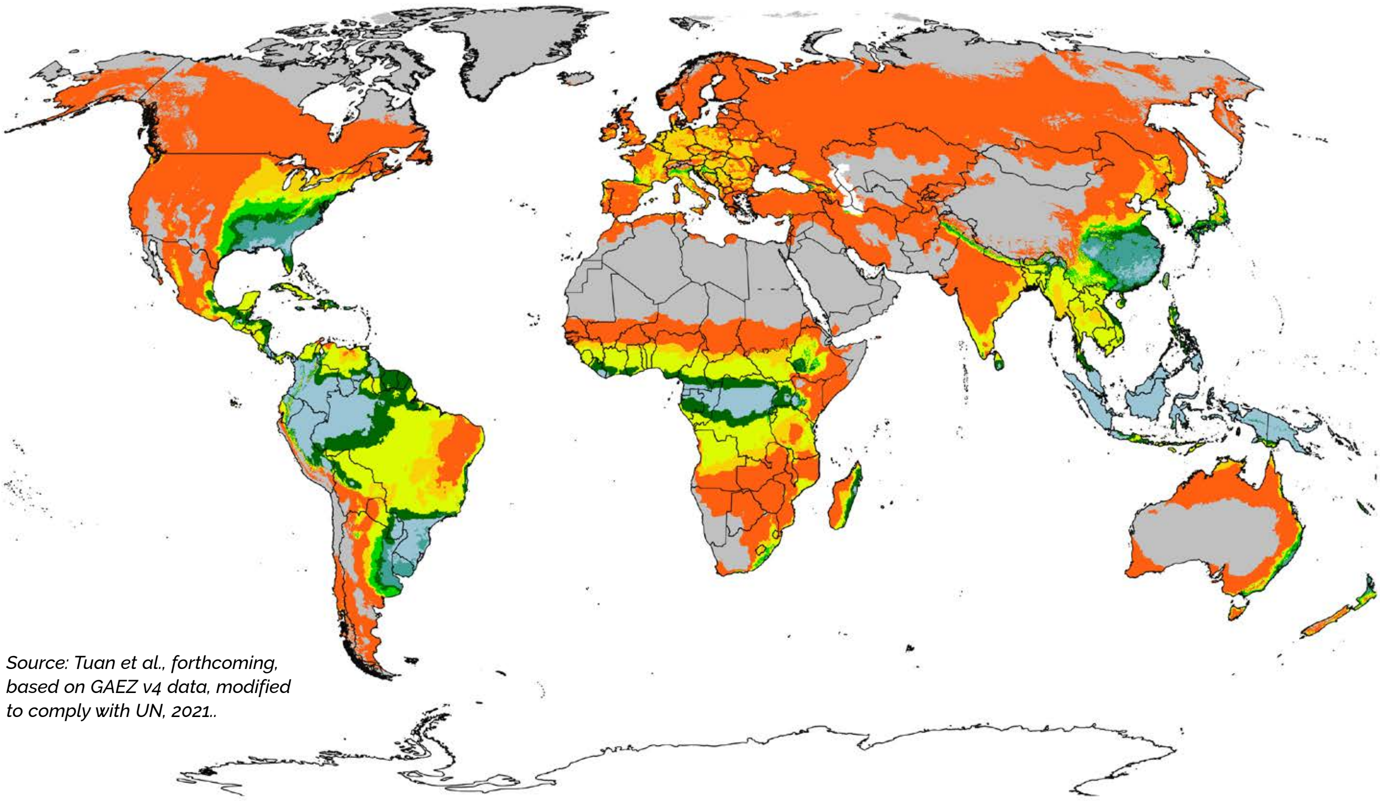
Land suitability for cropping is not static; shifts in suitability and areas are anticipated as the climate changes. Using land resources planning tools, such as the GAEZ methodology, together with climate models, provides invaluable insights into how these changes will redistribute land available for production for different crops and livestock and identify potential impacts on productivity and yield gaps.

MAP S.14 **LAND-SUITABILITY SHIFTS OF RAINFED WHEAT BETWEEN BASELINE CLIMATE (1981–2010) AND THE 2080S (ENS-RCP 8.5)**



Source: Tuan et al., forthcoming, based on GAEZ v4 data, modified to comply with UN, 2021.

MAP S.15 MULTIPLE CROPPING ZONE CLASSES FOR RAINFED AGRICULTURE FOR THE 2080S (ENS-RCP 8.5)



Source: Tuan et al., forthcoming, based on GAEZ v4 data, modified to comply with UN, 2021..

Map S.14 illustrates shifts in land areas suitable for rainfed wheat for a high-emission/high-temperature scenario to the 2080s (RCP 8.5), leading to a 4.2 °C temperature increase. Wheat production would increase in Argentina, Australia, Canada, Chile and Northern Eurasia, and decline in most of Central Africa and parts of Brazil, Central Asia and India. Other crop results are mixed, with some predicted to increase and others to reduce potential cropped areas.

Map S.15 illustrates a shift in opportunities for multiple cropping zones projected into the 2080s, showing the effects of climate change. Supplementary irrigation could also extend the growing season and add value. However, introducing irrigation brings another set of problems, such as access to equipment and water, cost and the required skills to practice efficient irrigation practices.

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TABLE S.7 ABSOLUTE AND PERCENTAGE CHANGES OF RAINFED MULTIPLE CROPPING POTENTIALS BETWEEN BASELINE CLIMATE (1981–2010) AND THE 2080 CLIMATE (ENS-RCP 4.5)

		FUTURE CLIMATE (2080S ENS-RCP 4.5)								CHANGE			
	Rainfed multiple cropping zones (000 ha)	NO CROPPING	SINGLE CROPPING	LIMITED DOUBLE CROPPING	DOUBLE CROPPING	DOUBLE CROPPING WITH RICE	DOUBLE WETLAND RICE CROPPING	TRIPLE CROPPING	TRIPLE RICE CROPPING	TOTAL BASELINE CLIMATE (1981–2010)	TOTAL 2080S (ENS-RCP 4.5)	DIFFERENCE (000 HA)	DIFFERENCE (%)
BASELINE CLIMATE (1981–2010)	No cropping	3 862 810	975 100	3 880	50	0	0	0	0	4 841 840	3 981 700	−860 140	−18
	Single cropping	118 890	4 058 270	367 440	18 720	300	0	0	0	4 563 620	5 223 350	659 730	14
	Limited double cropping	0	165 950	332 550	135 270	42 490	1 070	30	0	677 360	889 780	212 420	31
	Double cropping	0	22 490	181 180	948 510	69 640	44 770	2 010	0	1 268 600	1 371 080	102 480	8
	Double cropping with wetland rice	0	1 540	4 680	53 820	53 410	60 170	48 650	0	222 270	185 750	−36 520	−16
	Double wetland rice cropping	0	0	50	205 760	14 050	332 850	84 950	3 640	641 300	678 190	36 890	6
	Triple cropping	0	0	0	2 120	5 860	36 760	129 340	91 060	265 140	275 640	10 500	4
	Triple wetland rice cropping	0	0	0	6 830	0	202 570	10 660	732 590	952 650	827 290	−125 360	−13
	Total 2080s (RCP 4.5)	**3 981 700**	**5 223 350**	**889 780**	**1 371 080**	**185 750**	**678 190**	**275 640**	**827 290**				

Note: Green indicates no change.
Source: Tuan et al., forthcoming, based on GAEZ v4 data.

Table S.7 lists the absolute and percentage changes in rainfed multiple cropping potential between baseline climate (1981–2010) and the 2080s (ENS-RCP 4.5).

Climate change will bring problems for many, and benefits for some. In some regions, such as Central Africa and Eastern Europe, land areas suitable for cropping will decrease, requiring changes in cropping, livestock and land and water management practices better suited to the new growing conditions. The tropics and subtropics are expected to benefit from multiple cropping. Globally, seed and germplasm exchange among ecoregions and increasing investment in crop breeding for tolerant traits will be crucial to develop crops and varieties that can withstand future changes in temperature, salinity, wind and evaporation.

3.4 Risk implications for land and water

For most common rainfed crops, some regions may benefit from climate change, as the area of suitable land will increase. Increasing temperatures will create options to expand cereal production northwards, benefiting Canada, Northern Eurasia, and parts of Oceania and Southern America. But some regions, such as Central Africa and Eastern

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Europe, will experience decreasing areas of suitable land, requiring cropping systems, land and water management practices, and integrated land-use systems that are better suited to the new agricultural conditions. Higher temperatures in the northern hemisphere and anticipated higher rainfall in some areas could allow the single-cropped area to increase by 9 751 000 km^2 (20 percent) (from no cropping). Double cropping with rice could increase by 601 000 km^2 (27 percent) and the potential area for triple rice cropping would be 910 000 km^2 (34 percent).

However, the consequences for biodiversity loss, carbon sequestration and water services on existing cropped areas and frontier soils would not be trivial. Frontier soils alone are estimated to contain up to 177 billion tonnes of carbon, which might be subject to release, and watersheds serving over 1.8 million people could be affected by the cultivation of climate-driven frontiers.

Water scarcity increases agricultural production risks as water availability, storage and conveyance systems reach their design limits. In many areas with high water stress, farmers manage their production risks by abstracting shallow groundwater for irrigation; in some cases, they use non-renewable groundwater. However, competition for diminishing high-quality groundwater is intensifying as aquifers suffer from over-abstraction and saline intrusion. Many aquifers also suffer from agricultural and industrial pollution.

Climate change increases drought risk by increasing the frequency and magnitude of extreme weather events, it changes the average climate conditions and climate variability, and it generates new threats in regions that may have little experience of dealing with drought. Droughts are slow to develop and not easily recognized at first, but they can quickly become a crisis when severe and damaging impacts emerge that are widespread and have underestimated impacts on societies, ecosystems and economies.

Due to low rainfall and changes in seasonal water availability, agricultural drought has particularly negative impacts on food security because of reduced crop yields, affected rangeland and forest productivity, and increased fire hazards. It especially affects smallholder families who do not have access to adequate water collection or irrigation services, and may lead to competition over diminishing resources.

Water pollution from agriculture is proliferating, as is pollution from domestic and industrial processes. New and emerging pollutants are adding to clean-up costs and challenging technological solutions for land and lacustrine and nearshore marine environments.

Drylands are at risk from a wide range of complex issues including unsustainable farming methods, overgrazing of rangelands, deforestation and climate change. These are compounded by socio-economic and governance issues such as inadequate investment, loss of indigenous knowledge and civil strife. Yet, drylands account for 15 percent of the world's river basins and support the livelihoods and food security of some 2.1 billion people.

The operational question for agriculture is complex. The sector should ask if the risks to food production can be reduced by changing agricultural land and water management practices for productive and resilient agricultural systems while reducing adverse impacts on livelihoods, human health and ecosystem services.

POTENTIAL FUTURE IMPACTS OF CLIMATE CHANGE ON CROPPING AND LAND MANAGEMENT


©FAO/Isaac Kasamani

Higher levels of carbon dioxide concentrations suggest a shift may be needed in land-use patterns and land management to maintain/enhance crop productivity.

Increasing temperatures would improve options for expanding cereal production to higher latitudes, benefiting especially Canada and Northern Eurasia. However, in other areas, such as the highly productive wheat areas in Central and Eastern Europe, it is likely to decline.

Increasing temperatures may adversely affect traditional cash crop production, such as coffee in Brazil and West Africa, and olives in the Maghreb. However, better growing conditions for coffee may occur in other areas such as Eastern Africa.

Alternative crops and changes in management practices, including technology transfer programmes, will be needed in some regions where farmers are forced to change their traditional cropping patterns.

Crop production in many areas would benefit from adopting higher inputs and improved crop management.

Climate change may bring opportunities for increasing multiple rainfed cropping, particularly in the tropics and parts of the subtropics.

Increasing investment in germplasm and seed exchange among ecoregions and crop breeding for tolerant traits will be crucial in developing crops and varieties that can withstand future changes in temperature, soil moisture supply, salinity, wind speed and evaporation.

For those areas where the climate becomes marginal for current staple and niche crops, there are alternative annual and perennial tree crops, livestock and soil and water management options available. Experiences from similar ecoregions and other socio-economic contexts should be analysed to guide how the land is best used in the future.

Socio-economic and ecological conditions will essentially determine the feasibility and justify investing in the most-appropriate adaptations. Such analysis and scenario development are essential elements of land-use planning, as are participatory approaches that involve all stakeholders, notably farmers, pastoralists, and fishers and foresters and their rural communities, and other users of the land and water resources (in aquaculture, beekeeping, greenhouse use, carbon manufacture and sand mining).

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4 RESPONSES TO RISKS AND ACTIONS

The SOLAW 2021 report establishes the state of land, soil and water resources, and the drivers, the risks and the opportunities for planning and investment. The risks to agricultural production are derived from natural variation in climate and human-made changes and pressures. These include the influence of socio-economic processes, policy decisions, and institutional and financial structures. Some drivers have led to more-conducive environments; others have created pressures and constraints, some by design and others by unexpected actions. A diagnosis of these diverse outcomes does not automatically lead to prescriptive single-purpose "solutions" but rather a programmatic treatment of land and water "state", which can turn natural processes and human action towards a desired state or new equilibrium.

Land and water resources and their governance underpin food systems that are productive, viable, resource-use efficient, resilient and inclusive of those who produce them and those who depend on them. Four key action areas, taken together, can facilitate a transition to sustainable land and water management.

Some key findings in this section...

- **Data are required to support planning:** Tools for sustainable planning and management are available. Data collection needs to improve. Monitoring the effects of climate change in relation to agroecological suitability will prove essential for planning resource use along the entire food value and supply chains.

- **Agriculture's "solution space" has expanded:** Advances in agricultural research have broadened the technical palette for land and water management.

- **No "one size fits all" solution exists, but there is a "full package" of workable solutions:** However, these will succeed only when there is a conducive enabling environment, strong political will, sound policies and inclusive governance, and full participatory planning processes across all sectors and landscapes.

Innovative information and communications technology, mobile technologies, remote-sensing services (example above from the FAO WaPOR platform, wapor.apps.fao.org), cloud-based computing and open access to data are benefiting smallholder farmers. However, it is important to avoid a "digital divide".

4.1 Action area I: Adopting inclusive land and water governance


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Effective and inclusive governance is essential for building capable and informed institutions and organizations. However, advances in land and water governance require coherent and integrated policies in the various sectors to deliver on the multiple objectives related to natural resources management, trade-offs, and related ecosystems and services. Coherence is needed across all levels of government and policy areas, as decisions outside the water and land domain can significantly affect natural resources. This imperative extends into transboundary resources management because water and sediment cross international borders.

Understanding and recognizing the relationship of customary and statutory land and water rights and the role of hybrid legal systems for inclusive water and land tenure regimes can form the basis for achieving a diverse array of policy and development goals. Effective, efficient and inclusive land and water policies need developing through multilevel governance. Multi-stakeholder and multidisciplinary approaches are critical in achieving integrated land and water management, including engagement with civil society, academia, local communities, women and girls, youth and the private sector.


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Evidence demonstrates that restoring degraded resources, sustaining intensification and increasing resilience can be achieved through planning and implementing integrated and multi-stakeholder initiatives at scale. This can be done through watershed or river basin management, integrated landscape management (ILM) and restoration, irrigation modernization and climate-smart agriculture (CSA), supported by long-term strategies, investments and innovative financing and partnerships to sustain initiatives and improve livelihoods.

Policy and legal frameworks governing land and water resources at national level are often disjointed or lack implementation, or have proven ineffective due to institutional and technical silos and mismatch in jurisdiction over ecologically interconnected resources. Integrated water resources management acknowledges that water needs managing as a system, usually as a basin, sub-basin or aquifer, and water system boundaries often do not correlate with political or administrative boundaries. To achieve good governance and increase water-use efficiency and sustainability, technical, financial and institutional solutions must be in place, followed by effective and coordinated cross-sectoral implementation.

Information about land and water (quantity and quality), distribution, access, risks and use is essential for effective decision-making.

Real-time digital information can enable policymakers to employ quality, accessible, timely and reliable disaggregated data, smart technologies and robust monitoring mechanisms to develop effective cross-sectoral policies to "leave no one behind".

Current levels of financing remain substantially inadequate to reach the international community's goal for life on land (SDG 15) and sustainable management of water (SDG 6). International funding and public and private investments are encouraged to improve the enabling environment and explore new approaches for investment in environmentally sustainable land, soil and water resources. Farmers must also be recognized as prime investors and not just beneficiaries of public subsidy and tariff protection.

Three main governance responses promise effective transformation towards coherent and equitable land and water governance and contribute to sustainable food systems, people and ecosystems:

- develop coordinated and coherent policy, legal and institutional arrangements across all sectors;
- devolve governance and address power differentials; and
- adopt adaptive governance and structural flexibility.

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4.1.1 Developing coordinated policy, legal and institutional arrangements

International conventions and high-level political commitments provide a strong mandate and support for multisectoral and integrated land and water governance. They provide the foundations for achieving SDGs and negotiating social, economic and environmental outcomes.

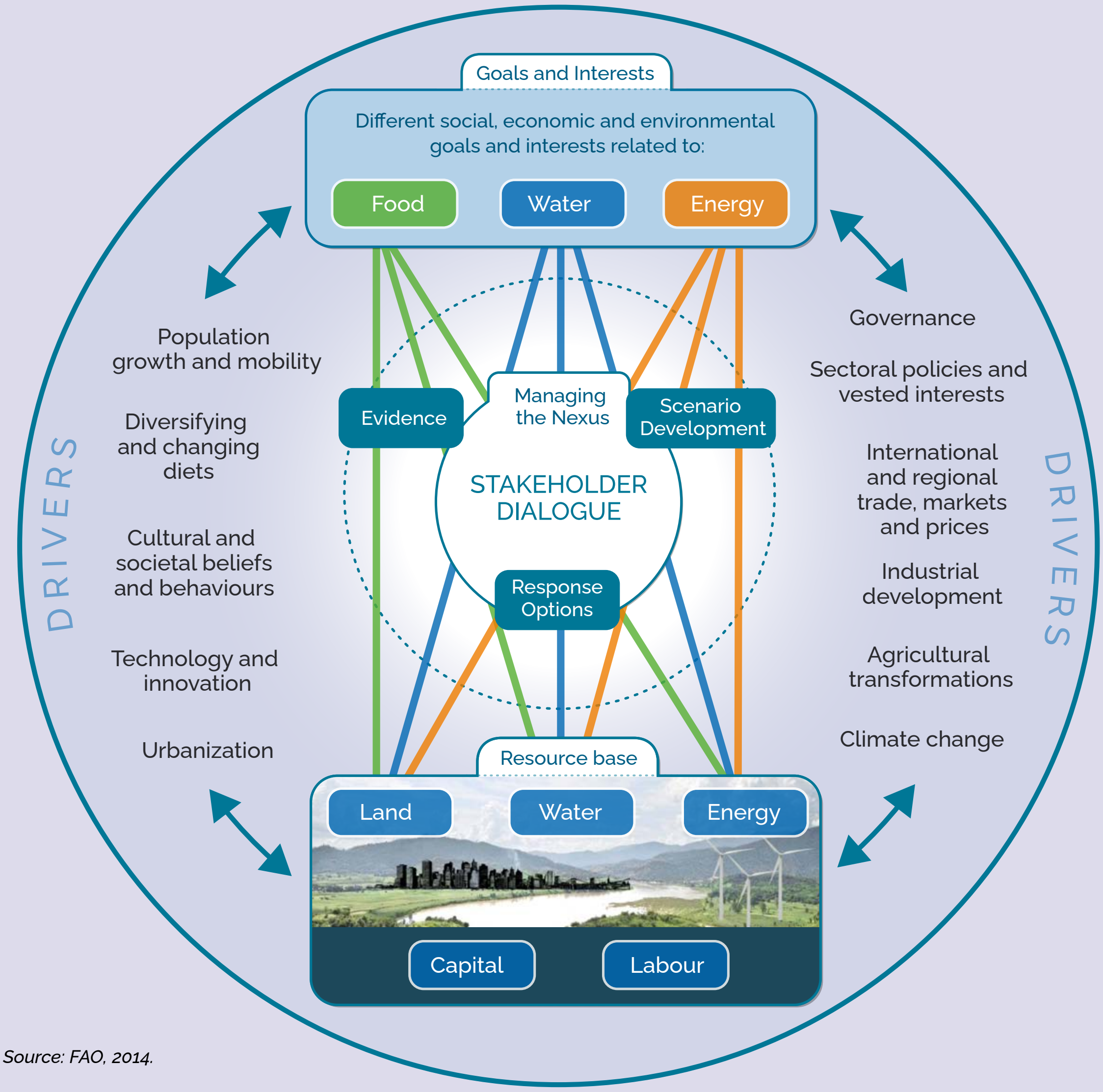
Solutions to address land and water challenges can be selected and adapted to specific circumstances, and supported by governance measures and strengthened institutions and capacities at all levels of decision-making. At a fundamental level, there is need for effective land and water resource governance measures to drive well-adapted investments and behaviour change. This is expected to turn sustainable resources and ecosystem management options into long-term actions at scale.

Governance arrangements and instruments are needed to understand and address trade-offs across sectors and reconcile economic development, social protection and environmental conservation goals. A clear focus is needed to mitigate inequalities around water allocation and land and

THE WATER–FOOD–ENERGY NEXUS APPROACH IN THE RED RIVER BASIN IN VIET NAM

Reservoirs in the upstream reaches of the Red River in northern Viet Nam regulate flows and generate much of the electricity needed for the modernization and industrialization strategies of Viet Nam. The same system supplies water for domestic use for irrigating 750 000 ha of rice in the Red River delta, which is critical to social stability and food security. Most irrigation systems use electric pumps with energy supplied from the upstream hydropower schemes.

As water becomes scarce and competition between the energy and agricultural sectors increases, there is still a lack of reliable and policy-relevant data and information to guide water allocation choices. Effective cross-sectoral consultation is needed to address this problem and to ensure decisions on water release and allocation are taken as part of an integrated, long-term and multi-sectoral strategy.



Source: FAO, 2014.

water access through recognizing, respecting and enforcing land and water tenure rights, in particular, access and user rights of individuals and groups who rely on those resources for food and livelihoods. Vulnerability and risk assessments are needed to avoid adverse risks.

Cross-sectoral and territorial approaches, such as ILM, IWRM and the water–food–energy nexus approach, provide valuable experiences to refine and apply integrated land and water governance frameworks that enable conservation, sustainable management, and restoration of land resources and ecosystems at scale and contribute to achieving SDGs. However, these approaches require strategic policy tools, particularly participatory land planning, incentive mechanisms, sustainable financing and competent decentralized institutions. These will need equipping with up-to-date diagnostic, planning and evaluation tools, integrated data sets, up-to-date digitalized administration tools and multi-stakeholder approaches.

Proven strategies for enhancing nutrition and ecosystem health and sustainable and resilient agrifood systems that rely on soil, water and biodiversity management include agroecology, conservation agriculture, organic agriculture, agroforestry and integrated crop–livestock systems.

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Land, soil and water actions within and beyond the farm are becoming mainstream to help address trade-offs to reconcile production and ecosystem management, increase agricultural productivity and climate resilience, reduce food loss and waste, change food consumption patterns, and transition to food systems that are more resource efficient.

4.1.2 Devolving governance and addressing power differentials

Devolving governance and addressing power differentials are prerequisites to informing policies adapted to socio-economic and ecological settings, and to implementing strategies that benefit the poor. Inclusive land and water governance requires deliberate linkages across institutions, scales and sectors, and engagement of all actors. Platforms for dialogue and consensual approaches are needed to enable effective engagement and negotiation by civil society, including marginalized groups, with the government and the corporate sector. This will help ensure negotiated trade-offs are equitable, and allow transition to sustainable food and agricultural systems.

BOX S.3
KORONIVIA JOINT WORK ON AGRICULTURE (KJWA)

This initiative provides a platform for strengthening land and water governance by integrating climate adaptation and mitigation policies across agricultural sectors. Specific issues addressed under KJWA include methods and approaches for assessing: adaptation, adaptation co-benefits, mitigation, improved soil carbon, health and fertility in grasslands and croplands; improved livestock management (including agropastoral production) systems, socio-economic and food security dimensions of climate change in agriculture; and modalities for implementing outcomes. In addition, the process facilitates multi-stakeholder knowledge exchange and identifies key policy and governance interventions and good practices for scaling up to support CSA, livelihoods and food security.


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Source: UNFCCC, 2018.

4.1.3 Adopting adaptive governance and structural change

The landmark Koronivia Joint Work on Agriculture (KJWA) highlights and prioritizes the climate-related risks through public policies and governance instruments, recognizing land as a critical part of the climate solution (Box S.3).

Instruments, such as payments for environmental services, can incentivize adoption of sustainable and productive land and water management and agrifood systems by transferring some benefits to land users and stimulating further investment.

Experiences in scaling up SLM and restoration demonstrate the need for substantial, long-term and targeted incentives to engage the various stakeholders, from design through to planning, implementing and monitoring. There is a need for clear land tenure and use rights.


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4.2 Action area II: Implementing integrated solutions at scale

The international community has promoted sound and sustainable natural resources management and restoration, including specific approaches for land, soil and water and ecosystem services. These approaches can help define critical thresholds in natural resource systems, leading to beneficial outcomes when wrapped up as packages or programmes of technical, institutional, governance and financial support.

BOX S.4

INTEGRATED CATCHMENT PLANNING AND GOVERNANCE FOR SLM SCALING OUT

The Transboundary Agroecosystem Management Project in the Kagera River basin was one of the 36 projects of the TerrAfrica Strategic Investment Programme for SLM in sub-Saharan Africa.

The Kagera River basin (Burundi, Rwanda, Uganda and United Republic of Tanzania) supports the farming, herding and fishing livelihoods of over 16 million people. Yet, rapid population growth, intensification of agriculture, progressive reduction in farm sizes, and unsustainable land and water management practices have degraded the resource base.

Catchment planning and management approaches were integrated into local governance strategies to promote participatory and sustainable land, water and biodiversity management. In Burundi and the United Republic of Tanzania, watershed management groups were established to prioritize and oversee implementation, resulting in improvements in food security and resolution of resource conflicts. In Uganda and the United Republic of Tanzania, participatory land-use planning enabled communities and the government to endorse the results of catchment planning and integrated agroecosystem management for achieving agricultural productivity, natural resources, climate, biodiversity, food security and livelihood benefits.

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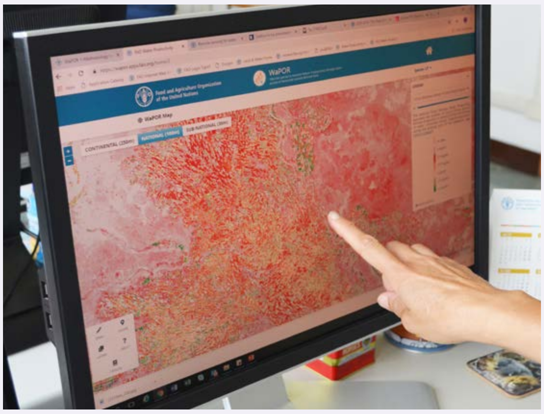
Source: FAO, 2017.

4.2.1 Planning land and water resources – a crucial first step

Sustainable resources management across all agroclimatic zones is a crucial first step. As pressures on land and water systems risk compromising agricultural productivity where growth is most needed, land and water resources planning at different decision-making levels will play a key role in promoting sustainable and efficient resource use.

A wide range of resource planning tools and approaches support decision makers, planners and practitioners, working at global, national and local levels, to plan, take actions and scale out SLM options (Box S.4). Although lack of data often constrains effective planning, resources planners respond to the challenge and use remote sensing, big data and innovative analytical methods that revolutionize planning. Models are increasingly used in participatory approaches involving all stakeholders. They are used to develop and adapt food and agricultural systems to improve economic and social conditions and generate multiple benefits and opportunities for local and national economies and private/public investments.



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New tools are helping resources planners to understand the extent and location of yield and production gaps, as many regions continue to suffer poor rainfed crop yields and production shortfalls. In sub-Saharan Africa, for example, yields are only 24 percent of what is achievable with higher levels of input and sound resources management. Substantial yield gaps also occur in Central America, India and the Russian Federation, attributed to low inputs and ineffective management. Effective planning enables decision makers to target interventions and enhance food production according to needs and investment opportunities.

The land resources planning toolbox developed by FAO offers a resource that supports participatory land resources planning. It provides information and an inventory of tools and approaches to help stakeholders working in different regions and sectors and at different levels. It is web based, freely available and updated regularly with summary descriptions and links to a comprehensive range of land resources planning tools and approaches developed by FAO and other institutions.

FAO water resources tools include water accounting and auditing, water harvesting, modular farming systems, non-conventional water resources planning, a drought toolbox including early warning systems, AquaCrop, the environmental flow tool and an integrated fisheries system to increase benefits and sustainability by integrating fisheries with irrigation schemes.

Land and water management also needs to be an integral part of disaster risk management plans, flood and drought management plans, national adaptation plans and plans to meet NDCs developed under the Paris Agreement.

4.2.2 Packaging workable solutions

The private sector's diverse spectrum, from small-scale farmers through to those involved in processing, storing, transporting and marketing phases of the food value chain, including their suppliers, offers a significant opportunity to respond to land and water challenges. Their choice of technology and site selection for operations, environmental stewardship and social responsibility practices are under a spotlight, and offer more initiatives and best-practice examples, including certification and corporate disclosure schemes.

FAO adopted sustainable intensification and CSA to help Members adapt to future increases in demand for calories and to limited land and water resources. Sustainable intensification includes increasing resource-use efficiency and optimizing external inputs, minimizing adverse environmental impacts of food production, closing yield gaps on underperforming existing agricultural lands, and using improved crop varieties and livestock breeds.

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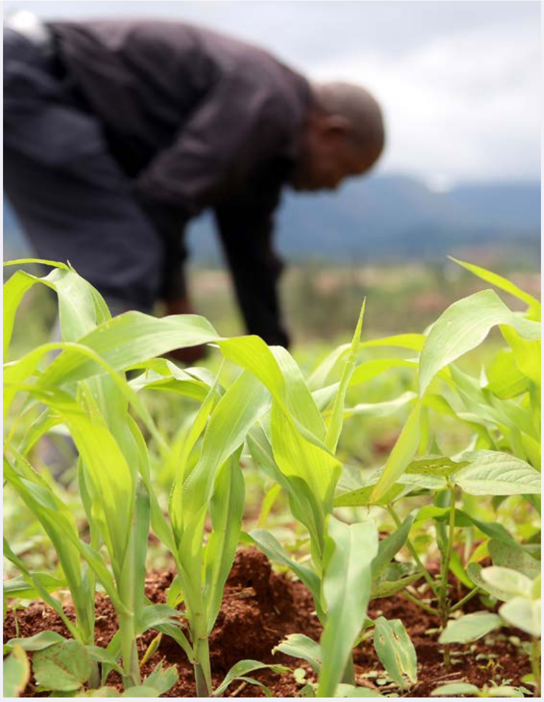

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Climate-smart agriculture aims to increase agricultural productivity and incomes, adapt and build resilience to climate change, and reduce GHG emissions.

The *World water development report 2018* focuses on NbSs for water. These solutions can be a powerful strategy for encouraging the agricultural sector to redirect investment in ecosystem services. They offer long-term and cost-effective interventions to address water management, soil restoration, biodiversity and conservation.

Integrated land and water management approaches are now supercharged with information and communications technology (ICT) and products. Even the simple introduction of mobile phones will provide the coordination backbone for multidisciplinary and multi-stakeholder land management and will remove many barriers to scaling out (Box S.5). Climate-smart programmes can now push sophisticated environmental or pest control content to users in the field.

Treating land and soils with care and managing water responsibly can be emphasized through knowledge-based approaches, particularly when targeted through landscape or environmental services approaches.

Agriculture's "solution space" has expanded. Advances in agricultural research have broadened the technical palette for land and water management. Nature-based solutions can be combined with pest control, crop phenology and soil biodiversity, and applied at scale to reduce the build-up of environmental pressures.

Increasing land and water productivity is crucial for achieving food security, sustainable production and SDG targets. However, there is no "one size fits all" solution. A "full package" of workable solutions is now available to enhance food production and tackle the main threats from land degradation, increasing water scarcity and declining water quality. But these will succeed only when there is a conducive enabling environment, strong political will, sound policies and inclusive governance, and full participatory planning processes across all sectors and landscapes.

Measures to adapt to and mitigate the impacts of climate change in agriculture are part of a continuum ranging from addressing the drivers of vulnerability to explicitly targeting climate change impacts.

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BOX S.5

ADVANCES IN ICT HELP SMALLHOLDER RICE FARMERS TO EXPLOIT CROP DIVERSIFICATION

Advances in ICT, remote sensing and big data can push targeted policies and strategies cost-effectively. Knowledge and mobile phone applications to support farmers and herders improve productivity, manage associated environmental risks, and ensure sustainable land and water management are available. An example includes identifying rice fallows in Asia in real time. This provides opportunities to exploit fallows for crop diversification, such as growing food legumes, applying nutrients to address soil and plant deficiencies, and minimizing agrochemicals, and also for climate forecasting.

Source: Biradar et al.*, 2020.*

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4.2.3 Avoiding and reversing land degradation

Human-induced land degradation is now a priority, although it has been largely ignored in the past. It is avoidable and reversible in many instances. Approaches such as SLM that address soil degradation challenges and manage soil moisture, plant growth and associated and biodiversity will be crucial in meeting global food security aspirations and SDGs. These will need mainstreaming and scaling out with support from effective policies and financial mechanisms. Studies suggest that restoration costs less than a third of the cost of inaction, and preventing degradation is generally far less costly than restoration.

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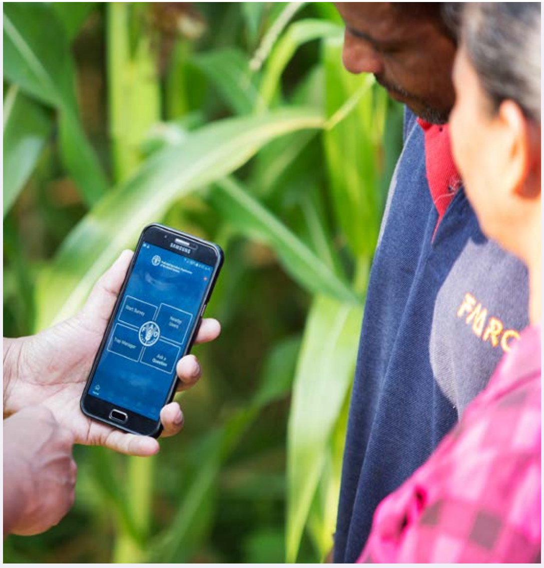
Land degradation neutrality, a state where land area and quality support ecosystem function and enhance food security, can help governments face the challenges of degradation and set targets and plan interventions based on the principle of Avoid > Reduce > Reverse land degradation.

The World Overview of Conservation Approaches and Technologies (WOCAT) is a knowledge system to inform SLM and LDN implementation. The WOCAT system includes techniques and approaches that include water harvesting, soil and water conservation, rainfed and irrigated agriculture, livestock and agropastoral management, watershed management, and climate adaptation and mitigation.



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4.3 Action area III: Embracing innovative technologies and management

Technical responses are now better targeted across agriculture to improve land, soil and water management significantly. Mobile technologies are spreading rapidly, together with innovative on-farm mechanization. Remote-sensing services, cloud-based computing and open access to data and information on crops, natural resources, climatic conditions, inputs and markets already benefit smallholder farmers by integrating them into digitally innovative agrifood systems. Box S.5 illustrates one such example. However, care is needed to avoid a "digital divide" among those with different levels of access to new technologies. Sustainable land management and CSA can be combined with land, soil and water management and taken to scale to maintain production levels.

4.3.1 Tackling problem soils

Soil salinization takes up to 1.5 million ha of farmland out of production annually. The consequences of allowing the continued build-up of soil salinity are significant. Options are available to deal with salinity issues and drainage of salt-affected soils vital to future food security in arid and semi-arid environments. In addition to traditional methods for leaching soils, one option is to accept saline drainage water and adopt biosaline agriculture by selecting salt-tolerant crops and appropriate cropping patterns and management practices. If planned at the watershed or landscape level, this adaptive approach can reduce environmental degradation and restore the ecosystem in drylands.

The agriculture sector needs to accept responsibility for managing environmental risks by reducing chemical inputs and animal waste on land, which are a global priority. Integrated pest management and the International Code of Conduct for the Sustainable Use and Management of Fertilizers (Fertilizer Code) are instruments designed to counter the trend towards unsustainable agricultural intensification and the potential for increased use and harmful effects of fertilizers, pesticides and herbicides. The Fertilizer Code offers guidance to tackle misuse, underuse and overuse of fertilizers, bearing in mind nutrient imbalances and soil pollution.

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4.3.2 Addressing water scarcity and drought

Rainfed agriculture accounts for 80 percent of cultivated land and produces 60 percent of global food and fibre production. Improving production and resilience requires optimizing soil water use by improving rainwater capture, increasing soil moisture retention, maximizing infiltration and minimizing surface run-off and evaporation. Soil moisture is key to soil health and function. It helps to sequester SOC and stops carbon-rich soils from drying out and increasing their emissions.

Freshwater scarcity is driving renewed interest in irrigation, which accounts for 70 percent of all freshwater withdrawals and 90 percent of all freshwater consumption. New planning, design and evaluation technologies, such as water accounting and auditing, ICT and automation are helping to modernize existing schemes and inform new designs. Attention is shifting from ill-defined water-use efficiencies to increasing water productivity, making real water savings and meeting farmer demand for more flexible and reliable water supplies.

Water storage provides a buffer for managing climate uncertainty and variability, for managing differences in supply and demand, and for building resilience to climate change. Storage is declining globally, but this trend needs reversing. A shift from conventional infrastructure-led approaches to storage management to an appreciation of all the different kinds of storage (natural and built) is already taking place. Increased conjunctive management of surface and groundwater storage, as opposed to conjunctive use, is expected to spread risk and provide a wider range of social and environmental benefits.

Most countries still put drought in the same category of natural disasters as floods and earthquakes. This wastes valuable resources and does not help to build resilience for future events. Shifting to a risk management approach can significantly lessen drought risks and impacts. A "three-pillar" approach that requires investment in monitoring and early warning systems, studies to assess vulnerability to drought and actions to reduce adverse impacts is now being deployed.

Green infrastructure and NbSs contribute to minimizing flood risk by using ecosystem-based approaches for flood protection. A case in point is floodplain restoration rather than dike construction. Green infrastructure provides benefits to society by avoiding flood damage to existing infrastructure, and offers additional benefits such as biodiversity improvements, water quality improvements and recreation opportunities.

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Nature-based solutions can protect against river flooding in agricultural, urban, hydro-geomorphological and forest settings. Agricultural measures aim to manage run-off and reduce flood risk. Forest measures aim to manage woodlands by intercepting land overflow or by encouraging infiltration and soil water storage. Hydro-geomorphological intervention includes wetland and floodplain restoration and management, induced channel meandering and regrading of stream beds to match pre-development fluvial energy gradients.

A circular economy is equally as applicable to agricultural water management as to the broader food systems. It offers opportunities to use non-conventional waters that might otherwise go to waste, such as saline and brackish water, agricultural drainage, water containing toxic elements and sediments, and wastewater effluents. Other aspects of reuse within the farming system include nutrient recycling, regenerating soil health, and reducing non-renewable energy and materials and inputs used in rainfed and irrigated systems.

4.3.3 Going beyond the farm

Many actions beyond the farm and in food systems bear directly on land, soil and water management, and are becoming mainstream. They include current approaches to reconciling agricultural production and ecosystems management, adopting regenerative practices on cropland and grasslands, increasing agricultural productivity, reducing food loss and waste, attempting to change food consumption patterns, and the advent of circular food systems that improve resource-use efficiency. These reflect the potential benefits of adopting advanced agricultural systems across diverse landscapes and social settings that generate various

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products, employment, secure livelihoods, and nutritious and sustainable diets, while sustaining resources and healthy functioning ecosystems and contributing to reduced GHG emissions and increased carbon sequestration potential.

Innovative approaches that target transitioning to sustainable food systems, food security and nutrition can be adapted and applied in specific land and water settings. The approaches depend on the entry point such as agroecology, conservation agriculture, organic agriculture, agroforestry, integrated crop–livestock systems, CSA and sustainable intensification. The 2021 Food Systems Summit recognized the importance of such transitioning as multisector territorial approaches for scaling up proven practices.

Progress in breeding crop varieties and livestock traits has been good since 2000. These are vital to boost yields and tolerance to various stressors, such as drought, waterlogging, cold and salinity. They will also be increasingly important in adapting to climate change and complementing existing solutions, such as adding more water, agrochemicals and mechanization. Genetically modified crops continue to be the subject of a long-running debate regarding risks to biodiversity, human and environmental health, and benefit sharing.

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Reducing food loss and waste is one of the most-promising measures to improve food security, lower production costs, reduce pressures on natural resources and improve environmental sustainability. Sustainable Development Goal Target 12.3 calls for halving per capita global food waste at retail and consumer levels and reducing food losses along the production and supply chains by 2030.

Circular food systems are needed to overcome inefficiencies in the current, essentially linear, economic model involving extracting natural resources to make products, using them for a limited period and discarding them into landfill as waste. The estimated annual cost to the global food system amounts to USD 1 trillion. The alternatives are farming close to rural settlements and cities, regenerative food production, using natural processes rather than chemicals, recycling, minimizing waste and pollution, and improving nutrition and sustainable diets.

Rural communities living in drylands have developed agricultural systems and practices that are adapted to arid, semi-arid and subhumid conditions and drought risk over generations of experience. They depend on limited land potential and water resources, and have developed mixed crop–livestock systems based on short-season drought-resilient crops and receding floodwaters alongside wetlands and river plains. They can provide lessons, knowledge and experience for countries recently experiencing water shortage and drought due to climate change.

4.4 Action area IV: Investing in long-term sustainability

Rethinking investments in agriculture is needed to support integrated land and water resources management in rainfed and irrigated agriculture and to focus on policy coherence. The high costs of degradation and inaction highlight the urgency to increase investments in sustainable land, soil and water management and in restoring degraded ecosystems, including viable land and water management technologies, integrated landscape approaches in priority river basins and ecosystems at risk. Emerging events following the advent of COVID-19 in early 2020 also need to be part of future investments, as they have exposed vulnerabilities in global supply chains that are still playing out.

The main scope of international investment in agriculture sectors has included agricultural development and governance, irrigation and drainage improvement, water resources management, climate change and, to a lesser extent, land and soil resources management. Many projects also seek to improve agribusiness, have an ecological or environmental focus, or focus on poverty alleviation and community development. Conventional funding has aimed to maximize

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agricultural efficiency and find competitive advantage, which has meant that in land- and water-scarce areas in particular, food self-sufficiency has been given a priority lower than that of producing exports of high-value crops.

Investments are therefore needed to move from infrastructure solutions and increasing production to sustaining productivity of rainfed and irrigated systems through improved governance, integrated interventions at scale and innovation in management and technology.

Investment in integrated interventions at scale shows great promise, and can be supported through innovative financing and incentive mechanisms. Public investment can help to develop capacities across producer associations, regulators and applied research. An effective land and water governance framework that mobilizes responsible investments and promotes the adoption of innovative management and technology in concert with sustainable land and water practices is a realizable goal. It requires understanding trade-offs among sectors, conflicts between land and water use for agriculture, forests and urban needs, and the urgent need to curb GHG emissions, through avoiding deforestation and enhancing carbon sequestration.

Investments from the private sector need to complement investments from development banks and environmental funds. Governments can encourage consumers, non-governmental organizations and businesses to adopt responsible investments towards land and water management and sustainable food and agriculture systems.

Farmers and local communities are also key investors when productivity gains help sustain livelihoods and improve income levels. Incentivizing farmers to become investors in sustainable land and water management can bring all-round environmental benefits. However, they will need support from innovative financing and instruments that reconcile production and environmental management. Instruments that support community-based land and water productivity improvements, small-scale infrastructure and access to microcredit are all likely to be effective.

Finally, it should be stressed that complementary investment is needed in data and information management to improve connectivity among all producers, markets and regulators. Investment in innovative technologies and research is also needed, particularly in renewable energy systems and genetic applications. Early warning systems and performance monitoring will also improve on-farm decision-making, while information on adverse environmental and social impacts will help guide responsible investment.

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5 KEY FINDINGS OF SOLAW 2021

Land and water systems are just managing to meet the demand placed upon them by an increasingly complex global food system driven by unrelenting population growth. There is little room for expanding the area of productive land, yet 98 percent of global calorie production is derived from land. The environmental integrity of these systems needs to be safeguarded if they are to be kept in play.

The current patterns of agricultural intensification are not proving sustainable. High levels of land and water use are stretching the productive capacity of land and water systems to the limit, and severely degrading land and environmental services in the process. Climate change is expected to increase evapotranspiration and alter the quantity and distribution of rainfall, leading to changes in land/crop suitability and greater variations in river run-off and groundwater recharge.

At the same time, farming systems are polarizing. Large-scale commercial holdings dominate agricultural land use, concentrating many millions of smallholders in subsistence farming on lands susceptible to degradation and water scarcity. Food security for millions of poor is threatened by water scarcity, with groundwater depletion affecting vulnerable rural populations.


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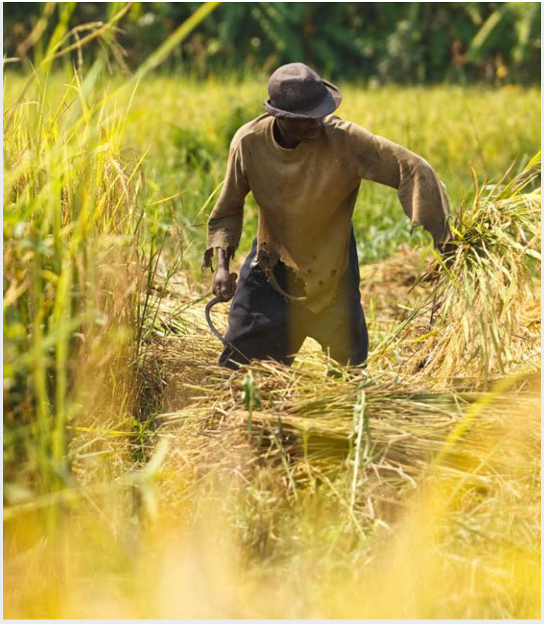
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The social challenges and environmental risks faced by agriculture continue to proliferate. Pressures on land and water resources arise largely within agriculture and the wider food system, generating significant GHG emissions and aggressive soil and water pollutants. The slow-onset risks of human-induced land degradation, soil erosion, salinization and groundwater pollution may not be salient, yet they run deep and are persistent. The role of soil and water management in reducing agriculture's GHG emissions will be pivotal.

However, despite this level of pressure, land degradation is reversible. Remedial land management is possible but only under much-reformed land and water governance that can take remediation to scale and distribute benefits to those who depend on stable, long-term access to productive land and fresh water.

There is no doubt that agriculture's "solution space" has expanded. Advances in agricultural research have broadened the technical palette for land and water management. Rapid improvements in information technology offer the prospect of digital democracy. However, to apply solutions at scale, land and water governance will need adjustment to make advances inclusive and to provide support to farmers for innovation.

Any advance in transforming food systems to meet future demand will require a focus on land resource planning in which systemic analyses of land, soils and water are combined with poverty and food security monitoring. The tools for planning and management are available. Data collection and information dissemination need to improve. Monitoring the effects of climate change in relation to agroecological suitability will prove essential for planning resource use along the entire food value and supply chains.

Implementation of plans through integrated multisectoral approaches need not be complex. Such approaches can be intuitive and may require only close collaboration across sectoral boundaries. However, farmers and resources managers need to be much more risk aware and work together with planners in setting their responses and contingency planning.

The level of support provided to agriculture will need to be redirected to bring about desired gains in the long-term stability of agriculture's natural resources base and the livelihoods of those who depend upon them. Planning a way out of the downward spiral of land degradation and water scarcity offers promise when combined with forward-looking incentives for climate adaptation and mitigation. There is now scope for progressive multiphased financing of agricultural projects that can be linked with redirected subsidies to keep land and water systems in play.

Finally, no "one size fits all" solution exists, but a "full package" of workable solutions is available. These will succeed only when there is a conducive enabling environment, strong political will, and inclusive governance of land and water.

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

Systems at breaking point

Synthesis report 2021

Satisfying the increased demand for food is placing pressure on the world's water, land and soil resources. Agriculture has its part to play in alleviating these pressures and contributing positively to climate and development goals. Sustainable agricultural practices can lead to direct improvements in the state of land, soil and water, and generate ecosystem benefits as well as reduce emissions from land. Accomplishing all these requires accurate information and a major change in how we manage the resources. It also requires complementing efforts from outside the natural resources management domain to maximize synergies and manage trade-offs.

The objective of *The state of the world's land and water resources for food and agriculture* (SOLAW 2021) report is to build awareness of the status of land and water resources, highlighting the risks, and informing on related opportunities and challenges. It also aims to underline the essential contribution of appropriate policies, institutions and investments. Recent assessments, projections and scenarios point to the accelerated depletion of land and water resources and associated loss of biodiversity. The SOLAW 2021 report highlights the major risks and trends related to land, soil and water resources, and presents the means for resolving competition among users and generating the desirable benefits. The report provides an update of the knowledge base and presents a suite of responses and actions to enable decision makers to make an informed transformation from degradation and vulnerability towards sustainability and resilience.

#SOLAW2021

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