Food and Agriculture
Organization of the
United Nations

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

Systems at breaking point

Synthesis report 2021

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FOREWORD

The state of the world's land and water resources for food and agriculture (SOLAW 2021) provides new information on the status of land, soil and water resources, and evidence of the changing and alarming trends in resource use. Together, they reveal a situation that has much deteriorated in the last decade, when the first SOLAW 2011 report highlighted that many of our productive land and water ecosystems were at risk. The pressures on land and water ecosystems are now intense, and many are stressed to a critical point.

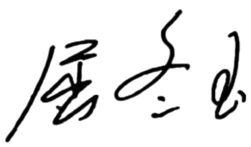
Against this background, it is clear our future food security will depend on safeguarding our land, soil and water resources. The growing demand for agrifood products requires us to look for innovative ways to achieve the Sustainable Development Goals, under a changing climate and loss of biodiversity. We must not underestimate the scale and complexity of this challenge. The report argues that this will depend on how well we manage the risks to the quality of our land and water ecosystems, how we blend innovative technical and institutional solutions to meet local circumstances, and, above all, how we can focus on better systems of land and water governance.

The interlinked actions and coalitions resulting from the 2021 United Nations Food Systems Summit provide an important entry to renew national and global priorities, and as a basis to advance the transformation of our agrifood systems to be more efficient, inclusive, resilient and sustainable.

A meaningful engagement with the key stakeholders – farmers, pastoralists, foresters and smallholders – directly involved in managing soils and conserving water in agricultural landscapes is central. These are nature's stewards and the best agents of change to adopt, adapt and embrace the innovation we need to secure a sustainable future.

I invite you to read the SOLAW 2021 report with a view to the fundamentals of all terrestrial agrifood production. Land degradation and water scarcity will not disappear. However, while the scale of the challenge is daunting, whether as cultivators of land or consumers of food, even small shifts in behaviours will see the much-needed transformation at the core of our global agrifood systems.

The new FAO Strategic Framework 2022-31 firmly commits the Organization to promote the sustainable management of our vital land and water ecosystems for better production, better nutrition, a better environment and a better life for all, leaving no one behind.



Dr QU Dongyu

FAO Director-General

PREFACE

Setting the scene

Human use of land and water for agriculture has not yet peaked, but all evidence points to slowing growth in agricultural productivity, rapid exhaustion of productive capacity and generation of environmental harm. Taking production that is more environmentally responsible and climate smart to scale can reverse trends in the deterioration of land and water resources and promote inclusive growth. This aligns with the aspirations of the FAO strategic framework: "better production, better nutrition, a better environment and a better life".

The past decade has seen the advent of several important global policy frameworks including the 2030 Agenda for Sustainable Development, the Paris Agreement on climate change, the Sendai Framework for Disaster Risk Reduction 2015–2030, the Small Island Developing States Accelerated Modalities of Action, the New Urban Agenda and the Addis Ababa Action Agenda on Financing for Development. The frameworks have introduced the Sustainable Development Goals (SDGs), nationally determined contributions (NDCs) and land degradation neutrality (LDN). In particular, there are dedicated SDGs for water, and targets for land and soil health. The frameworks are accompanied by global assessments of natural resources, including soils, forestry, biodiversity, desertification and climate. *The state of the world's land and water resources for food and agriculture: Systems at breaking point* (SOLAW 2021) report aims to take stock of the implications for agriculture and recommend solutions for transforming the combined role of land and water in global food systems.

Taking production that is more environmentally responsible and climate smart to scale can reverse trends in the deterioration of land and water resources and promote inclusive growth.

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The uncertainty of climate change and the complex feedback loops between climate and land present agriculture with amplified levels of risk that need to be managed. A global view points to a convergence of factors putting unprecedented pressure on land and water resources, leading to a set of human impacts and shocks in the supply of agricultural products, notably food. The SOLAW 2021 report argues that a sense of urgency needs to prevail over a hitherto neglected area of public policy and human welfare, that of caring for the long-term future of land, soil and water.

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Taking care of land, water and particularly the long-term health of soils is fundamental to accessing food in an ever-demanding food chain.

Shocks, including severe floods, droughts and the COVID-19 pandemic tend to divert attention away from development priorities. International finance institutions warn of the widening fault lines between developed and developing countries in meeting global goals while facing resurgent infections and rising death tolls from COVID-19. Recovery programmes offer opportunities to address urgencies and kick-start the process of change, including in land and water management.

Land, soil and water form the basis of the FAO commitment to the changes advocated in the 2021 United Nations Food Systems Summit. However, recognition and actions are needed to redirect the focus onto the land, on which 98 percent of the world's food is produced. Taking care of land, water and particularly the long-term health of soils is fundamental to accessing food in an ever-demanding food chain, guaranteeing nature-positive production, advancing equitable livelihoods, and building resilience to shocks and stresses arising from natural disasters and pandemics. They all start from land and water access and governance. Sustainable land, soil and water management also underpins nutritious, diverse diets and resource-efficient value chains in the shift to sustainable consumption patterns.

What SOLAW 2021 says

The SOLAW 2021 report comes at a time when human pressures on the systems of land, soils and fresh water are intensifying, just when they are being pushed to their productive limits. The impacts of climate change are already constraining rainfed and irrigated production over and above the environmental consequences resulting from decades of unsustainable use. This synthesis report presents the main findings and recommendations of the full SOLAW 2021 report and its annexes and background reports, which will be published in early 2022.

The SOLAW 2021 report builds on the concepts and conclusions given in the previous SOLAW 2011 report. Much has happened in the intervening years. Recent assessments, projections and scenarios from the international community paint an alarming picture of the planet's natural resources – highlighting overuse, misuse, degradation, pollution and increasing scarcity. Rising demands for food and energy, competing industrial, municipal and agricultural uses, and the need to conserve and enhance the integrity of the Earth's ecosystems and their services make the picture extremely complex and full of interlinkages and interdependencies.

The SOLAW 2021 report adopts the driver–pressure–state–impact–response (DPSIR) approach. This is a well-established framework for analysing and reporting important and interlinked relationships among sustainable agricultural production, society and the environment. The DPSIR approach provides a structure to report on cause–effect relationships to arrive at key policy recommendations and enable policymakers to assess the direction and nature of changes needed to advance sustainable management of land and water resources.

The **drivers** of demand for land and water resources are complex. By 2050, FAO estimates agriculture will need to produce almost 50 percent more food, livestock fodder and biofuel than in 2012 to satisfy global demand and keep on track to achieve "zero hunger" by 2030. Progress made in reducing the number of undernourished people in the early part of the twenty-first century has been reversed. The number has risen from 604 million in 2014 to 768 million in 2020. While prospects for meeting the nutritional requirements of 9.7 billion people by 2050 at the global level exist, problems with local patterns of production and consumption are expected to worsen, with increasing levels of undernourishment and obesity among the steadily growing and mobile population.

Options to expand cultivated land areas are limited. Prime agricultural land is being lost to urbanization. Irrigation already accounts for 70 percent of all freshwater withdrawals. Human-induced land degradation, water scarcity and climate change are increasing the levels of risk for agricultural production and ecosystem services at times and in places where economic growth is needed most.

Most **pressures** on the world's land, soil and water resources derive from agriculture itself. The increase in use of chemical (non-organic) inputs, uptake of farm mechanization, and overall impact of higher monocropping and grazing intensities are concentrated on a diminishing stock of agricultural land. They produce a set of externalities that spill over into other sectors, degrading land and polluting surface water and groundwater resources.

The **impacts** from accumulating pressures on land and water are felt widely in rural communities, particularly where the resource base is limited and dependency is high, and to a certain extent in poor urban populations where alternative sources of food are limited. Human-induced deterioration of land, soil and water resources reduces production potential, access to nutritious food and, more broadly, the biodiversity and environmental services that underpin healthy and resilient livelihoods.

A central challenge for agriculture is to reduce land degradation and emissions and to prevent further pollution and loss of environmental services while sustaining production levels. Responses need to include climate-smart land management attuned to variations in soil and water processes. Management options are available to increase productivity and production levels if innovation in management and technology can be taken to scale to transition to sustainable agrifood systems. However, none of these can go far without planning and managing land, soil and water resources through effective land and water governance.

Human-induced land degradation, water scarcity and climate change are increasing the levels of risk for agricultural production and ecosystem services at times and in places where economic growth is needed most.

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.

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Injecting a sense of urgency into making the necessary transformations in the core of the global food system is essential.

The SOLAW 2021 report indicates how **institutional and technical responses** can be packaged to address the challenges of increasing water and food security within land, soil and water domains, and, more widely, across agriculture and food systems. It stresses the importance of integrated approaches in managing land and water resources. Sustainable land management (SLM), sustainable soil management and integrated water resources management (IWRM) are all examples of such approaches, which can be blended with technology innovation, data and policies to accelerate improvement in resource-use efficiency, raise productivity and align progress with SDGs.

An important point to recognize is that many agents of change in the landscape remain excluded from the benefits of technical advances. This applies to disproportionately poorer and socially disadvantaged groups, with most living in rural areas. While technical solutions to specific land and water challenges may be within grasp, much will depend on how land and water resources are allocated. **Inclusive forms of land and water governance** will be adopted at scale only when there is political will, adaptive policymaking and follow-through investment. A primary focus on land and water governance is essential in creating the transformative changes needed to achieve patterns of sustainable agriculture that can enhance income and sustain livelihoods while protecting and restoring the natural resource base.

Significant complementary efforts will also be needed in food systems beyond the farm to maximize synergies and manage trade-offs in related sectors, particularly energy production. For this to happen, changes in policy, institutional and technical domains that disrupt "business as usual" (BAU) models may prove necessary.

Time is of the essence. Current trends in natural resource depletion indicate production from rainfed and irrigated agriculture is operating at or over the limit of sustainability. Injecting a sense of urgency into making the necessary transformations in the core of the global food system is essential.

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Overall supervision and review: L. Li and S. Koo-Oshima.

Early stage conceptualization: E. Mansur and O. Unver.

Coordination: F. Ziadat.

Chapter authors: V. Boerger, D. Bojic, P. Bosc, M. Clark, D. Dale, M. England, J. Hoogeveen, S. Koo-Oshima, P. Mejias Moreno, D. Muchoney, F. Nachtergaele, M. Salman, S. Schlingloff, O. Unver, R. Vargas, L. Verchot, Y. Yigini and F. Ziadat.

Editorial team: M. Kay (chief editor), S. Bunning and J. Burke.

Independent Advisory Committee: U. Apel, M. Astralaga, A. Bahri, F. Denton, J. Herrick, B. Hubert, B. Orr, G. de Santi, J. Sara, A. P. Schlosser, A. Szöllösi-Nagy and F. Tubiello.

Further contributions to chapters: W. Ahmad, A. Bhaduri, R. Biancalani, C. Biradar, A. Bres, D. Dale, F. El-Awar, S. Farolfi, S. Giusti, N. Harari, R. Mekdaschi Studer, E. Pek, S. Uhlenbrook, L. Verchot and P. Waalewijn.

External and internal technical reviewers: E. Aksoy, S. Alexander, J. Barron, T. Brewer, S. Burchi, A. Cattaneo, M. Chaya, T. Darwish, B. Davis, I. Elouafi, C. Giupponi, N. Harari, S. Hodgson, P. Lidder, J. Lundqvist, R. Mekdaschi Studer, J. Molina Cruz, L. Montanarella, V. Nangia, T. Oweis, A. Pandya, E. de Pauw, R. Poch, S. Ramasamy, C. Ringler, M. Torero, S. Uhlenbrook, H. Van Velthuyzen, L. Verchot, P. Waalewijn, Y. Wada and P. Zdruli.

Regional consultation process: M. Alagcan, J. Ariyama, I. Beernaerts, A. Bhaduri, T. Estifanos, J. Faures, M. Hamdi, T. Hofer, R. Jehle, T. Lieuw, Y. Niino, V. Nzeyimana, J. Quilty, E. Rurangwa and T. Santivanez.

Process facilitation: R. DeLaRosa, M. Kay, K. Khazal, O. Unver and F. Ziadat.

Copy-editor: C. Brown.

Preparation and review of thematic reports and case studies: M. Abdel Monem, D. Agathine, L. Battistella, O. Berkat, A. Bhaduri, R. Biancalani, E. Borgomeo, A. Bres, M. Bruentrup, A. Cattaneo, F. Chiozza, R. Coppus, D. Dale, B. Davis, P. Dias, M. England, S. Farolfi, J. Faures, L. de Felice, T. Fetsi, M. Flores Maldonado, G. Franceschini, E. Ghosh, I. Gil, V. Gillet, G. Grossman, G. Gruere, F. Haddad, M. Henry, J. Herrick, T. Hoang, A. Huber-Lee, S. Iftekhar, P. Kanyabujinja Nshuti, K. Khazal, B. Kiersch, D. Kulis, J. Lindsay Azie, C. Lucrezia, Z. Makhamreh, Y. Makino, M. Merlet,

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Preparation of statistics and maps: G. Ben Hamouda, J. Burke, F. Chiozza, R. Coppus, M. Hernán-dez, T. Hoang, K. Khazal, M. Marinelli L. Peiser and A. Sander.

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International Institute for Applied Systems Analysis

International Water Management Institute

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Organisation for Economic Co-operation and Development

Stockholm Environment Institute

Stockholm International Water Institute

Thünen Federal Research Institute for Rural Areas, Forestry and Fisheries

World Overview of Conservation Approaches and Technologies

KEY MESSAGES OF SOLAW 2021

The state

- **The interconnected systems of land, soil and water are stretched to the limit.** Convergence of evidence points to agricultural systems breaking down, with impacts felt across the global food system.
- **Current patterns of agricultural intensification are not proving sustainable.** Pressures on land and water resources have built to the point where productivity of key agricultural systems is compromised and livelihoods are threatened.
- **Farming systems are becoming polarized.** Large commercial holdings now dominate agricultural land use, while fragmentation of smallholders concentrates subsistence farming on lands susceptible to degradation and water scarcity.

The challenges

- **Future agricultural production will depend upon managing the risks to land and water.** Land, soil and water management needs to find better synergy to keep systems in play. This is essential to maintain the required rates of agricultural growth without further compromising the generation of environmental services.
- **Land and water resources will need safeguarding.** There is now only a narrow margin for reversing trends in resource deterioration and depletion, but the complexity and scale of the task should not be underestimated.

Responses and actions

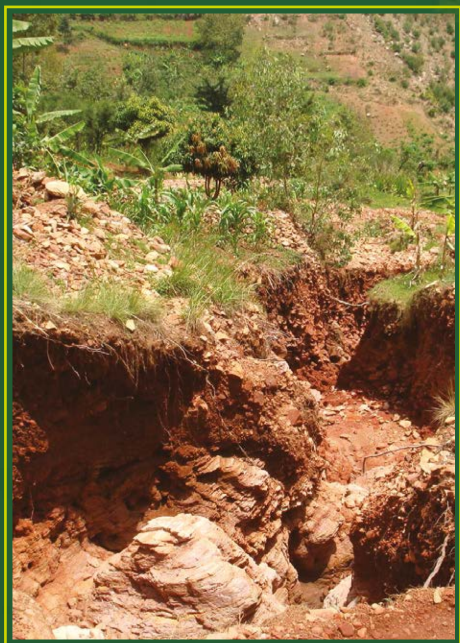
- **Land and water governance has to be more inclusive and adaptive.** Inclusive governance is essential for allocating and managing natural resources. Technical solutions to mitigate land degradation and water scarcity are unlikely to succeed without it.
- **Integrated solutions need to be planned at all levels if they are to be taken to scale.** Planning can define critical thresholds in natural resource systems, leading to the reversal of land degradation when wrapped up as packages or programmes of technical, institutional, governance and financial support.
- **Technical and managerial innovation can be targeted to address priorities and accelerate transformation.** Caring for neglected soils, addressing drought and coping with water scarcity can be addressed through the adoption of new technologies and management approaches.
- **Agricultural support and investment can be redirected towards social and environmental gains derived from land and water management.** 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.

Agriculture is a significant contributor to water stress in countries with high levels of water stress. *(See map on page 17.)*

Map source: FAO and UN-Water, 2021 modified to comply with UN, 2021.

Some key findings in this section...

- **Land and water systems are under pressure:** Advances in food systems require focusing on land, soils and water as interconnected systems.
- **Current patterns of intensification are not proving sustainable:** High levels of pollution and greenhouse gas emissions are stretching the productive capacity to the limit and severely degrading land and environmental services.
- **Climate change:** Evapotranspiration is expected to increase 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.



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*There is little room for expanding the area of productive land, yet **98 percent** of food is grown on land.*

©FAO/Giuseppe Bizzarri

1 STATE OF LAND, SOIL AND WATER

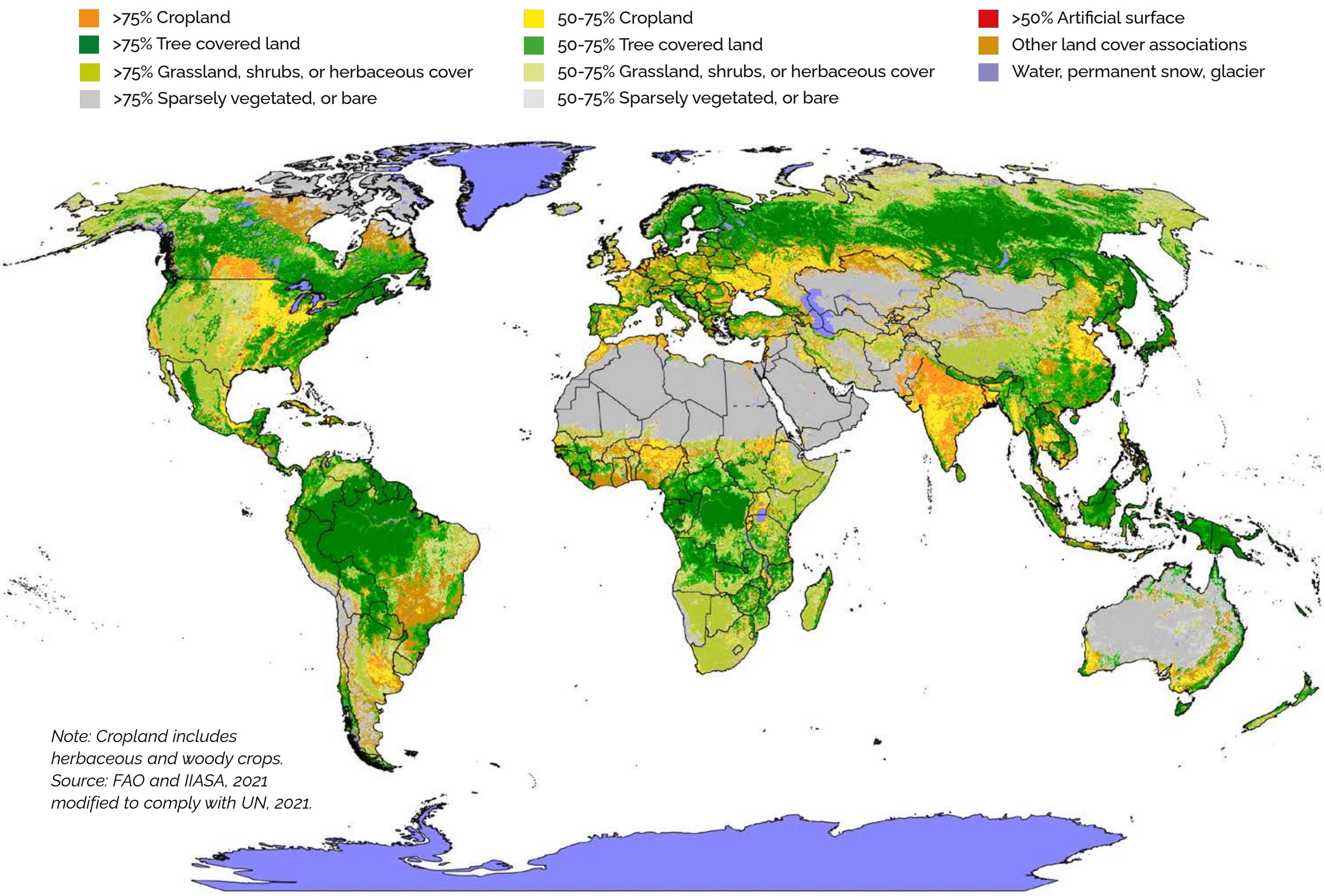
1.1 Pressures on land resources under climate change

1.1.1 Agricultural land use and climate

Agriculture uses some 4 750 million ha of land for cultivating crops and animal husbandry. Cultivated temporary and permanent crops occupy over 1 500 million ha, while land under permanent meadows and pastures occupies almost 3 300 million ha. The overall change in agricultural land area since 2000 is small, but land under permanent and irrigated crops has increased, while land under permanent meadows and pastures has significantly declined. Rapid growth in urban areas has displaced all types of agricultural land use (Map S.1) (Table S.1).

The agroclimatic context for the pattern of land use is changing rapidly. Farming enterprises are adapting to new thermal regimes that can upset crop growth stages and their supporting soil ecologies, with specific implications for spreading crop disease and pests (Map S.2). Fundamental changes to the water cycle, particularly the patterns of rainfall and periods of drought, are forcing adjustment of rainfed and irrigated production. Under climate change, growing periods may become longer in boreal and arctic regions, but shorter in areas affected by extended drought periods when compared with current reference lengths (Map S.3).

MAP S.1 DOMINANT LAND-COVER CLASSES



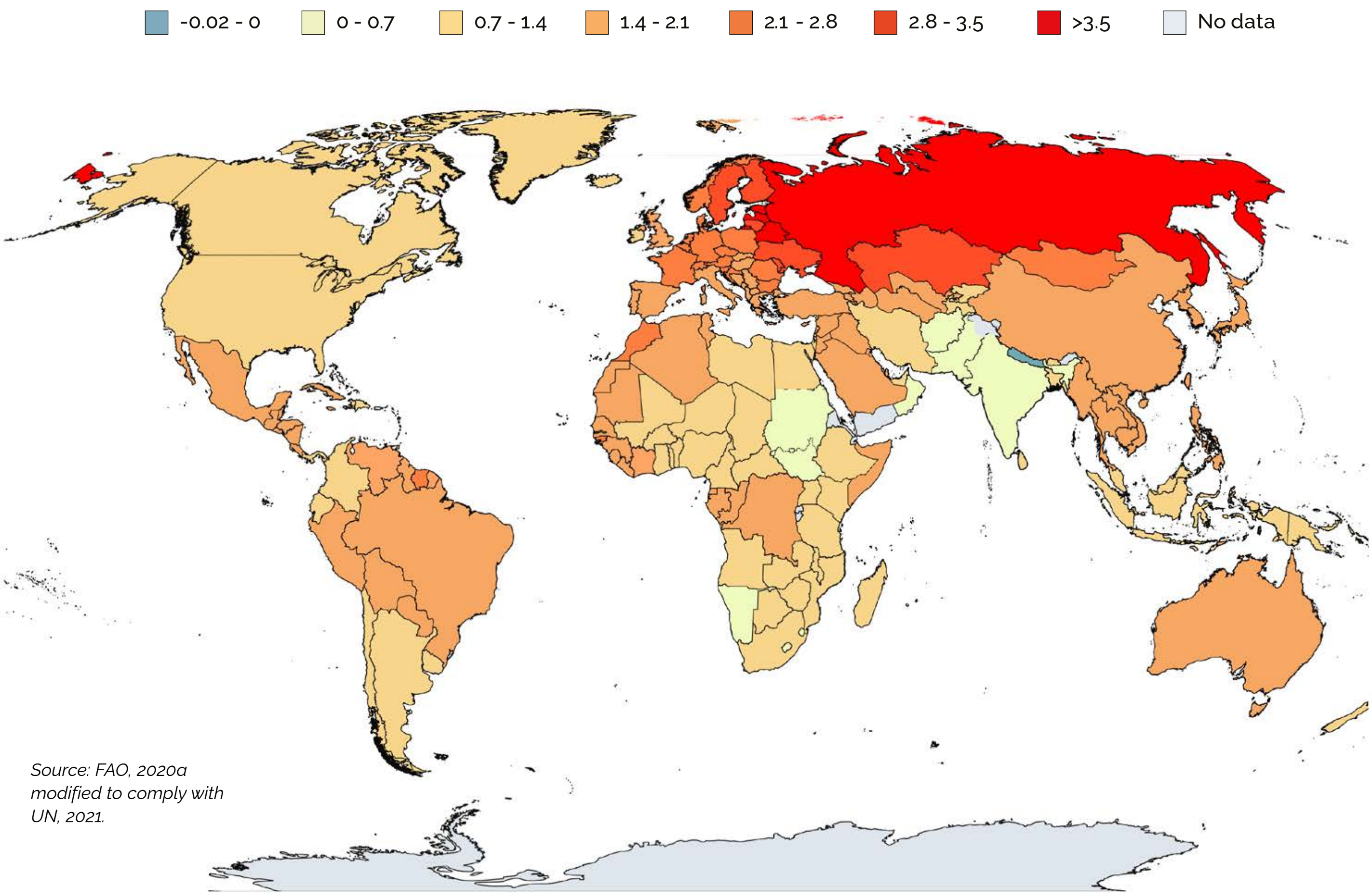
Note: Cropland includes herbaceous and woody crops.
Source: FAO and IIASA, 2021 modified to comply with UN, 2021.

TABLE S.1 LAND-USE CLASS CHANGE, 2000–2019 (MILLION ha)

LAND-USE CLASS	2000	2019	CHANGE
Land under permanent meadows and pastures	3 387	3 196	−191
Arable land (land under temporary crops)	1 359	1 383	+24
Land under permanent crops	134	170	+36
Cropland (arable land and permanent crops)	1 493	1 556	+63
Agricultural land (total of cropland and permanent meadows and pasture)	4 880	4 752	−128
Land area equipped for irrigation	289	342	+53
Forest land (land area > 0.5 ha with trees > 5 m + 10% canopy cover)	4 158	4 064	−94
Other land	3 968	4 188	+220

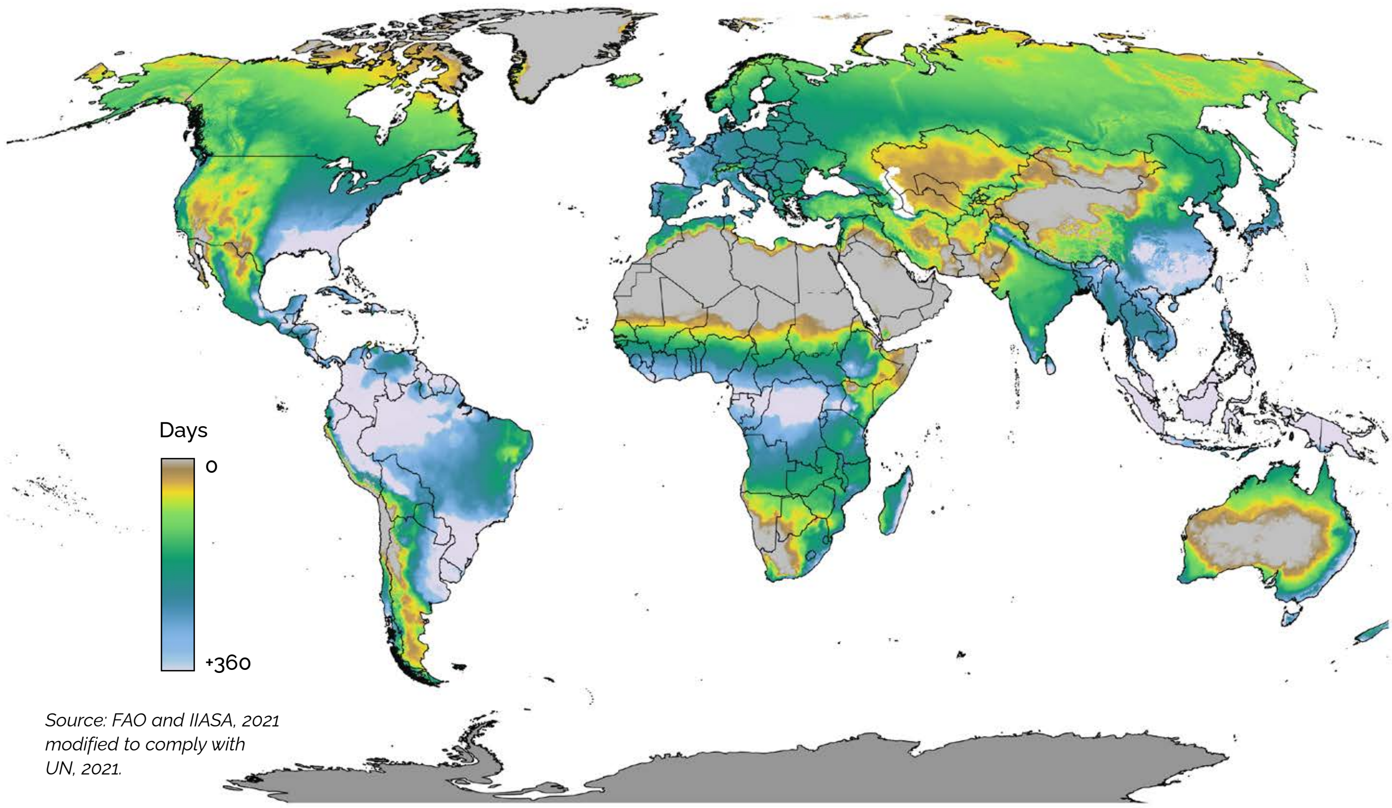
Source: FAO, 2020a.

MAP S.2 MEAN TEMPERATURE CHANGE, 1961–2020 (°C)



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

MAP S.3 REFERENCE LENGTH OF THE GROWING PERIOD, 1981–2010



Source: FAO and IIASA, 2021 modified to comply with UN, 2021.

Climate change impacts on the water cycle are expected to significantly affect agricultural output and the environmental performance of productive land and water systems. Climate models predict decreases in renewable water resources in some regions (mid-latitude and dry subtropical regions) and increases in others (mainly high latitudes and humid mid-latitude regions). Even where increases are projected, there may be short-term shortages due to changing streamflow caused by greater variability in rainfall.

1.1.2 Forest cover

As part of the global carbon cycle, forest cover is a valuable indicator of climate health. Global forest land cover is just over 4 billion ha, some 30 percent of the total land area (Map S.4). The net annual forest cover loss between 2010 and 2020 is estimated at 4.7 million ha/year compared with 5.2 million ha/year between 2000 and 2010 and 7.8 million ha/year between 1990 and 2000, taking account of forest expansion through regeneration and afforestation (Figure S.1).

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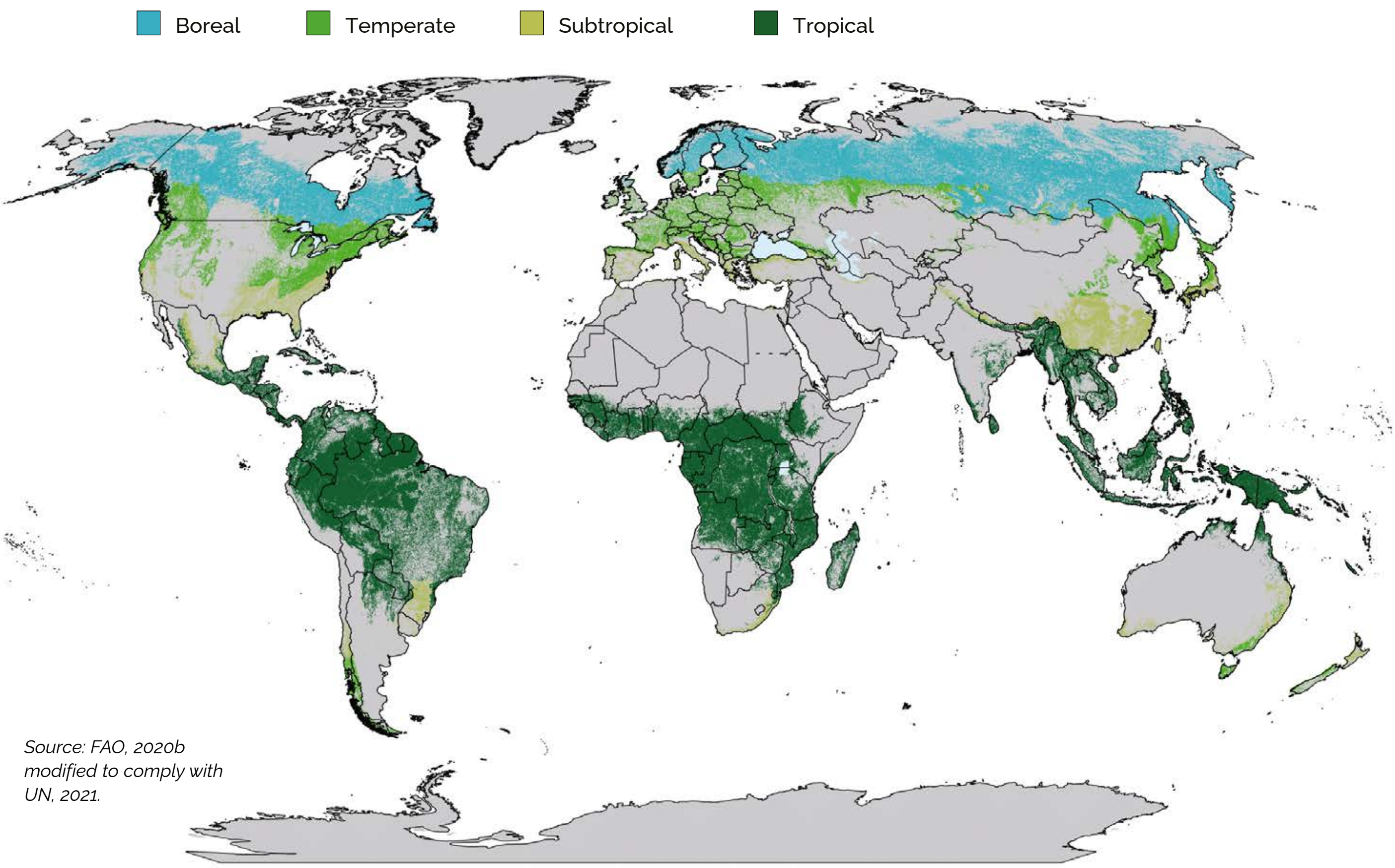
MAP S.4 GLOBAL DISTRIBUTION OF FORESTS BY CLIMATE DOMAIN, 2020



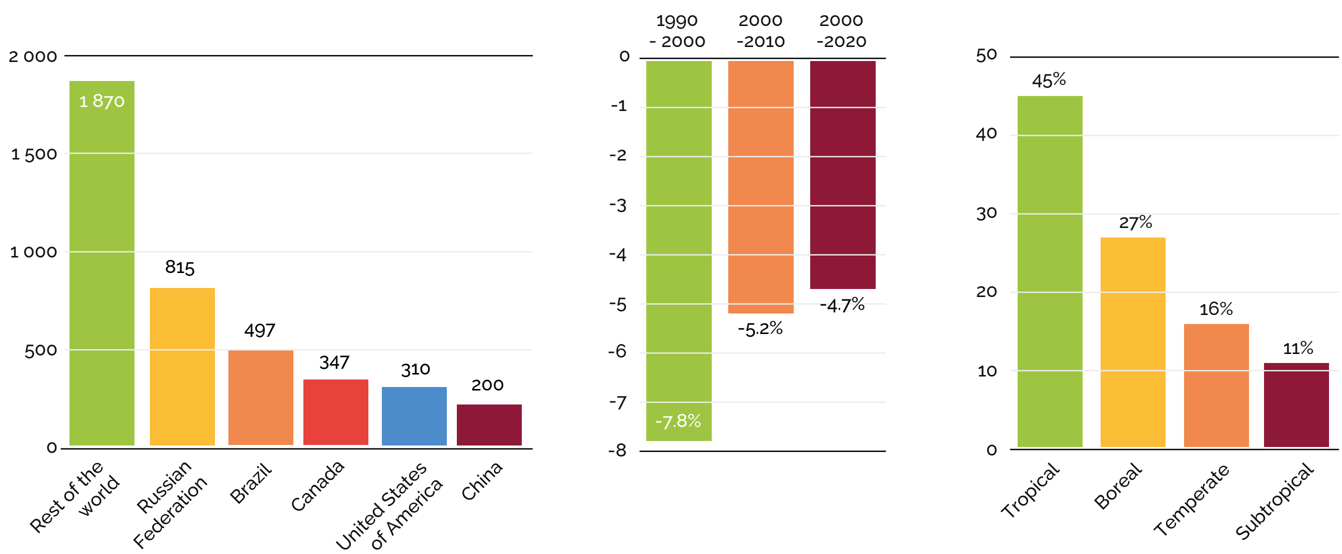
Source: FAO, 2020b modified to comply with UN, 2021.

FIGURE S.1 GLOBAL FOREST AREAS IN 2020 AND NET CHANGES BY DECADE, 1990–2020

Top five countries for forest area, 2020 (million ha)

Global annual forest area net change, by decade, 1990–2020 (%)

Proportion and distribution of global forest area by climatic domain, 2020 (%)



Source: FAO, 2020b.

1.1.3 The role of soils

Soils are an essential buffer or "regulator" of climate change. Soils under conventional agriculture continue to be a source of carbon dioxide emissions, but conservation techniques can halt, and in some instances, reverse the loss of soil organic carbon (SOC) (Map S.5). Peat soil degradation and drainage release large amounts of carbon through decomposition. Fires in drained peatlands accounted for about 4 percent of global fire emissions between 1997 and 2016. Agricultural practices also cause soils to emit other greenhouse gases (GHGs) in addition to carbon dioxide, and climate change exacerbates these emissions. Soils emit nitrous oxide when fertilizers are applied, and when nitrogen-fixing crops are planted. They also emit methane when flooded for rice cultivation.

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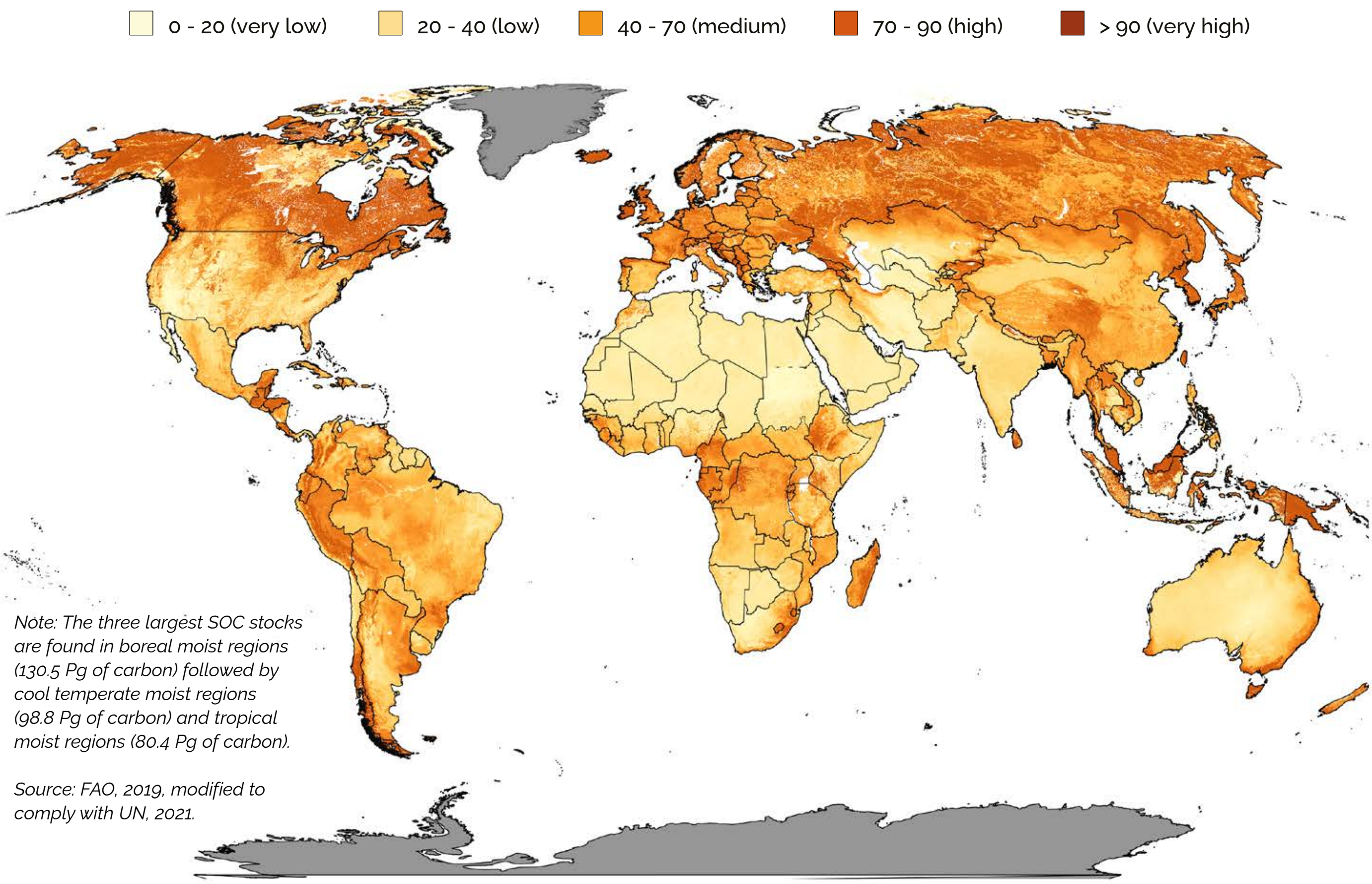
The global distribution of salt-affected soils (Map S.6) reflects naturally saline and sodic soils and a build-up of salts through human-induced soil water processes. Soil salinity is estimated to take up to 1.5 million ha of cropland out of production each year. Higher rates of evapotranspiration are expected to exacerbate the accumulation of salts in the surface horizons, but the extent of subsoil salinity at the 30–100 cm depth range is much more pronounced.

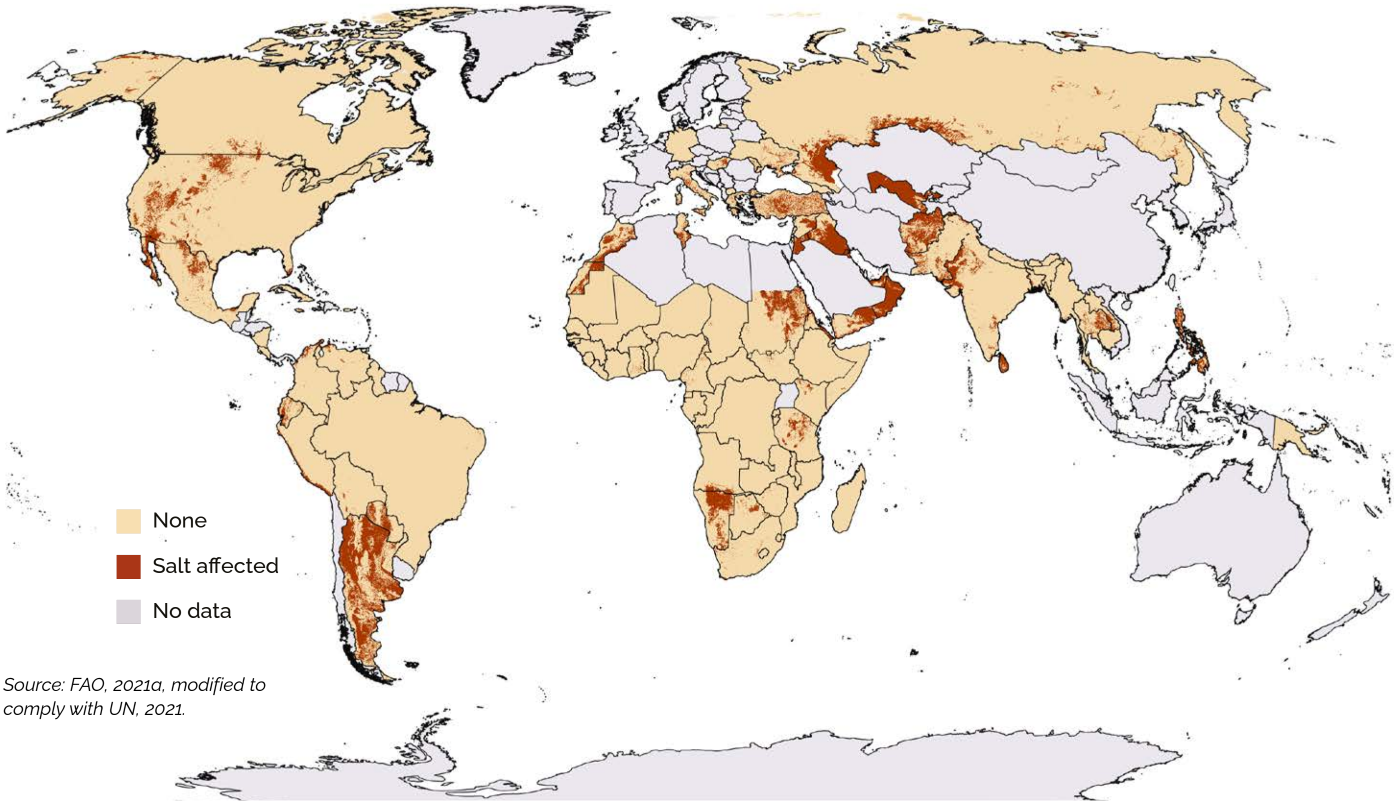
MAP S.5 GLOBAL SOIL ORGANIC CARBON, 2019 (tonnes/ha)



Note: The three largest SOC stocks are found in boreal moist regions (130.5 Pg of carbon) followed by cool temperate moist regions (98.8 Pg of carbon) and tropical moist regions (80.4 Pg of carbon).

Source: FAO, 2019, modified to comply with UN, 2021.

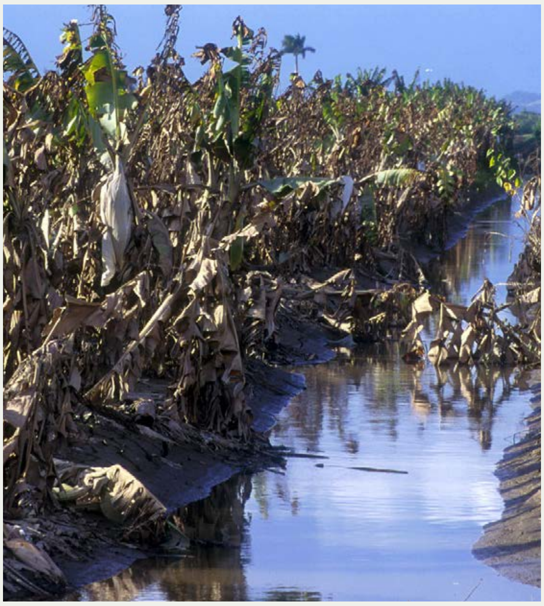
MAP S.6 SALT-AFFECTED SOILS, 30–100 cm, 2021



Source: FAO, 2021a, modified to comply with UN, 2021.

1.1.4 Accumulation of pressures

Pressures on land and water resources have never been so intense, and their accumulation is pushing the productive capacity of land and water systems to the limit. Cropland increased by 4 percent (63 million ha) between 2000 and 2019. Growth in arable land, mainly for irrigated crops, doubled, while that for rainfed cropping increased by only 2.6 percent over the same time period. Population increases have meant agricultural land available per capita for crops and animal husbandry declined by 20 percent between 2000 and 2017, to 0.19 ha/capita in 2017.



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The impacts of climate change, from severe floods and droughts to persistent heat domes, are producing predicted and also surprising changes. Increasing evapotranspiration from cropland is anticipated, as is variable rainfall, leading to changes in land/crop suitability and reduced yields where temperature stresses

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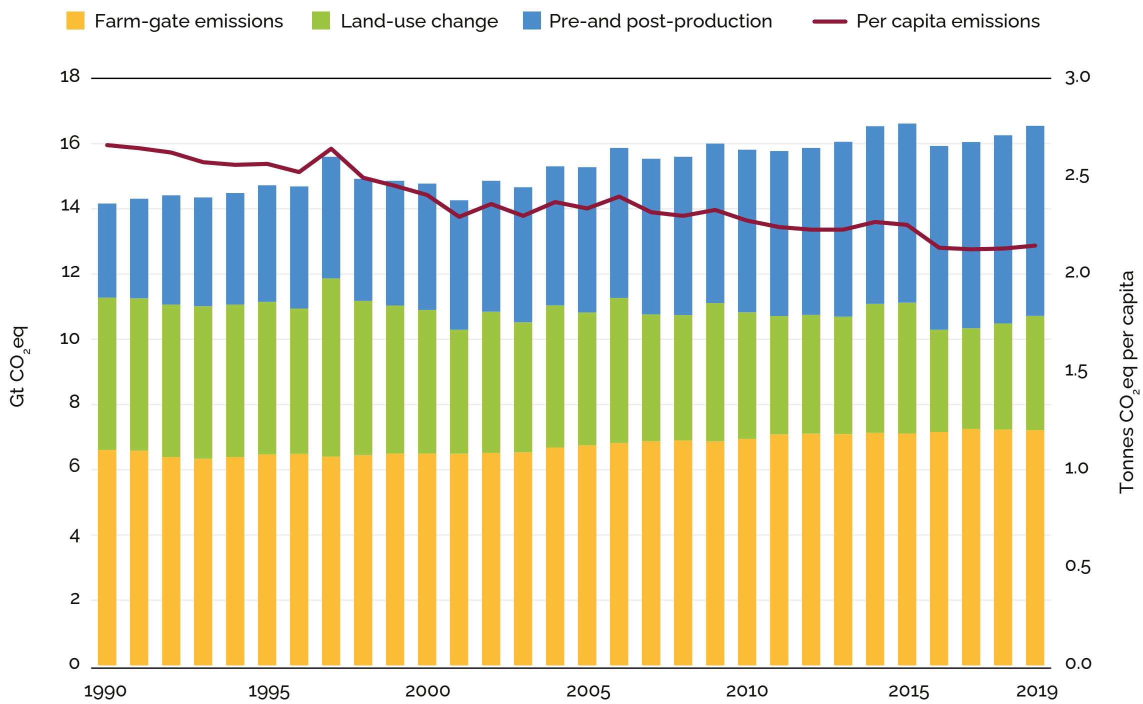
attenuate carbon assimilation. Greater variations in river run-off and groundwater recharge are expected, affecting rainfed and irrigated agriculture. Absorbing extreme floods on previously drained agricultural land presents a dilemma for urban and rural flood disaster planning when nature-based solutions (NbSs) are deployed.

In 2019, global anthropogenic emissions were 54 billion tonnes of carbon dioxide equivalent (CO_2-eq), of which 17 billion tonnes CO_2-eq, or 31 percent, came from agrifood systems. In terms of single gases, agrifood systems generated 21 percent of carbon dioxide emissions, 53 percent of methane emissions and 78 percent of nitrous oxide emissions. Emissions from agricultural land (farm gate) were the largest component of agrifood systems with around 7 billion tonnes CO_2-eq, followed by pre- and post-production processes (6 billion tonnes CO_2-eq) and land-use change (4 billion tonnes CO_2-eq). While emissions from agrifood systems increased globally by 16 percent between 1990 and 2019, their share in total emissions decreased, from 40 percent to 31 percent, as did the per capita emissions, from 2.7 to 2.1 tonnes CO_2-eq per capita (Figure S.2).

FIGURE S.2 GLOBAL AGRIFOOD SYSTEM GHG EMISSIONS BY LIFE-CYCLE STAGE AND PER CAPITA EMISSIONS

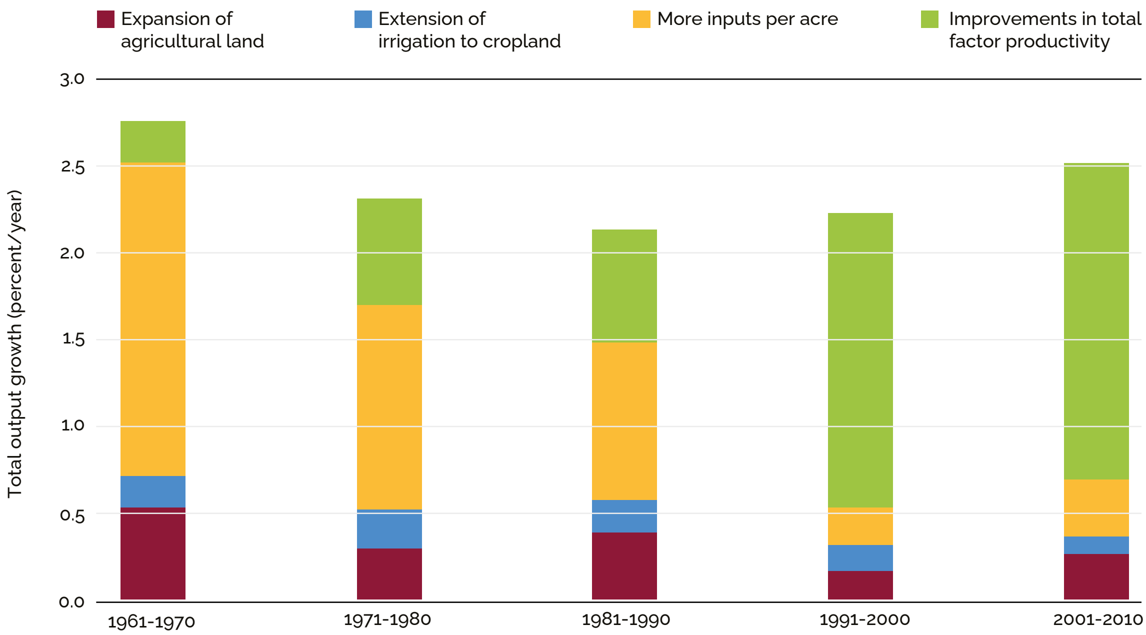


Source: FAO, 2021b.

1.1.5 Implications for agricultural productivity

Future climate change scenarios point to the need for changing cropping patterns and management practices to adapt to changes in crop/land suitability. Agricultural systems are already adapting with more-precise use of technology and inputs, partly as a response to climate change, but mainly as a response to the more-sophisticated demands of the global food system. For this reason, the significance of traditional measures of land and water productivity has declined as more factors of production are taken into account. Indeed, while growth in agricultural land use and irrigated areas has stagnated, total factor productivity in agriculture has increased by 2.5 percent each year over the past few decades, reflecting greater efficiency in the use of agricultural inputs. It has replaced resource intensification as the primary source of growth in world agriculture (Figure S.3). This gain has raised awareness of the need for sustainable agriculture and efficient use of limited natural resources. While the use of agricultural inputs has intensified to meet current demand, the resulting environmental impacts have accumulated to the point where a wide range of environmental services are affected, limiting agriculture's capacity to respond. At the same time, intersectoral competition for land and water resources is intense, so the scope to extend irrigated areas and convert new land to agriculture is extremely constrained.

FIGURE S.3 TOTAL FACTOR PRODUCTIVITY GROWTH IN WORLD AGRICULTURE, 1961–2010



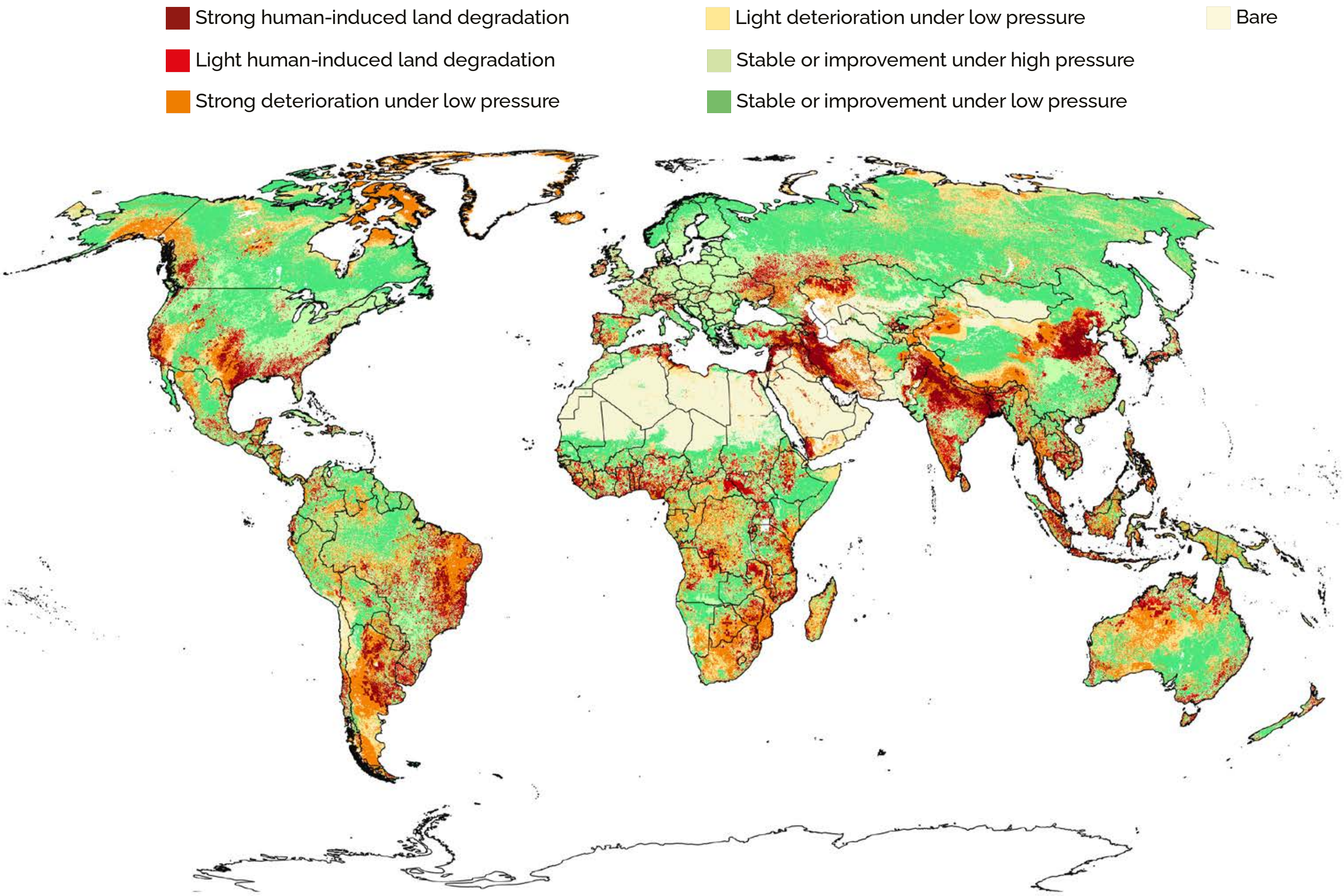
Source: USDA, 2021.

1.2 Human-induced land degradation

As agriculture intensifies, converging evidence indicates the extent and severity of land degradation (Map S.7), where soil is eroded, nutrients are depleted and salinity increases. Human-induced degradation affects 34 percent (1 660 million ha) of agricultural land (Table S.2). Extending cultivation into areas of marginal land quality and increasing intensification on existing cropland are constrained by soil erosion and depletion of carbon, nutrients and soil biodiversity. The treatment of soils with inorganic fertilizers to increase or sustain yields has had significant adverse effects on soil health, and has contributed to freshwater pollution induced by run-off and drainage.

Box S.1 summarizes the method used to assess global land degradation based on adaptation of the Global Land Degradation Information System (GLADIS).

MAP S.7 LAND-DEGRADATION CLASSES BASED ON SEVERITY OF HUMAN-INDUCED PRESSURES AND DETERIORATING TRENDS, 2015



Note: Global distribution of land degradation. Overall trend combined with cumulative pressure by direct human drivers. Human-induced land degradation refers to a negative trend, which is caused by human activity. Deterioration refers to a negative trend caused by natural phenomena, or by human action where status is low.

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

TABLE S.2 EXTENT OF HUMAN-INDUCED LAND DEGRADATION, 2015 (MILLION ha)

DEGRADATION	GLOBAL	DRYLANDS	HUMID AREAS
Total	1 660	733	927
Strong	850	418	432
Light	810	315	495

Note: Antarctica, Greenland and land with more than 90 percent bare cover (the great deserts) are excluded. For humid areas, the cold zone where potential evapotranspiration is greater than 400 is also excluded.

Source: Coppus, forthcoming.

Globally, the biophysical status of 5 670 million ha of land is declining, of which 1 660 million ha (29 percent) is attributed to human-induced land degradation. The remaining 4 010 million ha is classified as deteriorated caused by natural processes or has an anthropogenic origin. About half of the deteriorated land has a low status, and is likely to be more sensitive to degradation processes than high-status areas. About 656 million ha, 12 percent of the overall global decline, is under moderate pressure, which may be enough to trigger human-induced land degradation. Most of these areas are probably affected by human-induced land degradation, which means about 41 percent of the global decline can be attributed to human-induced land degradation.

BOX S.1
GLOBAL LAND-DEGRADATION ASSESSMENT USING AN ADAPTED GLADIS METHOD

Overall biophysical status and trend indices are determined using an adapted GLADIS methodology. This applies a geographic information system approach to calculate separate biophysical status and trend indices for six components – biomass, soil health, water quantity, biodiversity, economic services and cultural services. It combines them to give an overall status index and a trend index. Trends refer strictly to changes over time.

INPUT LAYERS FOR OVERALL BIOPHYSICAL STATUS, OVERALL TREND AND CUMULATIVE PRESSURE BY DRIVERS

ITEM	SOIL	WATER	VEGETATION	DEMOGRAPHY
Status	Nutrient availability Soil carbon content Water erosion Wind erosion	Groundwater recharge Water stress	Native species richness Above-ground biomass	Built-up cover
Trend	Soil erosion change Soil protection change	Freshwater change Water stress change	Change in land productivity Forest biomass change	Population density change
Driver	Agricultural expansion, deforestation, fire, grazing density, population density and ratio of invasive/native species			

BOX S.1 (CONTINUED)

Maps for overall biophysical status, trend and cumulative pressure represent three different dimensions of land degradation. When combined, they give insight into the relationships among the patterns, processes and their causes. Regions at risk occur when the overall status and trend are combined. Areas with a low biophysical status and exposure to deterioration are at risk of ending in a degraded state. Areas with high biophysical status and exposed to substantial deterioration are also likely to be at risk. Integrating pressure from human activities with biophysical status and trends is a first step in distinguishing natural from human-induced degradation.

Maps published in peer-reviewed journals provide input layers. The criteria for selecting these include availability, readiness to be used, relevance according to the literature and publication date.

The **biophysical status** of land resources is based on nine input layers that reflect their present (or latest known) biophysical condition. These include soil nutrient availability, SOC, water erosion rate, wind erosion, groundwater recharge, water stress, native species richness, above-ground biomass and artificial land cover (urban and infrastructure).

The **trend** is based on seven input layers that indicate changes in soil, water, vegetation and population density; they include changes in soil erosion, soil protection, fresh water, water stress, land productivity and forest biomass. The time factor varies between 10 and 20 years.

Direct anthropogenic **drivers** are used to estimate pressure exerted by human activities: agricultural expansion, deforestation, fire extent and frequency, grazing density, population density and ratio of invasive/native species.

Regions at risk are large contiguous areas with low biophysical status and subject to strong or light deterioration. Regions with substantial deterioration and interspersed high and low biophysical status are also at risk. Stable or improving areas are presently not at risk.

Land-degradation classes are defined based on the trend of land deterioration and the presence of anthropogenic drivers. A highly negative trend coinciding with high pressure is characteristic of substantial human-induced land degradation. The land's resilience (ability to withstand anthropogenic pressures) also plays a role, for instance, when strong anthropogenic drivers do not coincide with negative trends.

Table S.3 shows the regional breakdown of the global estimate of human-induced land degradation. A fifth of human-induced degraded land is in sub-Saharan Africa, followed by Southern America with 17 percent. Northern America is about five times the size of South Asia, but both regions contributed 11 percent to global degradation. In relative terms, South Asia is the most-affected region, with 41 percent of its area suffering from human-induced degradation, of which 70 percent is strongly degraded. Southeast Asia follows with 24 percent, of which 60 percent is severe, and Western Asia has 20 percent, of which 75 percent is strongly affected. Deserts are not included in these estimates.

TABLE S.3 **EXTENT OF HUMAN-INDUCED LAND DEGRADATION BY REGION, 2015**

CONTINENT/ REGION	AREA AFFECTED BY HUMAN-INDUCED DEGRADATION (MILLION ha)	TOTAL LAND AREA OF REGION (MILLION ha)	PERCENTAGE OF REGION AFFECTED (%)	STRONGLY DEGRADED (MILLION ha)	SLIGHTLY DEGRADED (MILLION ha)
Sub-Saharan Africa	330	2 413	14	149	181
Southern America	281	1 778	16	153	128
South Asia	180	439	41	126	54
Northern America	177	2 083	8	82	95
East Asia	156	1 185	13	84	72
Western Asia	123	615	20	92	31
Southeast Asia	122	501	24	74	48
Australia and New Zealand	94	796	12	34	59
Eastern Europe and Russian Federation	83	1 763	5	21	62
Western and Central Europe	56	489	11	12	44
Central Asia	31	456	7	12	19
Northern Africa	22	579	4	9	13
Central America and Caribbean	11	76	14	5	5
Pacific Islands	0.14	7	2	0.11	0.03
World	**1 660**	**13 178**	**13**	**850**	**810**
High income	393	3 817	10	175	218
Upper middle income	621	5 604	11	326	295
Lower middle income	428	2 207	19	241	187
Low income	220	1 520	14	107	112
Low income and food deficit	283	2 062	14	133	149
Least developed	288	2 097	14	134	154

Note: Percentage of region affected refers to the portion of the total regional extent that is degraded. Antarctica, Greenland and land with more than 90 percent bare cover (the great deserts) are excluded.

Source: Coppus, forthcoming.

Human-induced land degradation primarily affects cropland. Although cropland covers only 13 percent of the global land-cover classes (11 477 million ha), degraded cropland accounts for 29 percent of all degraded areas. Almost a third of rainfed cropland and nearly a half of irrigated land are subject to human-induced land degradation (Table S.4).

TABLE S.4 LAND-DEGRADATION CLASSES FOR GLOBAL LAND COVER, 2015

LAND COVER	TOTAL AREA (MILLION ha)	DEGRADATION (MILLION ha)	DETERIORATION (MILLION ha)	STABLE (MILLION ha)	DEGRADED (%)	DETERIORATED (%)	STABLE (%)
Cropland	1 527	479	268	780	31	18	51
Rainfed	1 212	340	212	660	28	17	54
Irrigated	315	139	57	120	44	18	38
Grassland	1 910	246	642	1 022	13	34	54
Trees	4 335	485	1 462	2 388	11	34	55
Shrubs	1 438	218	584	636	15	41	44
Herbs	203	16	51	136	8	25	67
Sparse vegetation	1 034	85	499	450	8	48	44
Protected area	880	76	361	443	9	41	50

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

Source: Coppus, forthcoming.

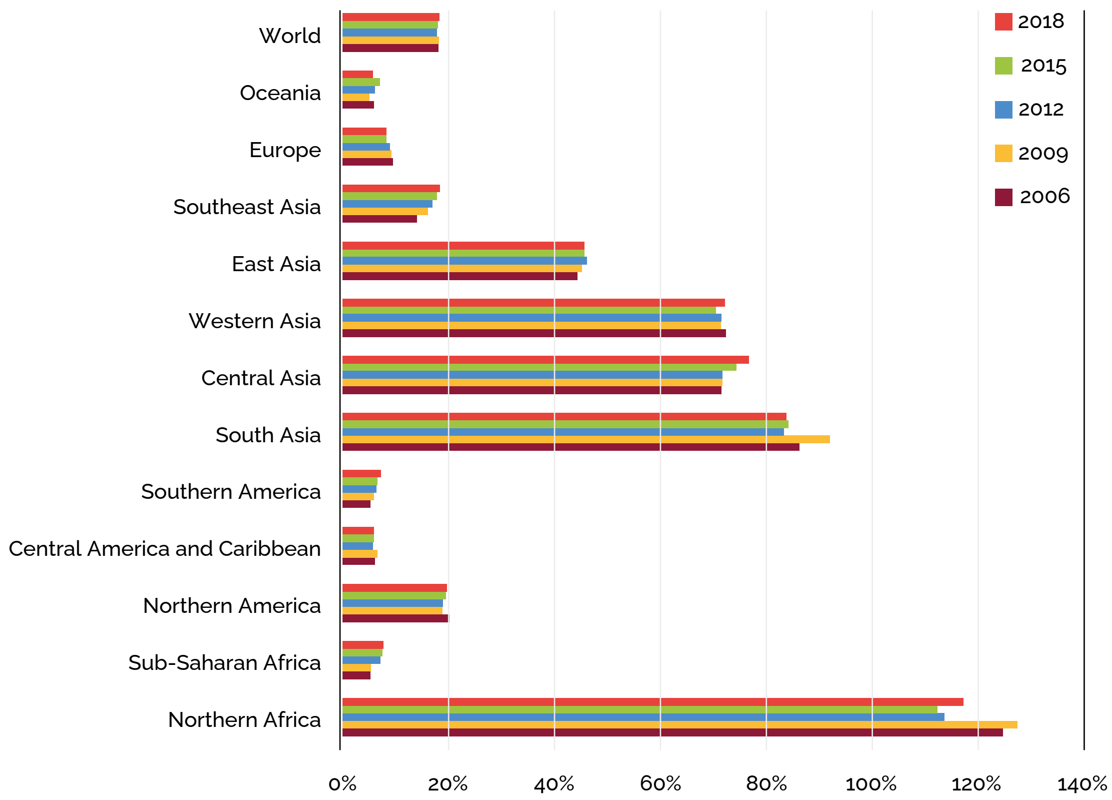
Grassland and shrub-covered areas that are used to graze animals or as sources of fodder have declined by 191 million ha over two decades to 3 196 million ha in 2019, and converted to cropland. Some 13 percent of the grassland area is degraded due to high anthropogenic pressures, and 34 percent has reduced biophysical status due to overgrazing and inadequate livestock mobility causing soil compaction and erosion, thus affecting soil function, plant growth and hydrological services. Intensive livestock production, which has grown rapidly to meet expanding demand for meat, particularly in middle- to high-income countries, places pressure on *in situ* water and soil resources for intensive feed and forage production. Concentrating inputs and animal waste have resulted in higher energy use from fossil fuels, higher methane emissions and higher point source water pollution from nutrients and antibiotics.

Over 60 percent of irrigated areas are degraded in Northern Africa, South Asia and the Middle East–Western Asia. The largest degraded areas are in the northern hemisphere, except for Southeast Asia. Globally, only 38 percent of irrigated land is stable.

In the Middle East and Western Asia, agricultural expansion, grazing and accessibility drive degradation, while in the densely populated areas of East Asia and South Asia, good accessibility and high grazing density are exerting high pressures on irrigated fields. Grazing, accessibility and deforestation drive environmental change in irrigated cropland in Southeast Asia. Grazing, accessibility and agricultural expansion contribute most to the pressure for irrigation expansion in the eastern United States of America.

The declines in status in East Asia and the Middle East–Western Asia are mainly due to decreasing freshwater availability, increasing water stress, reducing soil protection and increasing population. Similar degradation processes occur in South Asia. Major degradation processes in Southeast Asia are increasing erosion rates, rapidly decreasing forest biomass and increasing population. In the eastern United States of America, the

FIGURE S.4 CHANGES IN WATER STRESS BY GEOGRAPHICAL REGION, 2006, 2009, 2012, 2015 and 2018



Source: FAO AQUASTAT, 2021.

primary degradation processes are decline in available fresh water and loss of soil protection. Problems are similar in the western United States of America, but rising population density brings additional pressure.

1.3 Water scarcity

The global water budget is under pressure. Internal renewable water resources (IRWRs) from rivers and aquifers amount to 44 000 km^3/year, and withdrawals (all sectors) exceed 4 000 km^3/year, almost 10 percent of IRWRs. The local impacts of physical water scarcity and freshwater pollution are spreading and accelerating. In many cases, the first sign of scarcity from increased withdrawals is falling groundwater levels.

1.3.1 Sustainable Development Goal indicator 6.4.2

The SDG aggregate (all sectors) indicator 6.4.2 on water stress[1] is taken as an overall measure of physical water scarcity. At the global level, SDG indicator 6.4.2 reached an average of 18 percent in 2018, but this masks substantial regional variations (Figure S.4). Europe is experiencing a low stress level of

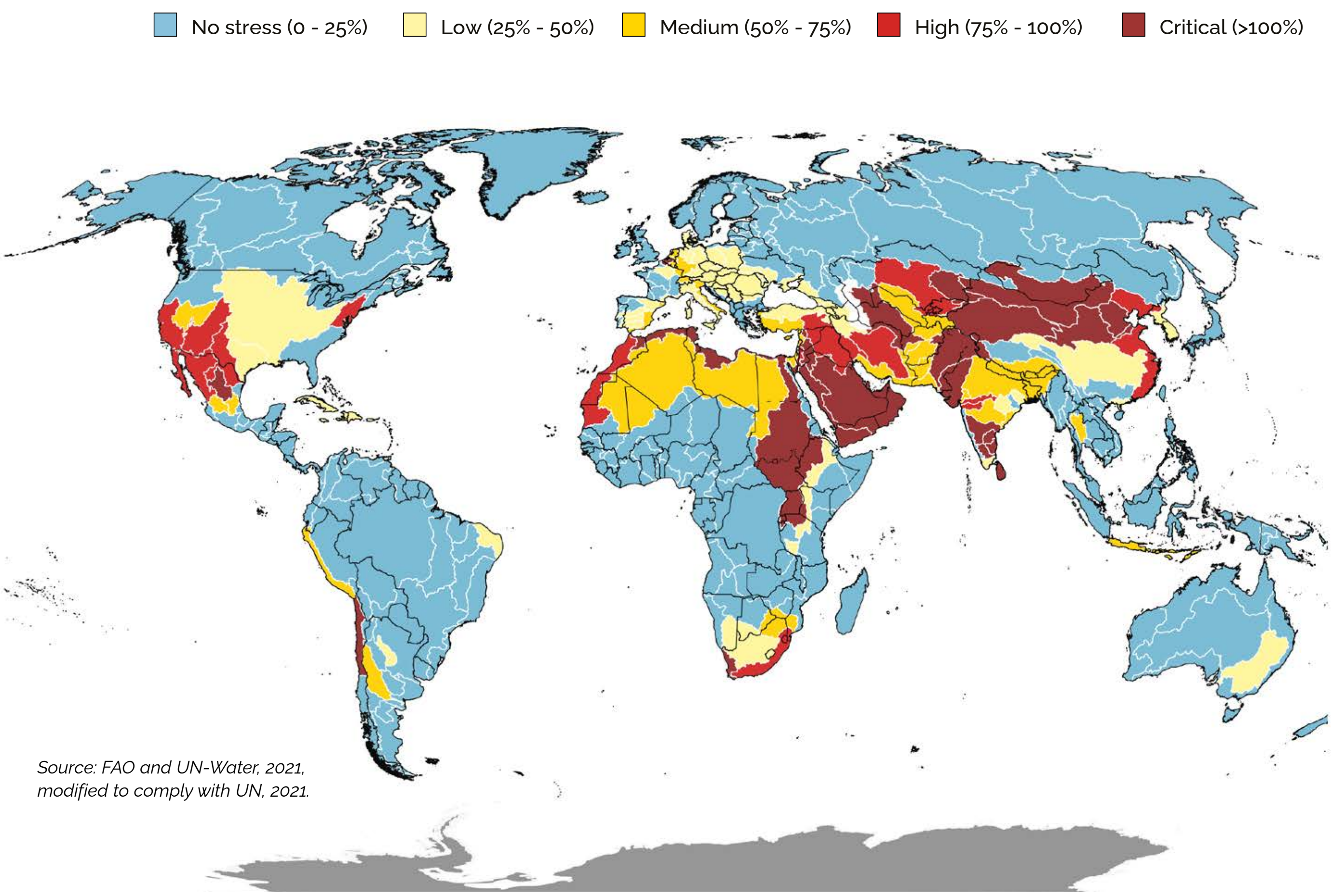
1 The SDG indicator 6.4.2 measures the level of water stress and is defined as the ratio of total fresh water withdrawn by all major sectors (agricultural, industrial and municipal) to total renewable freshwater resources, after considering environmental flow requirements. A ratio of 0–25 percent indicates no stress; 25–50 percent indicates low stress; 50–75 percent indicates medium stress; 75–100 percent indicates high stress; and more than 100 percent indicates critical stress.

8.3 percent. In comparison, the stress levels in East Asia and Western Asia are between 45 percent and 70 percent, in Central and South Asia, they are over 70 percent, while in Northern Africa, they are above 100 percent. Non-conventional water use in agriculture, such as water reuse and desalination, is still modest but growing, particularly in water-scarce areas such as the Middle East–Western Asia (Map S.8).

Water stress is high in all basins with intense irrigated agriculture and densely populated cities that compete for water, particularly where available freshwater resources are sparse due to climatic conditions. Countries are encouraged to disaggregate at the sub-basin level to give a detailed picture of water stress. Basins affected by high or critical water stress are located in regions with high water stress, such as Northern Africa, Northern America, Central and South Asia, and on the west coast of Latin America.

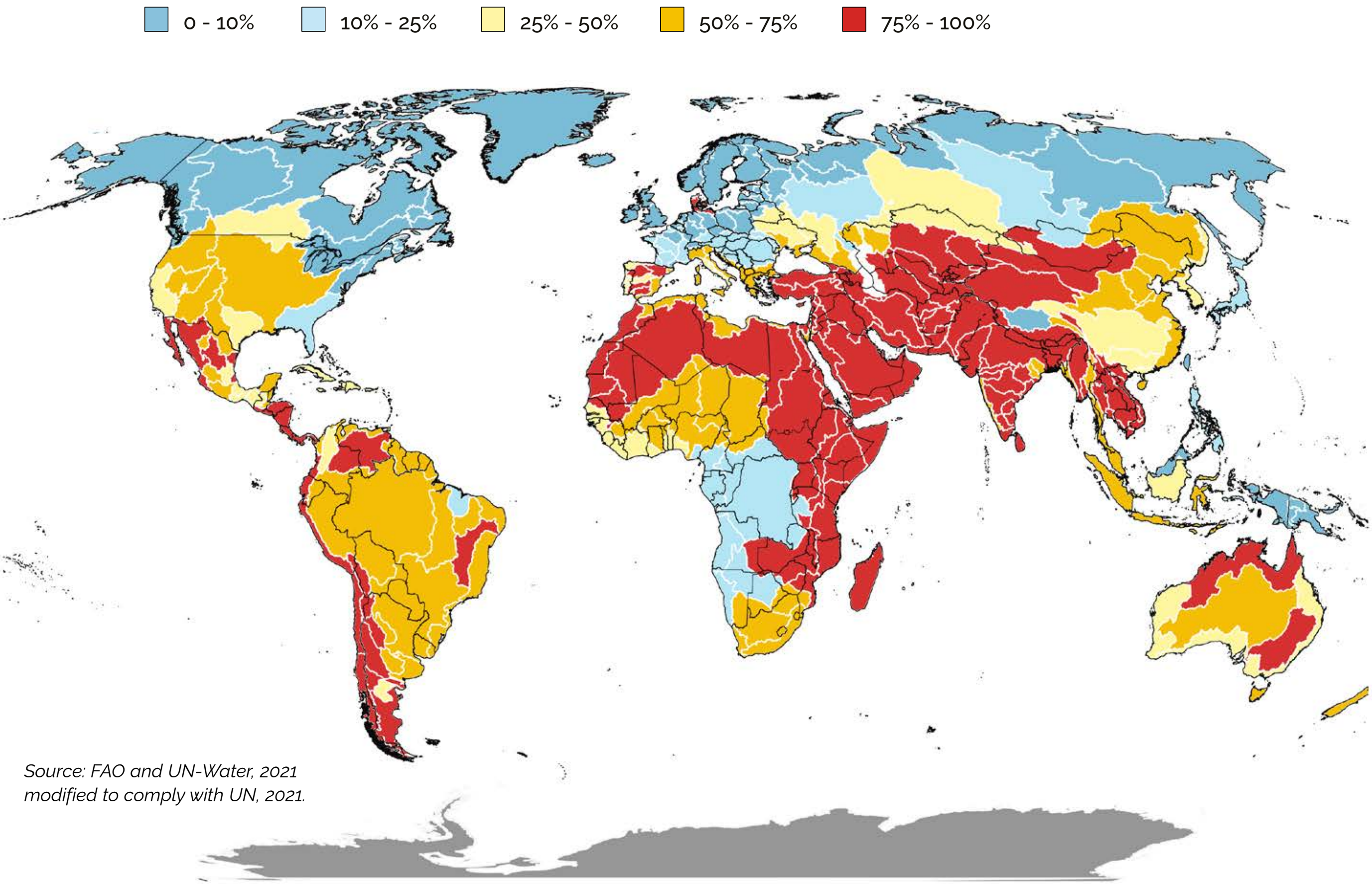
Agriculture is a significant contributor to water stress in countries with high levels of water stress. Agricultural withdrawals account for a substantial part of total withdrawals in Central Asia, the Middle East–Western Asia and Northern Africa (Map S.9). Water stress due to agricultural withdrawals illustrates the critical nature of the Nile and other river basins in the Arabian Peninsula and South Asia. These impacts are apparent in detail when distributed across areas equipped for irrigation.

MAP S.8 **LEVEL OF WATER STRESS OF ALL SECTORS BY MAJOR BASIN, 2018**



Source: FAO and UN-Water, 2021, modified to comply with UN, 2021.

MAP S.9 **LEVEL OF WATER STRESS DUE TO THE AGRICULTURAL SECTOR BY BASIN, 2018**



Source: FAO and UN-Water, 2021 modified to comply with UN, 2021.

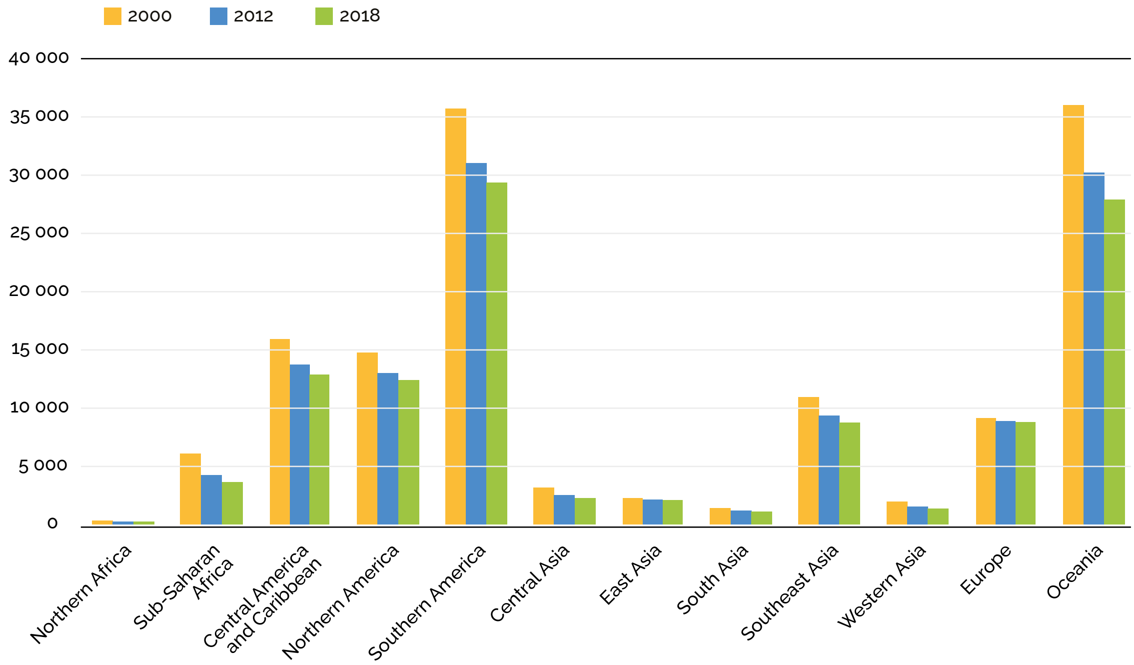
1.3.2 Per capita freshwater availability and withdrawals

The overall change in the per capita distribution of freshwater resources is consistent with population growth. Between 2000 and 2018, the decline in global per capita IRWRs was about 20 percent (Figure S.5). The change was greater in countries with the lowest per capita IRWRs, such as sub-Saharan Africa (41 percent), Central Asia (30 percent), Western Asia (29 percent) and Northern Africa (26 percent). The region with the lowest percentage change was Europe (3 percent).

On the demand side, the regions with the largest water withdrawals per capita were Central Asia and Northern America.

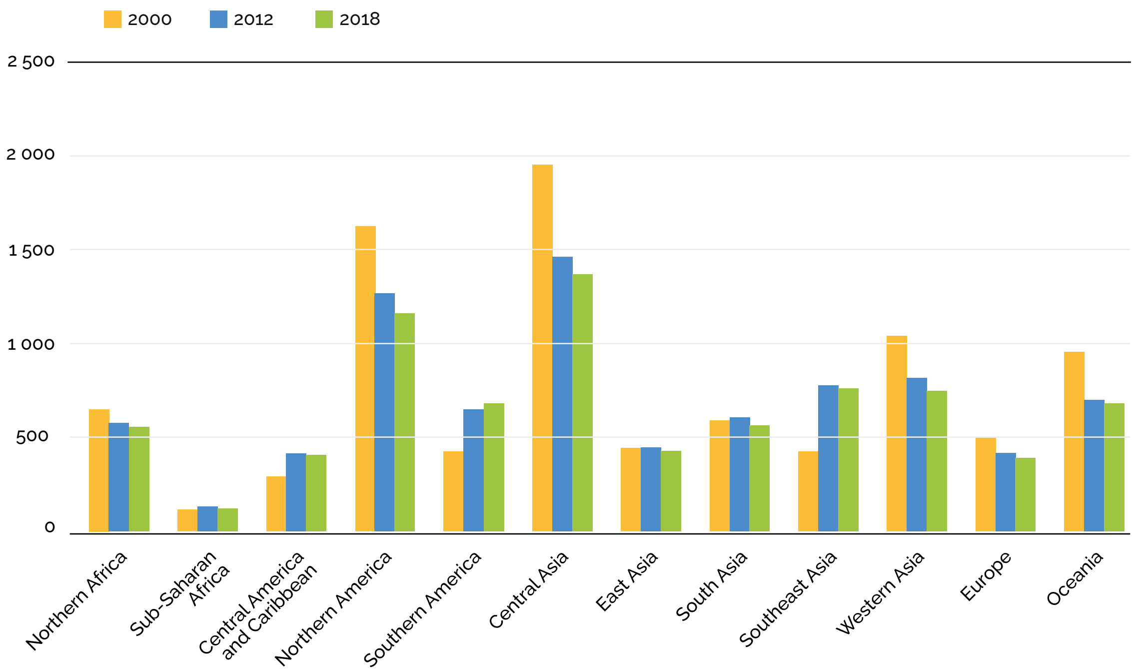
Total water withdrawals per capita declined from 2000 to 2018, except in Central America and the Caribbean, Southern America and Southeast Asia (Figure S.6). These trends are expected to persist as populations grow, partly due to overall increases in water productivity, including agriculture, and partly due to the prevalence of water scarcity induced by extended periods of aridity in areas of high population density.

FIGURE S.5 TOTAL ANNUAL IRWRS PER CAPITA BY GEOGRAPHICAL REGION, 2000, 2012 AND 2018 (m³/CAPITA)



Source: FAO AQUASTAT, 2021.

FIGURE S.6 TOTAL ANNUAL WATER WITHDRAWALS PER CAPITA BY GEOGRAPHICAL REGION, 2000, 2012 AND 2018 (m³/CAPITA)



Source: FAO AQUASTAT, 2021.

1.3.3 Groundwater depletion

Global groundwater withdrawals for irrigated agriculture are estimated at 820 km^3/year based on aggregated country-level reporting for 2018. This represents a 19 percent increase relative to 2010, when an estimated 688 km^3 was withdrawn for irrigated agriculture. Groundwater withdrawals for irrigated agriculture account for over 30 percent of agriculture's freshwater withdrawals and continue to grow at around 2.2 percent/year. The proportion of incremental evapotranspiration (consumption) over irrigated areas that can be attributed to groundwater is estimated at 43 percent due to the much lower conveyance losses associated with groundwater-sourced irrigation.

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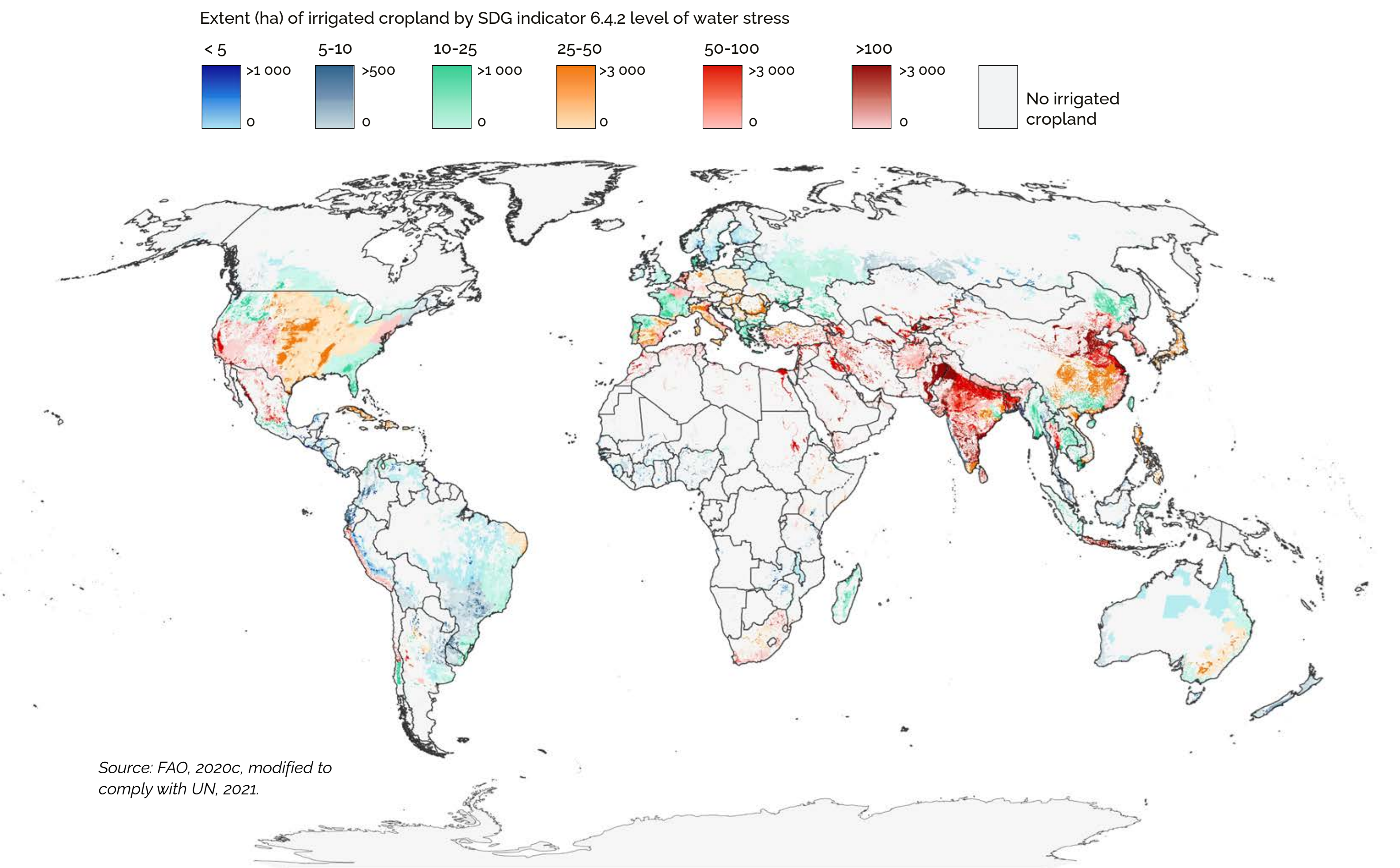
Groundwater use is already constrained. It is intensively exploited in most principal continental aquifers and along highly productive coastal plains, where saline intrusion is a constant threat. Irrigated areas under stress correlate strongly with intensive groundwater use and depleting aquifers (Map S.10).

MAP S.10 LEVEL OF WATER STRESS IN IRRIGATED AREAS, 2015



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

This level of groundwater exploitation is considered responsible for the loss of aquifer storage of 250 km^3/year, and more importantly, loss of aquifer function and utility to farmers as groundwater levels drop. Local impacts on production and livelihoods can be severe in aquifers that receive little or no recharge. Modelling the impact on irrigated crop production indicates that groundwater depletion will continue to place severe constraints in East Asia, the Middle East–Western Asia, Northern America and South Asia.

1.4 Extreme flood events

Climate models predict increasing frequency, intensity and amount of heavy precipitation as the global climate changes. More-intense rainfall is increasing the risk of landslides, extreme erosion and flash floods. The special report on climate change and land by the Intergovernmental Panel on Climate Change notes that tropical cyclones are already shifting towards the poles and the speed at which they move is slowing.

Increased exposure of coastal areas to intense and long-duration storms will lead to land degradation and affect coastal forest structure and composition. Sea-level rise already affects coastal erosion and salinization, leaving these areas vulnerable to catastrophic weather events. The annual crop production cycle in these areas is highly conditioned by climatic volatility: prolonged periods of drought and higher-frequency and more-intense rainfall and associated flooding.

Inland from coastal zones, overbank flooding is part of the natural hydrological cycle. It has been, and still is, responsible for bringing benefits to agricultural land (silt and nutrient replenishment). However, the land's ability to recover from flooding to maintain cropping calendars is an important element of the resilience of irrigated farming systems. The July–September flood event in 2010 in the Indus basin inundated at least 3.7 million ha of productive irrigated floodplain, disrupting rice food systems and industrial crops such as cotton well into 2011. Food protection for irrigated perimeters will generally be designed for events with 10–25 year return periods, while major river impoundment and storage infrastructure is generally designed to probable maximum precipitation.

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The sacrifice of irrigation schemes upstream of urban centres to contain excess flood flows has been a contentious issue in Southeast Asia, particularly when isolated areas of rural land have been converted into high-value "green-field" industrial sites.

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1.5 Water pollution from agriculture

Water pollution is a rising global crisis that directly affects health, economic development and food security. Although other anthropogenic activities such as human settlement (urbanization) and industry are major contributors, agriculture has become the dominant source of pollution in many countries. Degrading water quality is a significant threat to food safety and food security.

Currently, it is estimated that some 2 250 km³/year of effluent is discharged into the environment, 330 km³/year as urban wastewater, 660 km³/year as industrial wastewater (including cooling water) and 1 260 km³/year as agricultural drainage.

The capacity of soils to store, buffer and degrade waterborne contaminants is being exceeded by anthropogenic treatment of soils on cropland and pasture to the point where elevated levels of nitrogen, salinity and biological oxygen demand (BOD) in fresh water are widespread.

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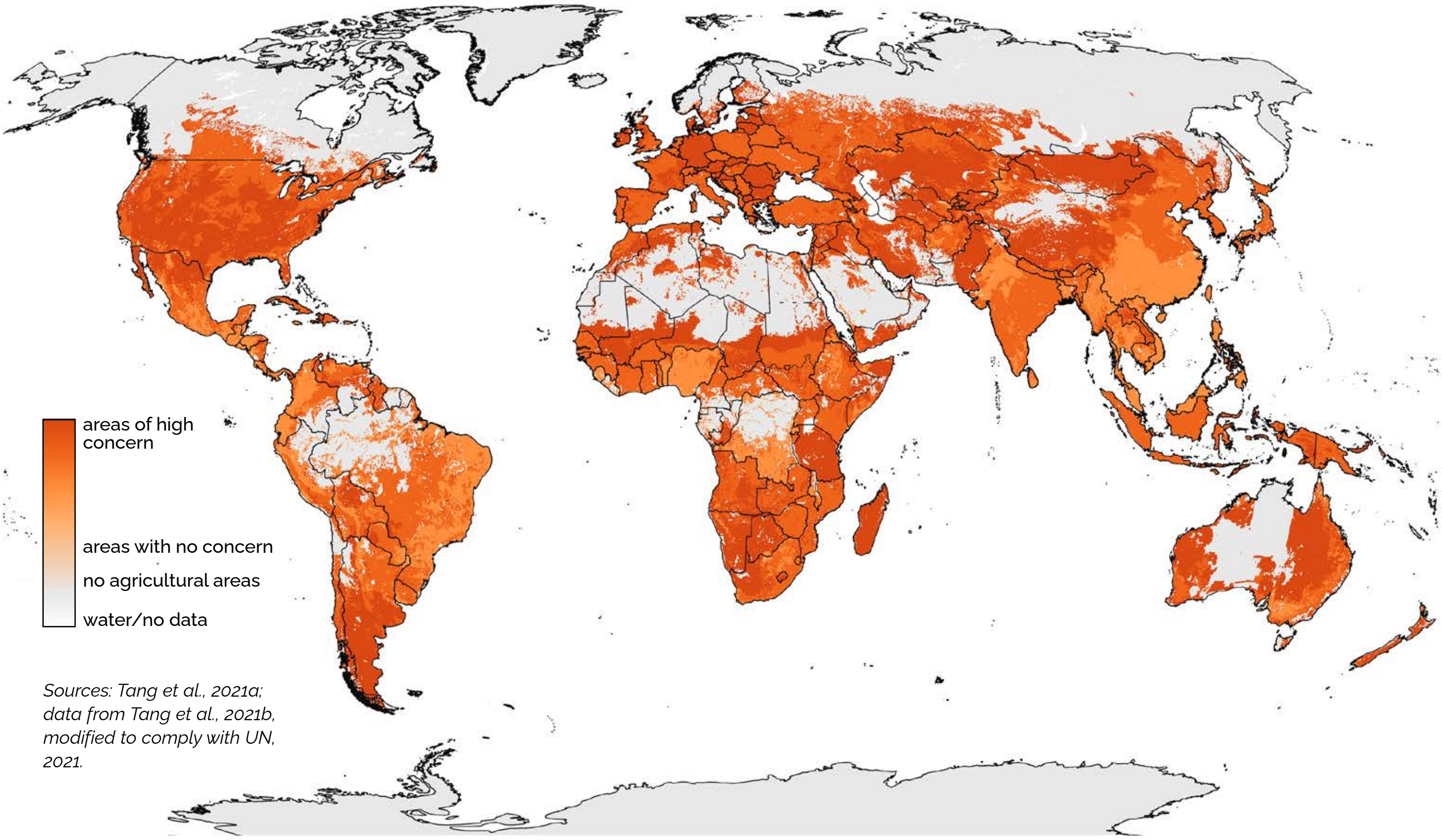
Agricultural use of reactive nitrogen synthetic fertilizer has continued to increase since 2000, from almost 81 million tonnes, to a peak of 110 million tonnes in 2017, with signs of a slight decline in 2018. Industrial fertilizer production and biological fixation of nitrogen in agriculture account for 80 percent of anthropogenic nitrogen fixation. The global growth rate of phosphorus use in agriculture is modest, from 32 million tonnes in 2000 to a peak of 45 million tonnes in 2016, followed by a marked decline. Estimates indicate the total phosphorus input to water bodies from anthropogenic use is about 1.47 million tonnes annually, with 62 percent from point sources (domestic and industrial) and 38 percent from diffuse sources (agriculture). Agricultural use of potash has risen from 22 million tonnes in 2000 to a peak of almost 39 million tonnes in 2018. The impact on freshwater eutrophication is not marked, as it is for nitrogen and phosphorus, although it contributes to salinity from run-off.

Of particular concern is pollution caused by emerging chemical contaminants, including pesticides, livestock pharmaceuticals and plastics, and potential antimicrobial resistance for which there is currently little regulation or monitoring. Map S.11 illustrates global regions of concern by pesticides.

MAP S.11 GLOBAL REGIONS OF CONCERN (GLOBAL AREAS SUSCEPTIBLE TO PESTICIDE POLLUTION)



Sources: Tang et al., 2021a; data from Tang et al., 2021b, modified to comply with UN, 2021.

SOME LAND AND WATER FACTS

- Rainfed farming produces 60 percent of the world's food on 80 percent of the cultivated land. Irrigated farming produces 40 percent on 20 percent of the land.
- Urban areas occupied less than 0.5 percent of the Earth's land surface in 2000. However, the rapid growth of cities (in 2018, 55 percent of the world's population were urban dwellers) has had a significant impact on land and water resources, encroaching on good agricultural land.
- Some 33 percent of the world's soil is moderately to highly degraded.
- Soil erosion carries away 20–37 billion tonnes of topsoil annually, reducing crop yields and the soil's ability to store and cycle carbon, nutrients and water. Annual cereal production losses due to erosion are estimated to be 7.6 million tonnes.
- Globally, agriculture accounts for 72 percent of all surface and groundwater withdrawals, mainly for irrigation.
- The SDG indicator 6.4.2 on global water stress increased from 17 percent in 2017 to 18 percent in 2018, with significant regional differences.
- Inland fish capture totalled 11.9 million tonnes in 2019, representing 13 percent of the total global capture fisheries' production. Just 17 countries produced 80 percent of the total global fish catch. Asia has the highest inland fish catch, representing 66 percent of the total global fish catch.

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About 1.2 billion people live in areas where severe water shortages and scarcity challenge agriculture and where there is a high drought frequency in rainfed cropland and pastureland areas or high water stress in irrigated areas.

2 SOCIO-ECONOMIC DRIVERS OF DEMAND FOR LAND AND WATER

Some 41 percent of South Asia suffers from human-induced land degradation, of which 70 percent is strongly degraded. (See map on page 10.)

Some key findings in this section…

- **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.

- **Inclusive land and water governance underpin productivity:** Land-use planning is urgently needed to guide land and water allocation and promote sustainable resources management.

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2.1 Socio-economic transitions and the global food system

The principal socio-economic variables driving demand for land and water resources are population growth, urbanization and economic growth. These all influence the climate. They drive demand for agricultural production in broadly predictable directions. However, geopolitical instability, conflicts and migration can lead to widespread poverty and food insecurity. After remaining stable for five years, the prevalence of undernourishment increased by 1.5 percentage points in 2020 – reaching a level of around 9.9 percent. In 2020, over 720 million people in the world faced hunger, and nearly one in three people (2.37 billion) did not have access to adequate food. Healthy diets were out of reach for around 3 billion people, especially the poor, in every region of the world in 2019.

The current pressures on limited renewable land, soil and water resources are unprecedented. Higher incomes and urban lifestyles change food demand towards more resource-intensive consumption of animal proteins, fruits and vegetables. The global population is expected to grow from 7.7 billion in 2019 to 9.7 billion by 2050 (26 percent). The fastest growth is in the poorest regions, including sub-Saharan Africa where the population will double by 2050, thus creating immense challenges to achieving SDGs, in particular, SDG 1 (no poverty), SDG 2 (zero hunger), SDG 6 (clean water and sanitation) and SDG 15 (life on land).

Globally, 80 percent of the extreme poor live in rural areas; most live in the developing world, and their livelihoods are disproportionally dependent on agriculture. This sector is key to reducing poverty and achieving SDGs, but it is highly exposed to current and

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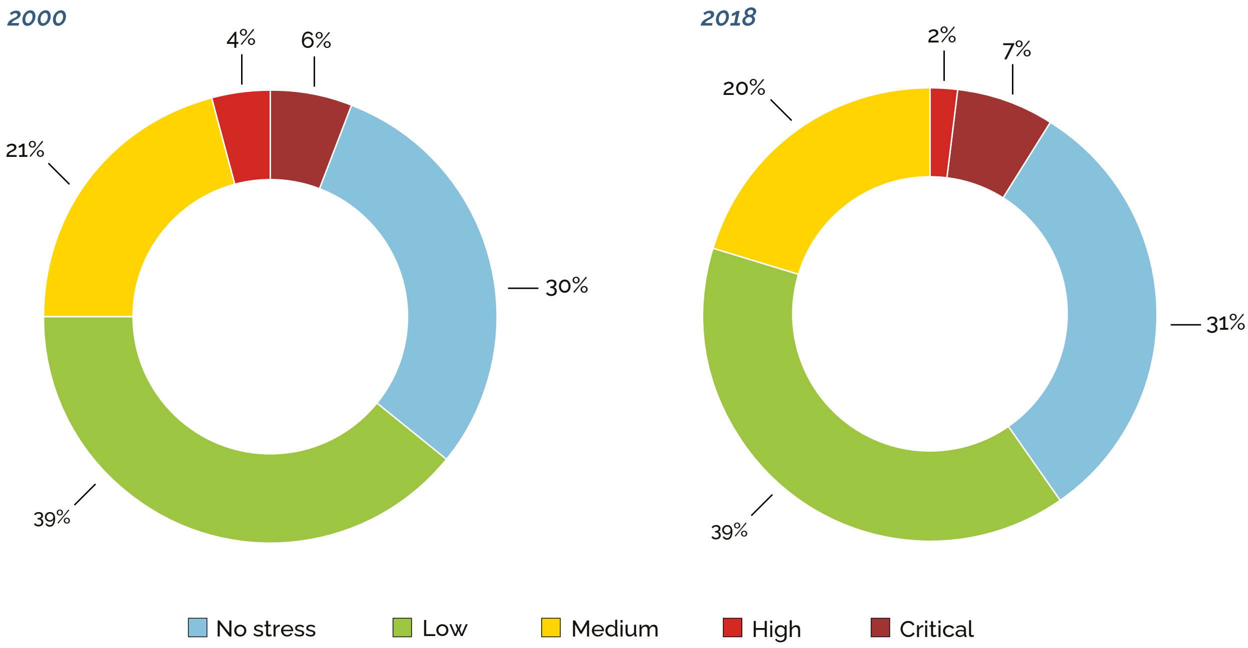
future climate risks. Responding to these risks has become an essential part of improving resilience strategies.

Uncontrolled urbanization and forced migration threaten sustainable resources management. By 2050, two out of three people will be living in towns and cities, with most growth in the less-developed regions of Africa and Asia. Urban dwellers consume 80 percent of all food produced. Processed foods can dominate urban diets and result in serious and widespread health consequences including malnutrition, obesity and micronutrient deficiencies.

2.2 Diminishing per capita water resources

More than 733 million people live in countries with high (70 percent) and critical (100 percent) water stress, accounting for almost 10 percent of the global population. Between 2018 and 2020, the number of people living in areas under critical water scarcity increased from 6 percent to 7 percent, but in areas of high water scarcity, numbers decreased from 4 percent to 2 percent (Figure S.7). About 1.2 billion people live in areas where severe water shortages and scarcity challenge agriculture and where there is a high drought frequency in rainfed cropland and pastureland areas or high water stress in irrigated areas.

FIGURE S.7 **POPULATION DISTRIBUTION ACCORDING TO COUNTRY THRESHOLD WATER STRESS, 2000 (LEFT) AND 2018 (RIGHT)**



Source: FAO and UN-Water, 2021.

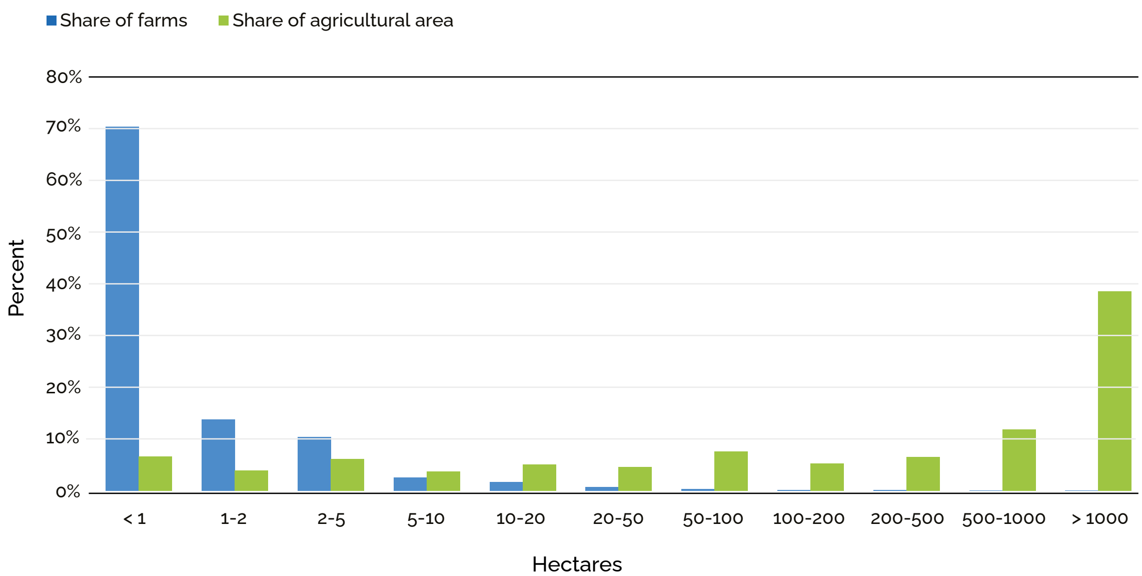
Increasing populations mean reduced natural resources available per capita. In sub-Saharan Africa, water availability per capita declined by 40 percent over the past decade, and agricultural land declined from 0.80 to 0.64 ha/capita between 2000 and 2017. Northern Africa, Southern Africa and Western Africa each have less than 1 700 m^3/capita, which is considered to be a level at which a nation's ability to meet water demand for food and from other sectors is compromised.

In addition, more than 286 rivers basins and about 600 aquifers cross international borders. However, over 60 percent of transboundary river basins and a much higher percentage of shared aquifers still lack any cooperative and adaptive transboundary management mechanisms to cope with resource allocation and water pollution control. Strengthening transboundary water cooperation is essential for reaching the water-related SDG targets and the broader SDGs.

2.3 Patterns of landholding are skewed

Although there are an estimated 608 million farm holdings in the world, farm size distribution is highly skewed towards large farms, with farms bigger than 500 ha accounting for more than 50 percent of total agricultural area. (Figure S.8). However, the number of farms is highly skewed towards smallholdings, with 84 percent of farms being below 2 ha, which occupy only 12 percent of the world's farmland. Thus, policy interventions for land management need to address the increasing concentration of land under a relatively small number of large commercial farming enterprises as much as the millions of smallholders with 2 ha or less. Their continued viability is critical for local food security in many low-income countries.

FIGURE S.8 GLOBAL DISTRIBUTION OF FARMS AND FARMLAND BY LAND SIZE CLASS, 2010



Source: Lowder, Sánchez and Bertini, 2021.

Between 1960 and 2010, the average farm size decreased in nearly all low- and lower middle-income countries and increased in a third of middle-income and nearly all high-income countries. However, there was a slight increase in average farm size in low-income countries from 2000 to 2010. In many low- and lower middle-income countries of Africa and South Asia, average farm size is shrinking, with implications for economic viability.

Increased concentration of farmland among larger farms in countries with higher income levels is occurring in most of the larger European countries (except Spain), and in Brazil and the United States of America. There is increased inequality with an apparent re-emergence of small farms, while the share of farmland on the largest holdings has increased. In 2010, the average farm size was 1.3 ha in low-income countries, 17 ha in lower middle-income countries, 23.8 ha in upper middle-income countries (excluding China) and 53.7 ha in high-income countries.

2.4 Access to land and water is constrained for some

Social structures determine the sustainability of natural resources. Societies drive land degradation and water scarcity, but these processes are not irreversible. Some societies have developed sustainable and resilient production systems to overcome degradation. Their experiences can inform decision makers about the potential of community-based resource management systems.

Reducing rural poverty requires equitable access to land and water resources. The lack of adequate access and capacities to take advantage of natural capital may overuse resources to meet short-term needs. The critical factors to tackling these issues lie in establishing good governance, effective institutions and secure tenure. There are strong synergies and trade-offs between poverty reduction policies and sustainable resources management. Current water laws tend to decouple water rights from land tenure.

Development trends and climate change impacts increase the competition for land and water resources and increase the risk to livelihoods of the poor and vulnerable. About 77 percent of smallholder farms in low- and middle-income countries are in water-scarce regions, and less than a third have access to irrigation. The greatest disparities in irrigation between smallholdings and large-scale farms are in Latin America and the Caribbean, South Asia and sub-Saharan Africa. Limited access to irrigation services can be a significant constraint on rural livelihoods, particularly in arid regions.

There are also strong gender and equity issues surrounding access to and management of land and water. Women comprise over 37 percent of the world's rural agricultural workforce, a ratio that rises to 48 percent for low-income countries. Their contribution is prominent in all agricultural subsectors. They comprise almost 50 percent of the world's small-scale livestock farmers and half the labour force in small-scale fisheries. Fewer than 50 countries have laws or policies that specifically mention women's participation in rural sanitation or water resources management. Women still account for less than 15 percent of agricultural landholders, and there are disparities in their access to agricultural support services.

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2.5 Competition and sectoral trade-offs: the water–food–energy nexus

There may be important synergies and trade-offs that cannot be addressed by sectoral strategies and investments alone. For example, growing bioenergy crops in rainfed or irrigated systems may help improve energy supply, but may also result in increased competition for land and water resources with impacts on local food security. Building dams for hydropower may produce energy and provide water storage for irrigation and domestic uses, but may displace people and adversely affect water availability in downstream agroecosystems. These and other similar developments would benefit from greater coordination through a water–food–energy nexus approach to optimize resource-use efficiency.

Many lessons have been learned from the tragic drying up of the Aral Sea in Central Asia, as the water resources were overexploited to grow irrigated cotton. This put excessive pressures on water supplies, creating salinization, pollution from agricultural chemicals and mining wastes on upstream rivers, and loss of aquatic species and fisheries and associated livelihoods.

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 ground-water 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.

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- **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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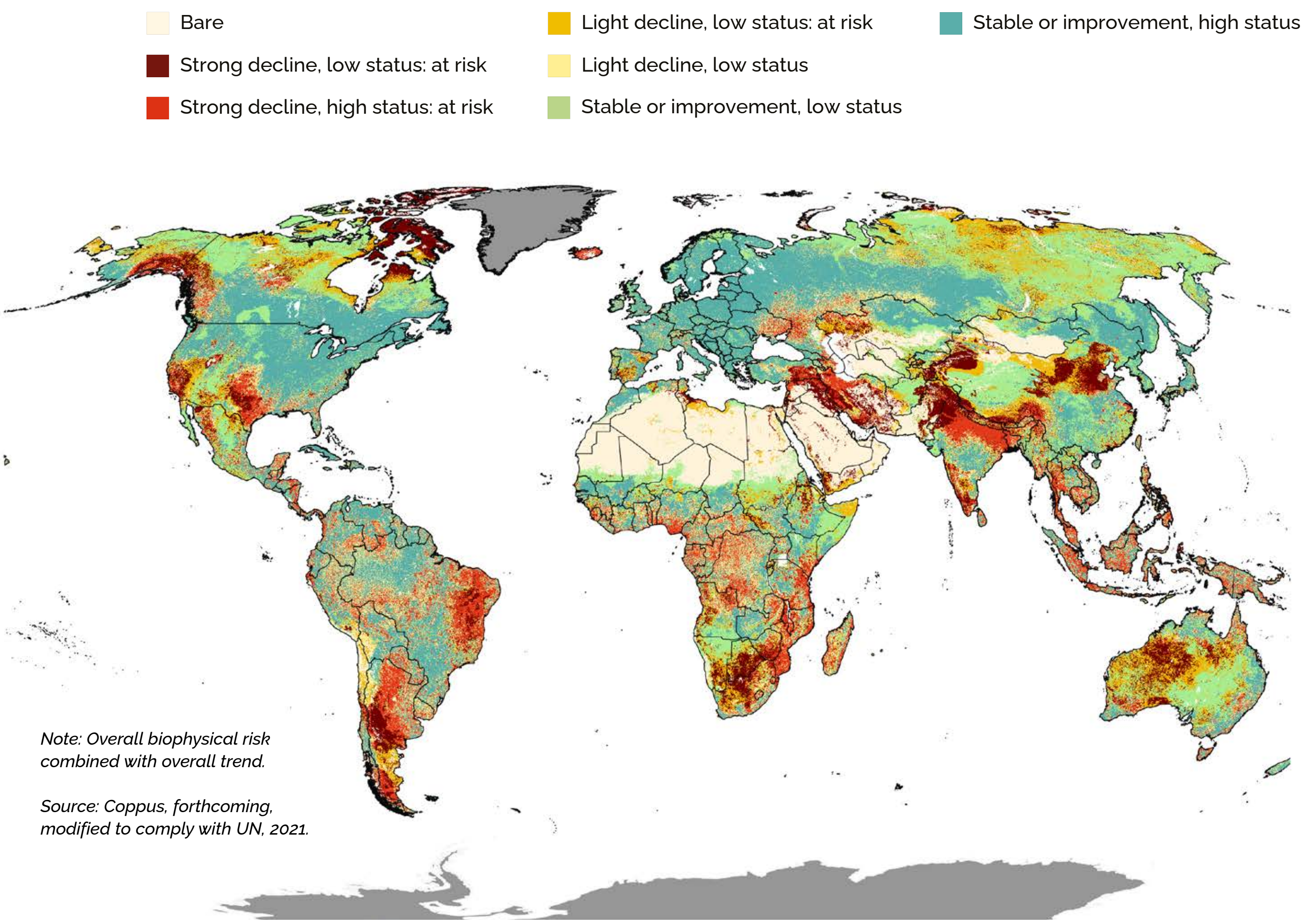
Pressures on land and water systems are compromising agricultural productivity. This is occurring precisely at times and in places where growth is most needed to meet sustainable global food targets. Human-induced land degradation and water scarcity raise risk levels for agricultural production and ecosystem 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.

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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).

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

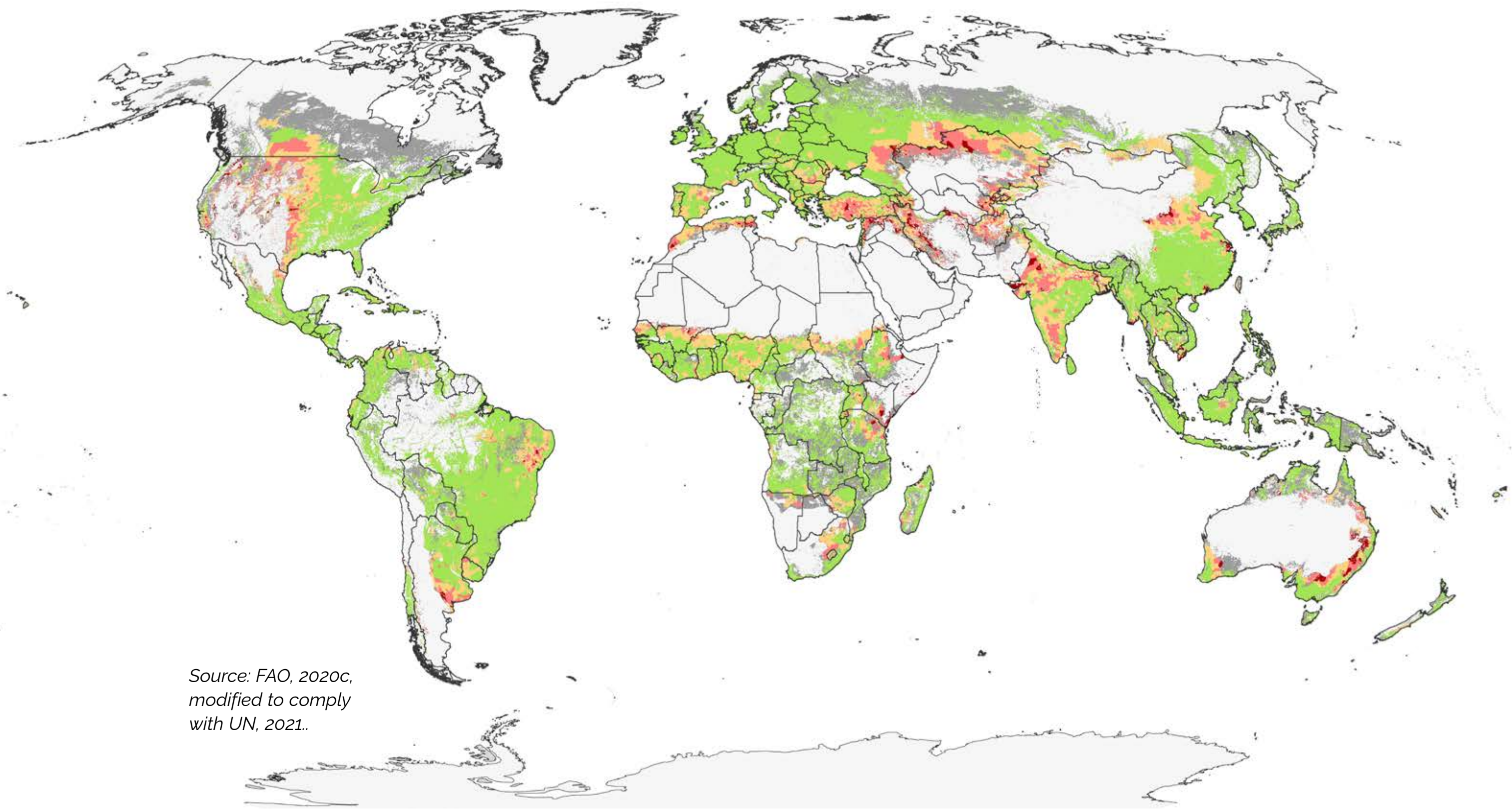
Note: The term degradation refers to high pressures from anthropogenic drivers. All other declines in biophysical status are defined as deterioration.

Source: Coppus, forthcoming.

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

Frequency of severe drought on rainfed cropland (%)

< 10 | 10-20 | 20-30 | > 30 | No data | No rainfed cropland



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).

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 (km^3)	IRRIGATED HARVESTED AREAS (MILLION ha)	INCLUDING ET IRRIGATION (km^3)	INCLUDING ET AND CC IRRIGATION (km^3)
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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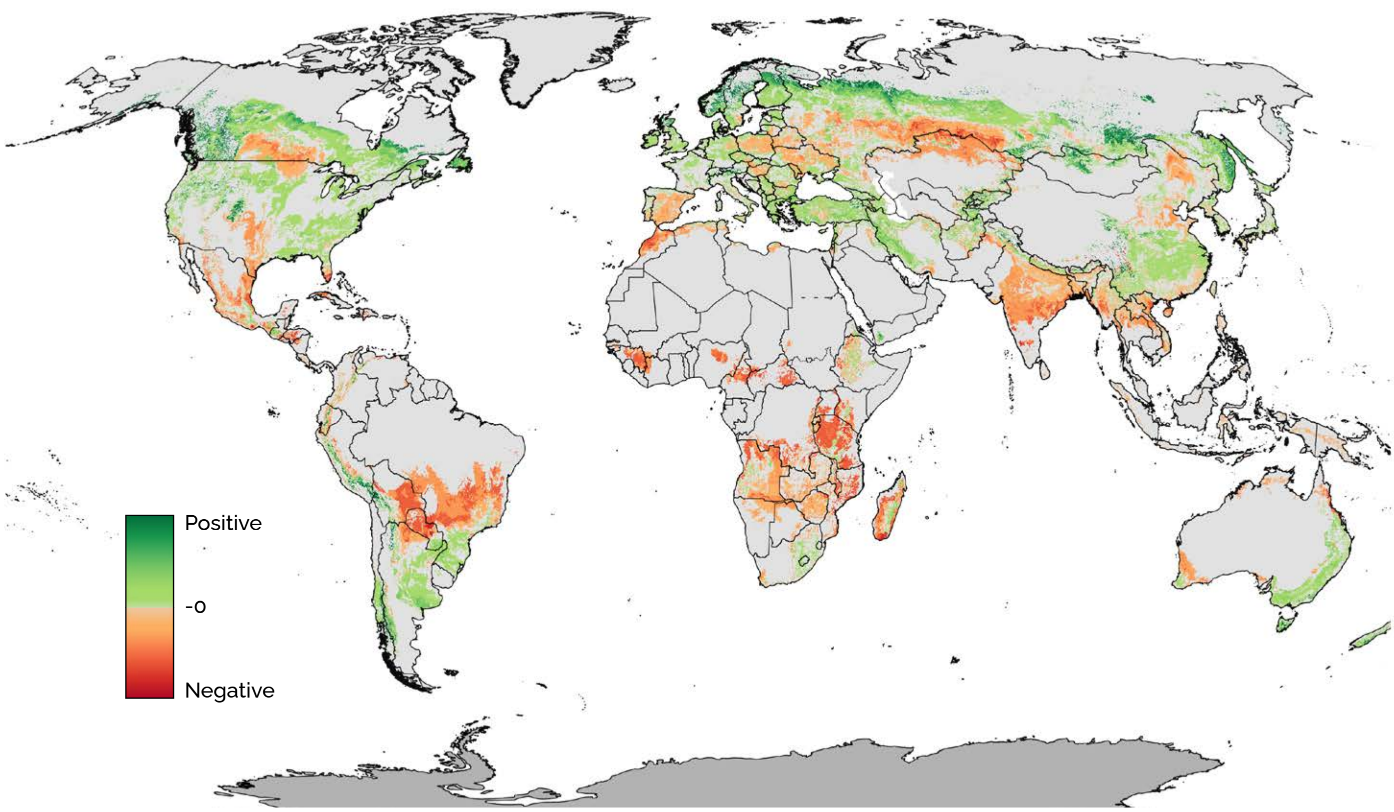
The water resource implications for this growth have been modelled for the SOLAW 2021 report. They indicate evapotranspiration would increase from 1 285 km³ in 2012 to 1 540 km³ by 2050 without climate change and to 1 730 km³ with climate change (Table S.6). Taking account of water requirements for land preparation and leaching, plus conveyance losses from withdrawal to consumption, would push annual gross agricultural withdrawals towards 3 500 km³.

3.3 From climate risk to rainfed production – shifting land suitability

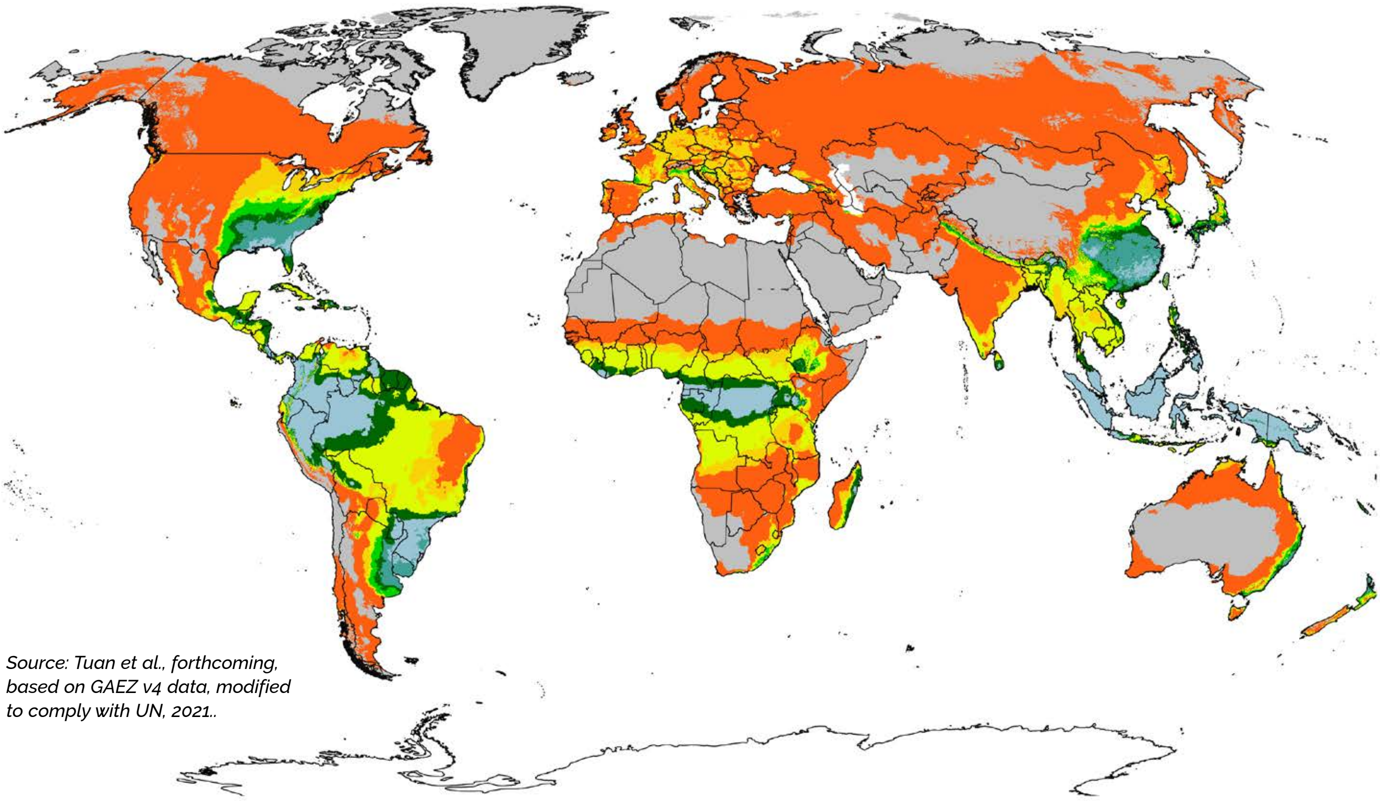
Land suitability for cropping is not static; shifts in suitability and areas are anticipated as the climate changes. Using land resources planning tools, such as the GAEZ methodology, together with climate models, provides invaluable insights into how these changes will redistribute land available for 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 km² (20 percent) (from no cropping). Double cropping with rice could increase by 601 000 km² (27 percent) and the potential area for triple rice cropping would be 910 000 km² (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

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


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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).

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".

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4.1 Action area I: Adopting inclusive land and water governance

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.

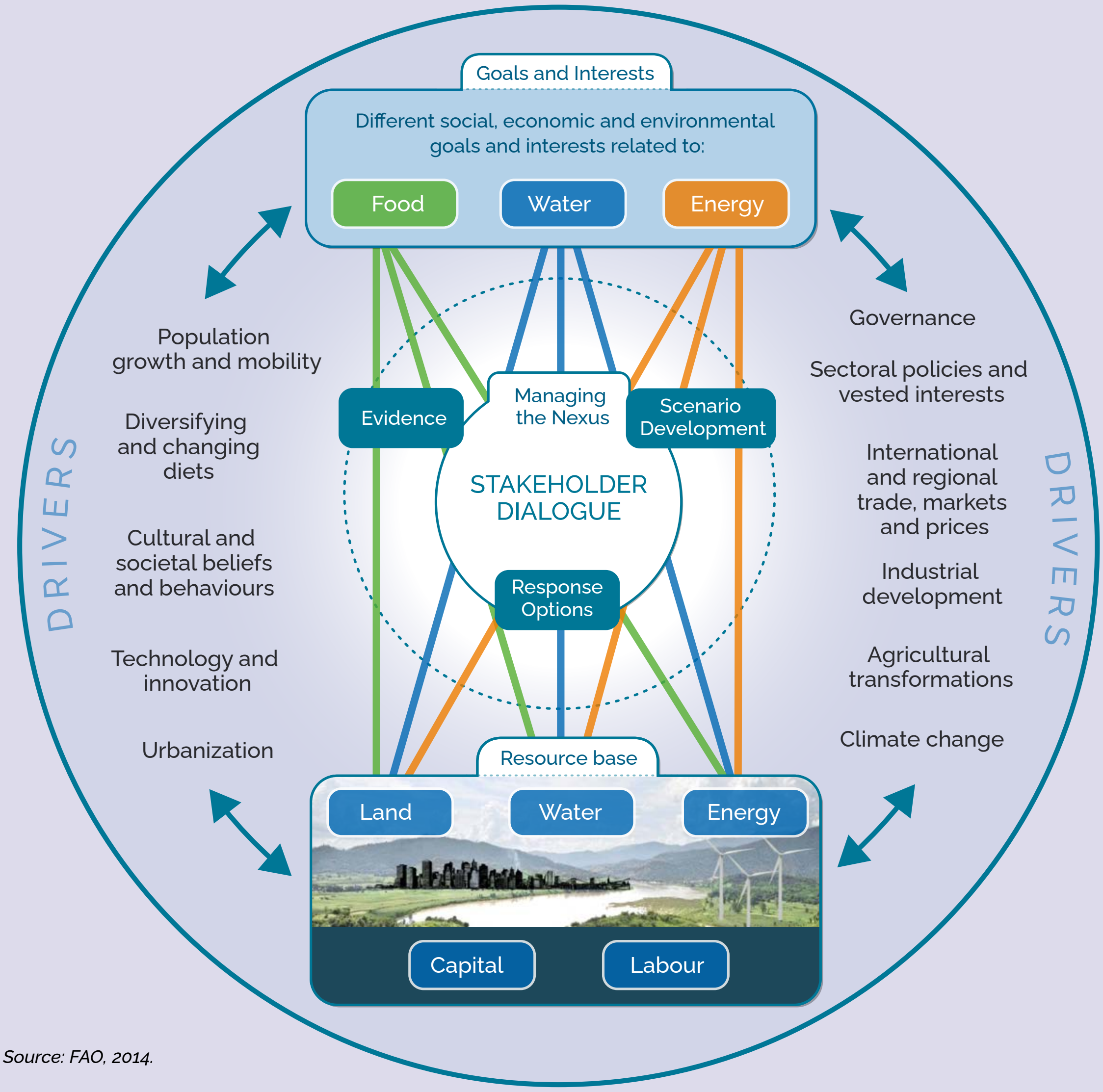
Solutions to address land and water challenges can be selected and adapted to specific circumstances, and supported by governance measures and strengthened institutions and capacities at all levels of decision-making. At a fundamental level, there is need for effective land and water resource governance 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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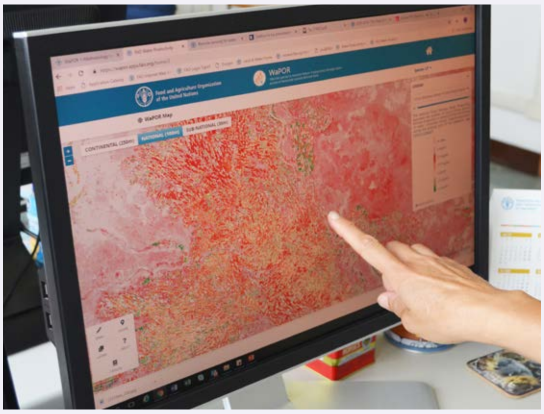
Source: FAO, 2017.

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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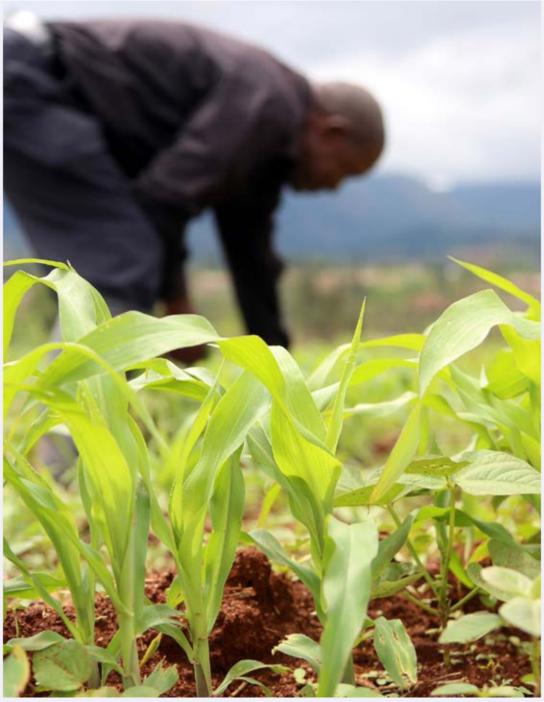

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Climate-smart agriculture aims to increase agricultural productivity and incomes, adapt and build resilience to climate change, and reduce GHG emissions.

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

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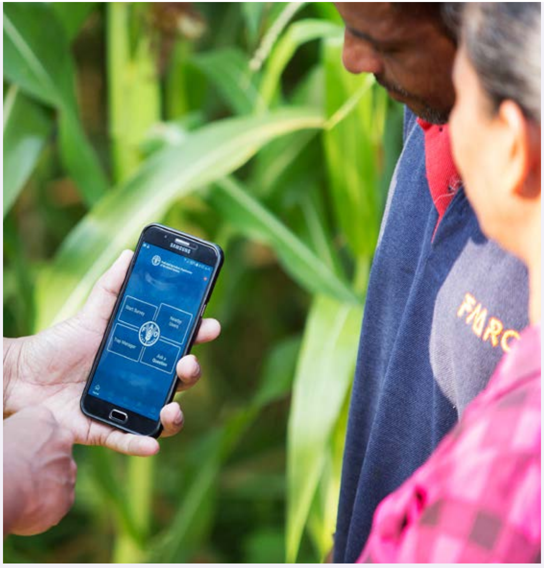
and SDGs. These will need mainstreaming and scaling out with support from effective policies and financial mechanisms. Studies suggest that restoration costs less than a third of the cost of inaction, and preventing degradation is generally far less costly than restoration.

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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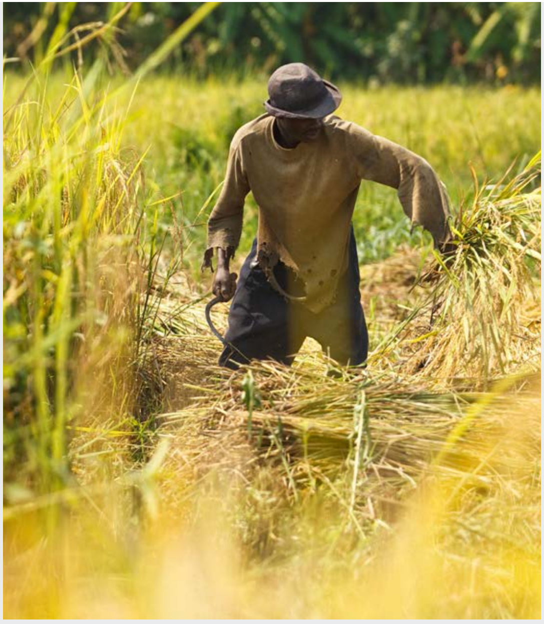

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The social challenges and environmental risks faced by agriculture continue to proliferate. Pressures on land and water resources arise largely within agriculture and the wider food system, generating significant GHG emissions and aggressive soil and 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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