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

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

Systems at breaking point

Synthesis report 2021

Food and Agriculture Organization of the United Nations
Rome, 2021

Required citation:
FAO. 2021. *The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point. Synthesis report 2021.* Rome. https://doi.org/10.4060/cb7654en

ISBN 978-92-5-135327-1

Cover photographs (from the top to bottom): ©FAO/Giulio Napolitano, ©FAO/Giuseppe Bizzarri, ©FAO/Alessia Pierdomenico, ©FAO/Sheam Kaheel

CONTENTS

Maps

Figures

Tables

Boxes

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.

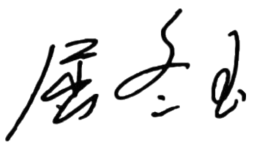
Against this background, it is clear our future food security will depend on safeguarding our land, soil and water resources. The growing demand for agrifood products requires us to look for innovative ways to achieve the Sustainable Development Goals, under a changing climate and loss of biodiversity. 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.

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.

©FAO/Giulio Napolitano

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.

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.

ACKNOWLEDGEMENTS

The preparation of the SOLAW 2021 report has benefited from the support and input of a number of individuals and institutions.

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,

F. Nachtergaele, V. Nzeyimana, V. Onyango, P. Panagos, L. Peiser, M. Petri, J. Preissing, O. Rochdi, W. Saleh, N. Santos, W. Scheumann, M. de Souza, H. Tropp, G. Veleasco and L. Verchot.

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

Publishing arrangements, communications and graphic design: M. Piraux, J. Morgan, K. Khazal and A. Asselin-Nguyen.

Secretarial assistance: A. Grandi.

Institutions involved in preparation: SOLAW 2021 is a collaborative effort led by the Land and Water Division of FAO in collaboration with several divisions/units at FAO headquarters, regional and country offices, senior advisers and key partners. Appreciation is given to the partner institutions that provided data and written contributions:

Agricultural Research for Development

Asian Soil Partnership

Australian Centre for International Agricultural Research

Environmental Law Institute

Federal Ministry for Food and Agriculture (Germany)

Future Earth/Water Futures Group

German Development Institute

Griffith University

International Center for Agricultural Research in the Dry Areas

International Center for Biosaline Agriculture

International Center for Tropical Agriculture

International Commission on Irrigation and Drainage

International Groundwater Resources Assessment Centre

International Institute for Applied Systems Analysis

International Water Management Institute

Joint Research Centre, European Commission

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.)*

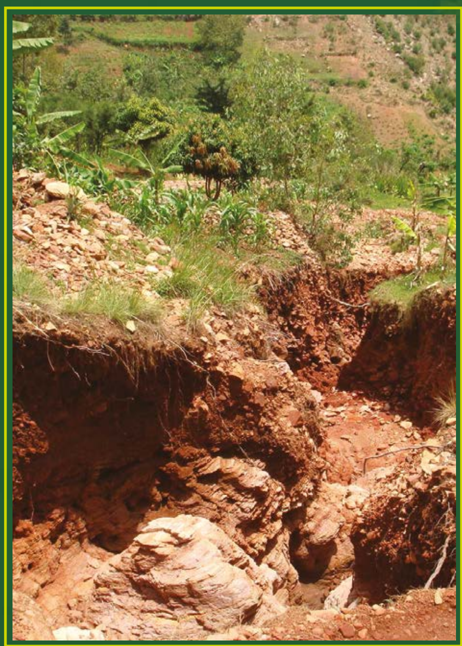
Map source: FAO and UN-Water, 2021 modified to comply with UN, 2021.

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.



*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

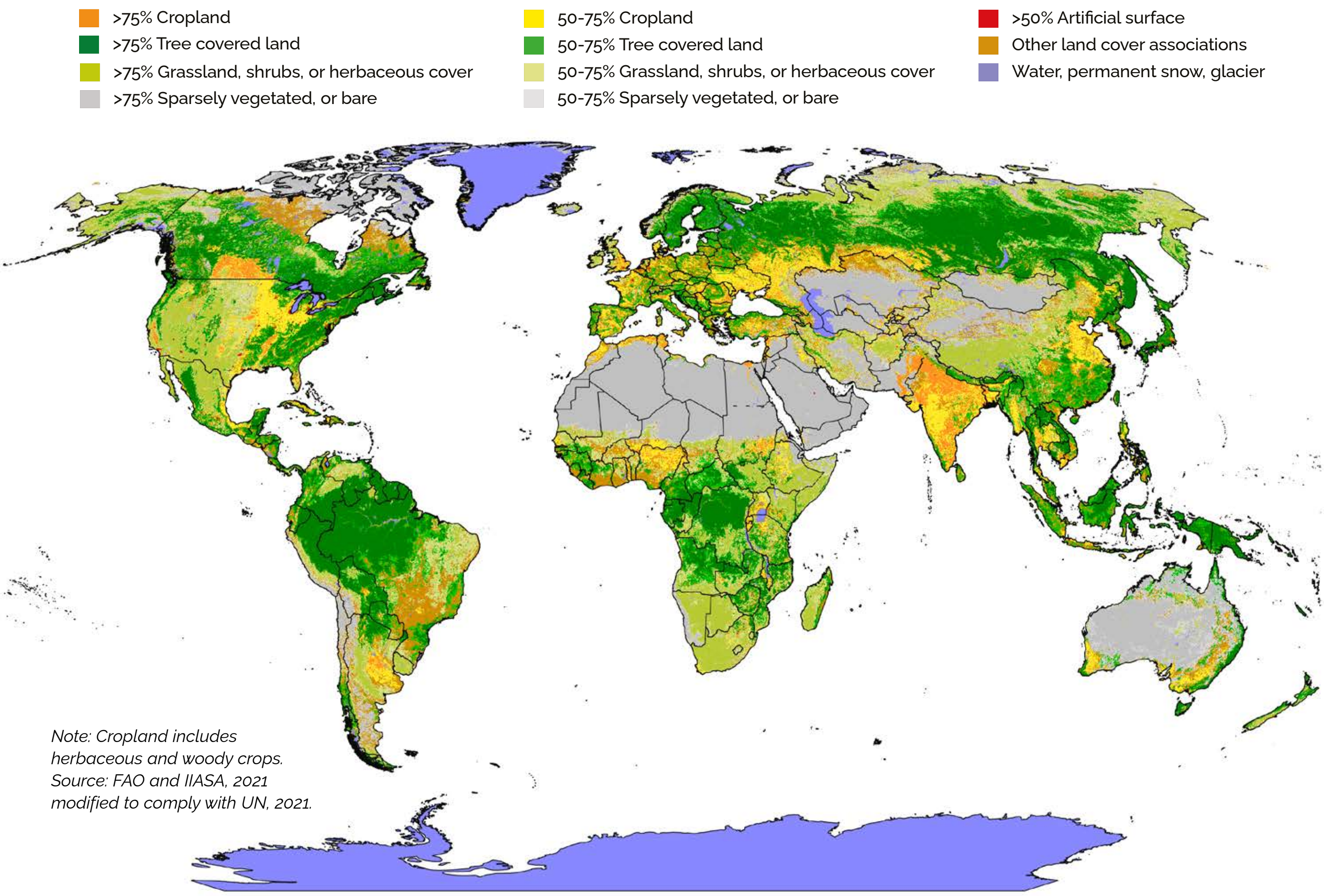
1.1 Pressures on land resources under climate change

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



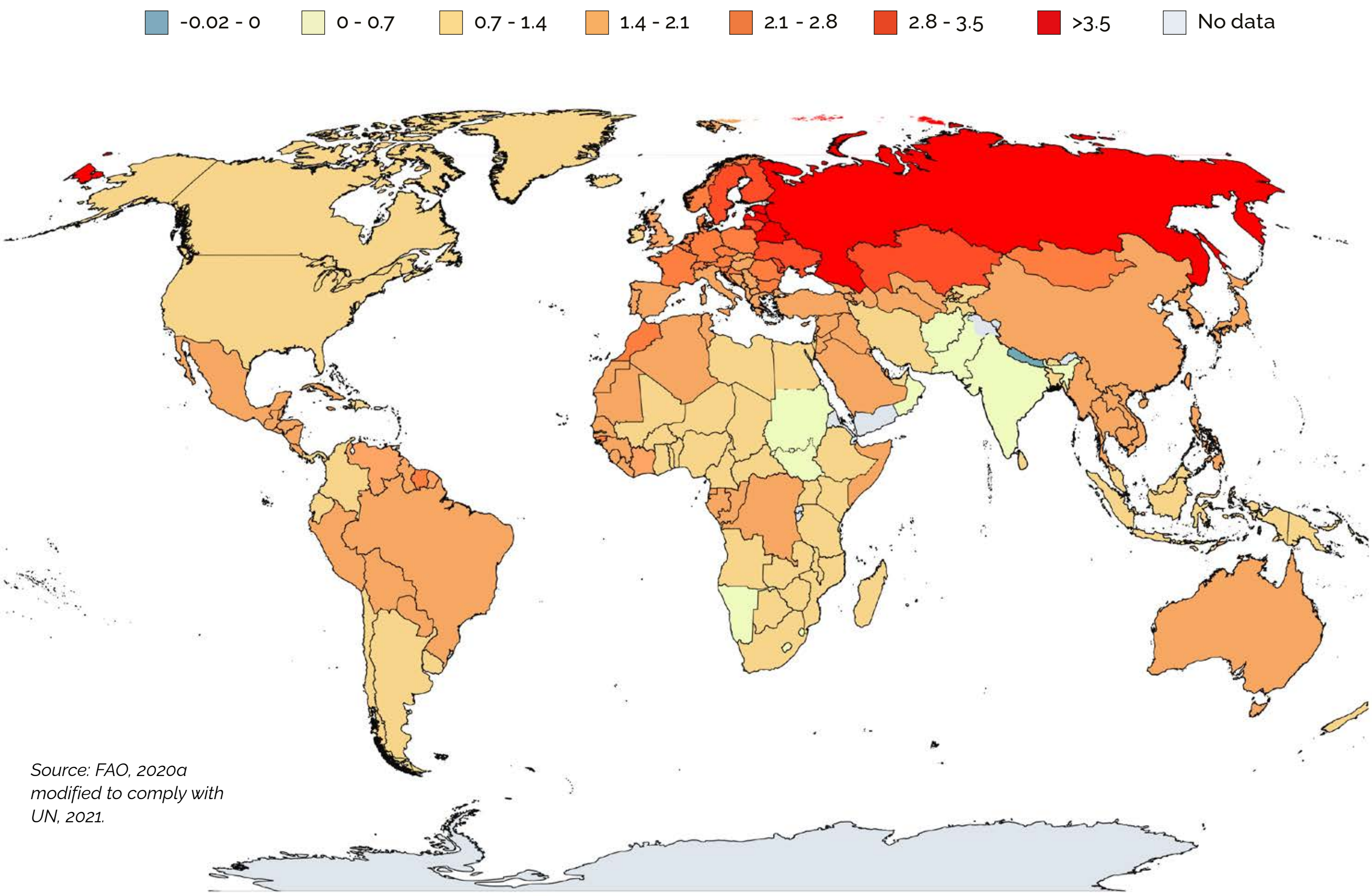
Note: Cropland includes herbaceous and woody crops.
Source: FAO and IIASA, 2021 modified to comply with UN, 2021.

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

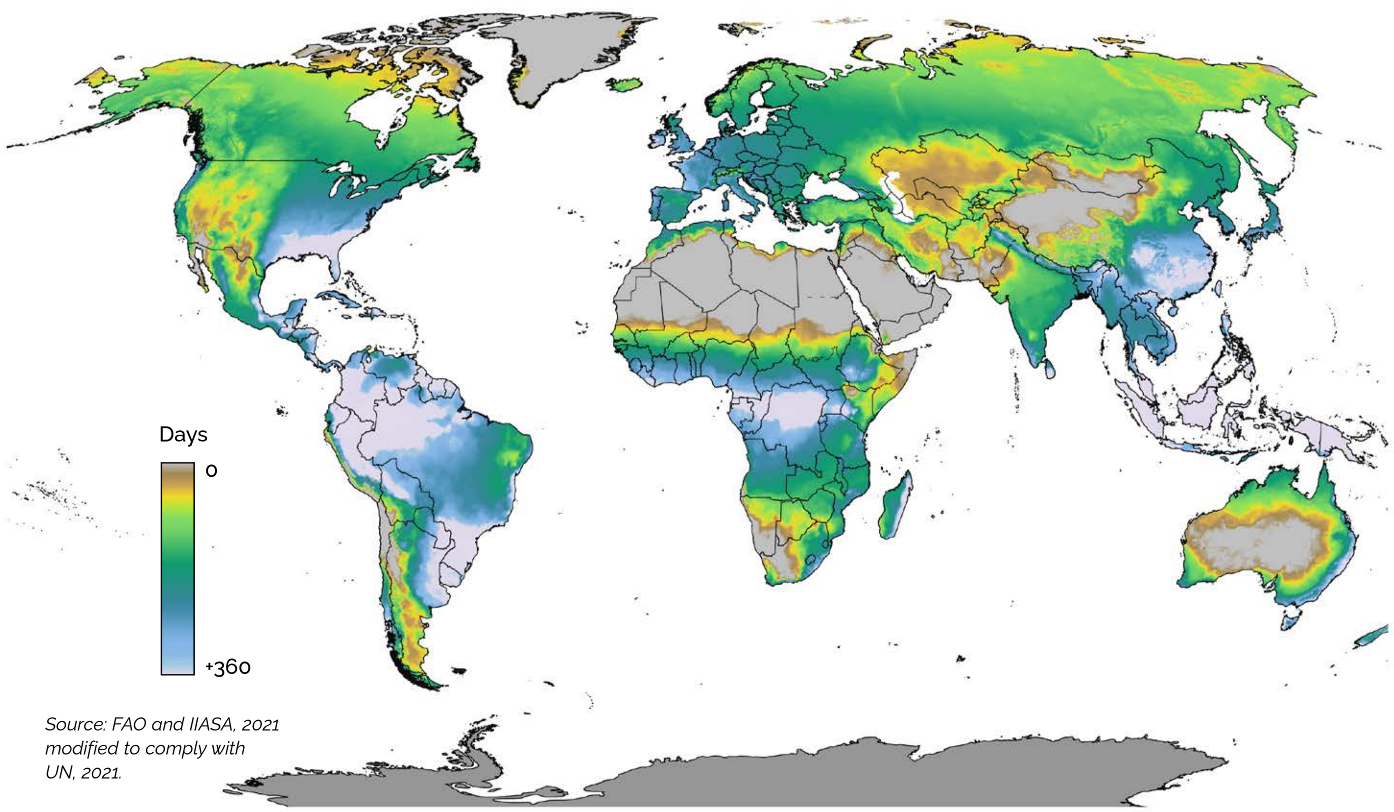
Source: FAO, 2020a.

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.

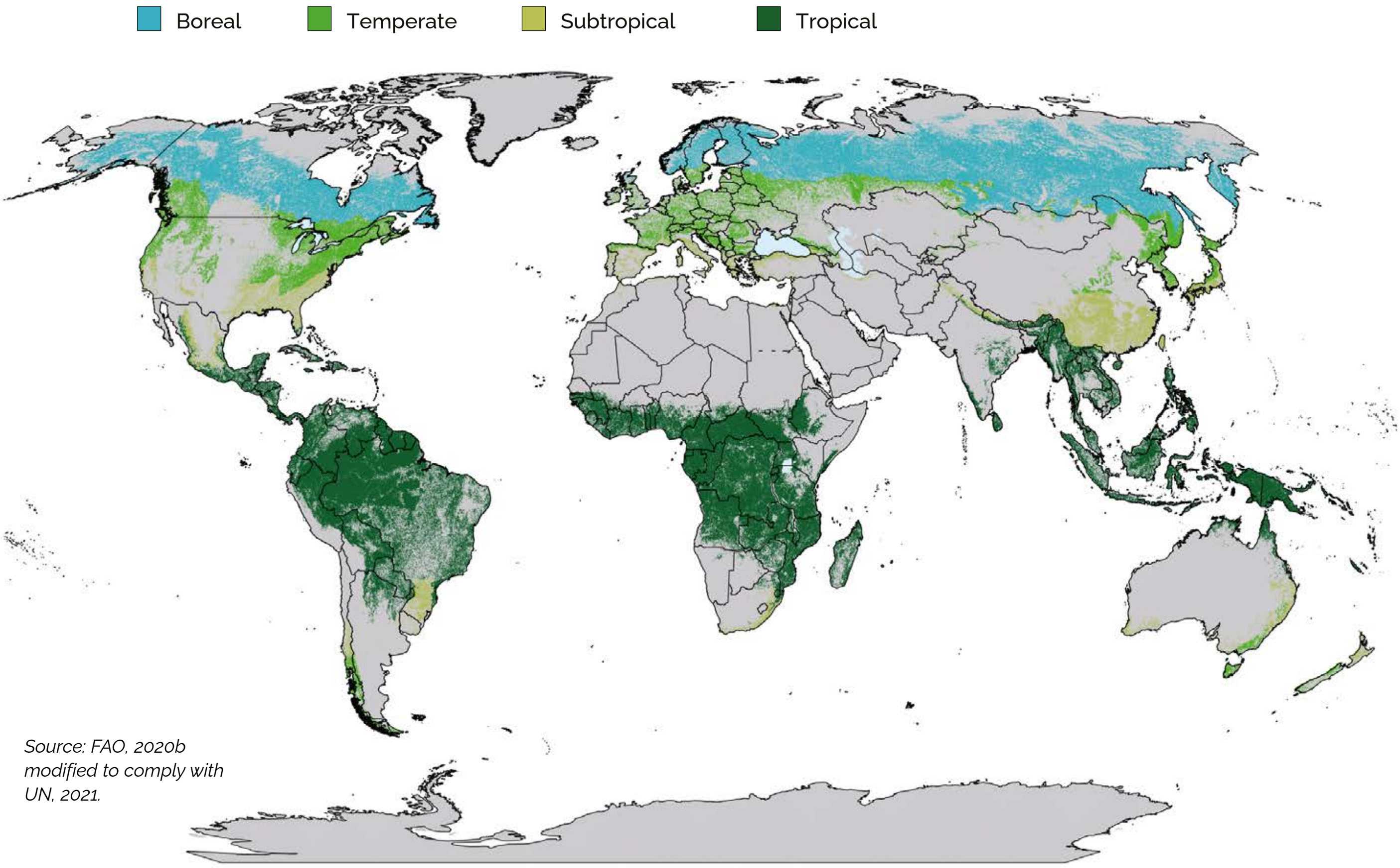
Climate change impacts on the water cycle are expected to significantly affect agricultural output and the environmental performance of productive land and water systems. Climate models predict decreases in renewable water resources in some regions (mid-latitude and dry subtropical regions) and increases 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).

©FAO/Vasily Maksimov

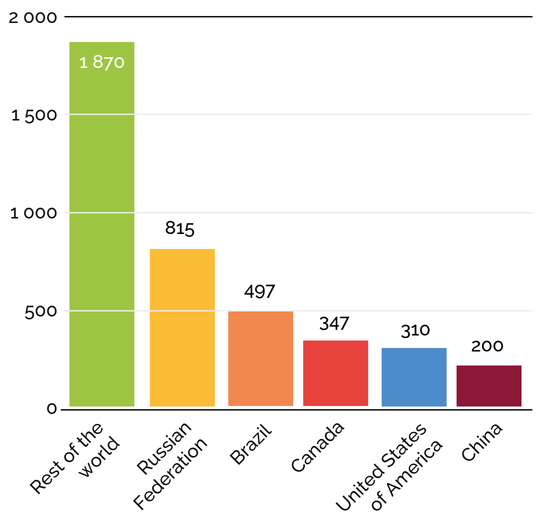
MAP S.4 GLOBAL DISTRIBUTION OF FORESTS BY CLIMATE DOMAIN, 2020



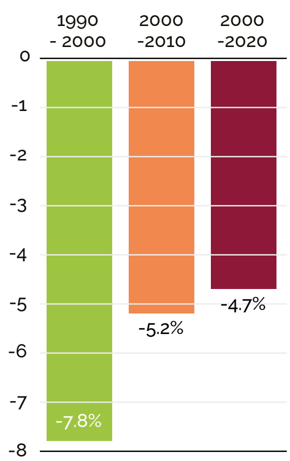
Source: FAO, 2020b modified to comply with UN, 2021.

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

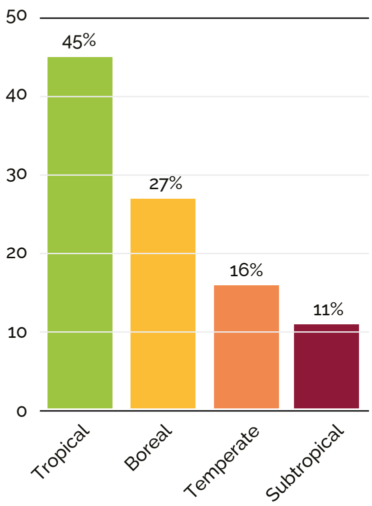
Top five countries for forest area, 2020 (million ha)



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

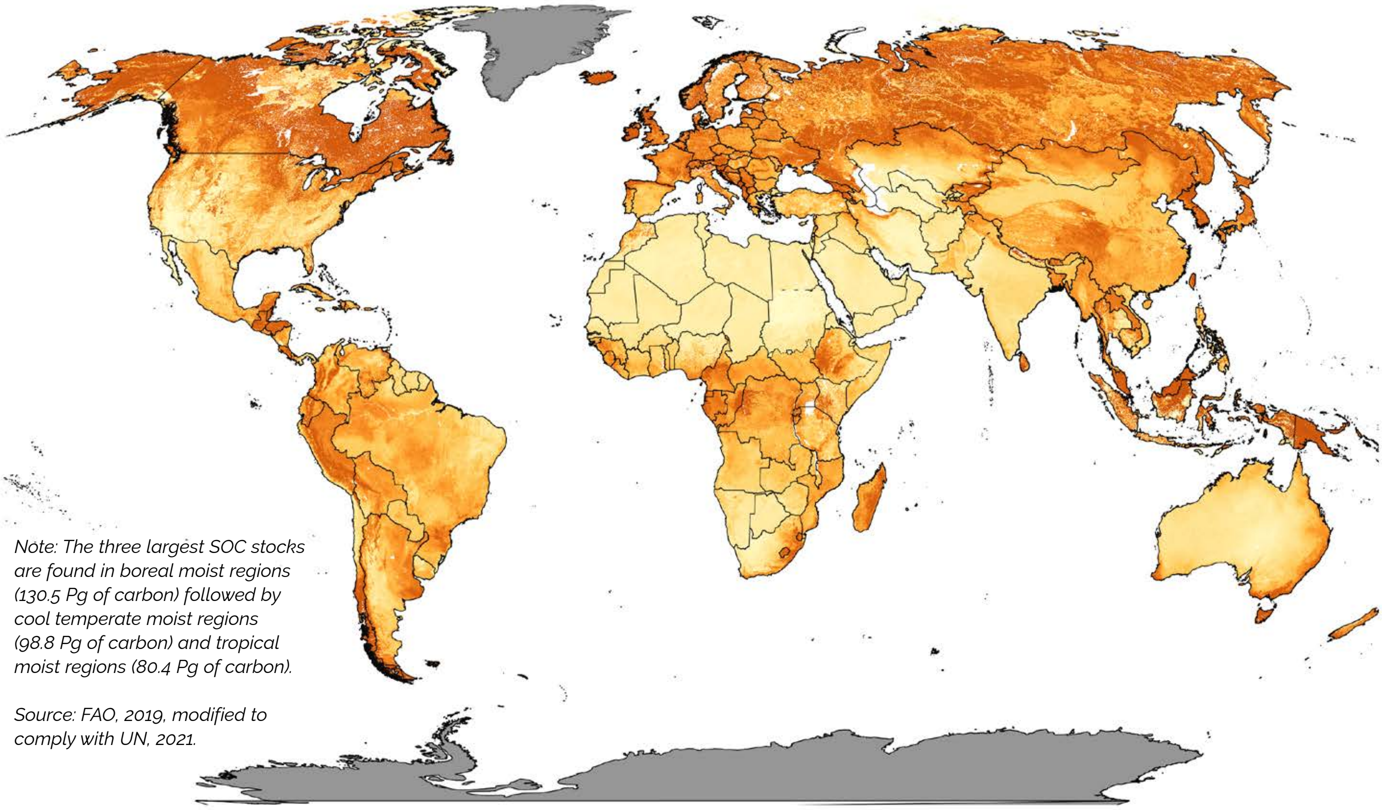
Soils are an essential buffer or "regulator" of climate change. Soils under conventional agriculture continue to be a source of carbon dioxide emissions, but conservation techniques can halt, and in some instances, reverse the loss of soil organic carbon (SOC) (Map S.5). Peat soil degradation and drainage 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.

©FAO/Stefanie Glinski

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)**

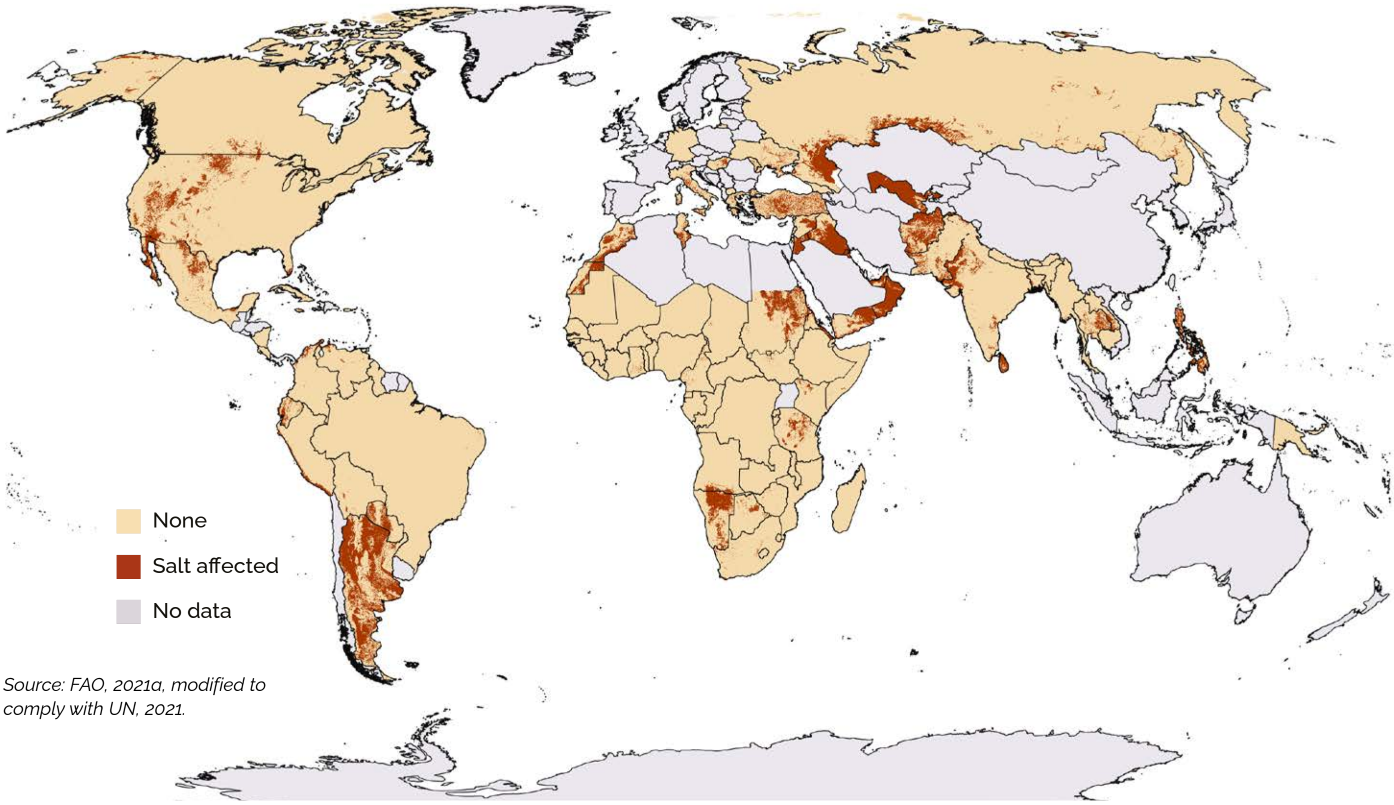
0 - 20 (very low) | 20 - 40 (low) | 40 - 70 (medium) | 70 - 90 (high) | > 90 (very high)



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.

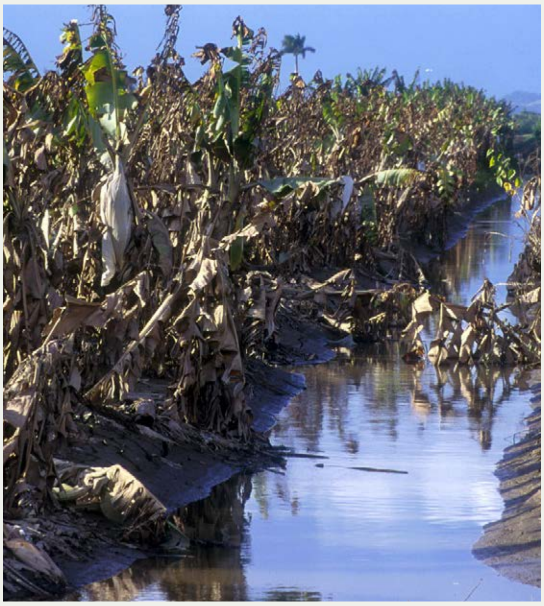
MAP S.6 SALT-AFFECTED SOILS, 30–100 cm, 2021



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.



©FAO/Lou Dematteis

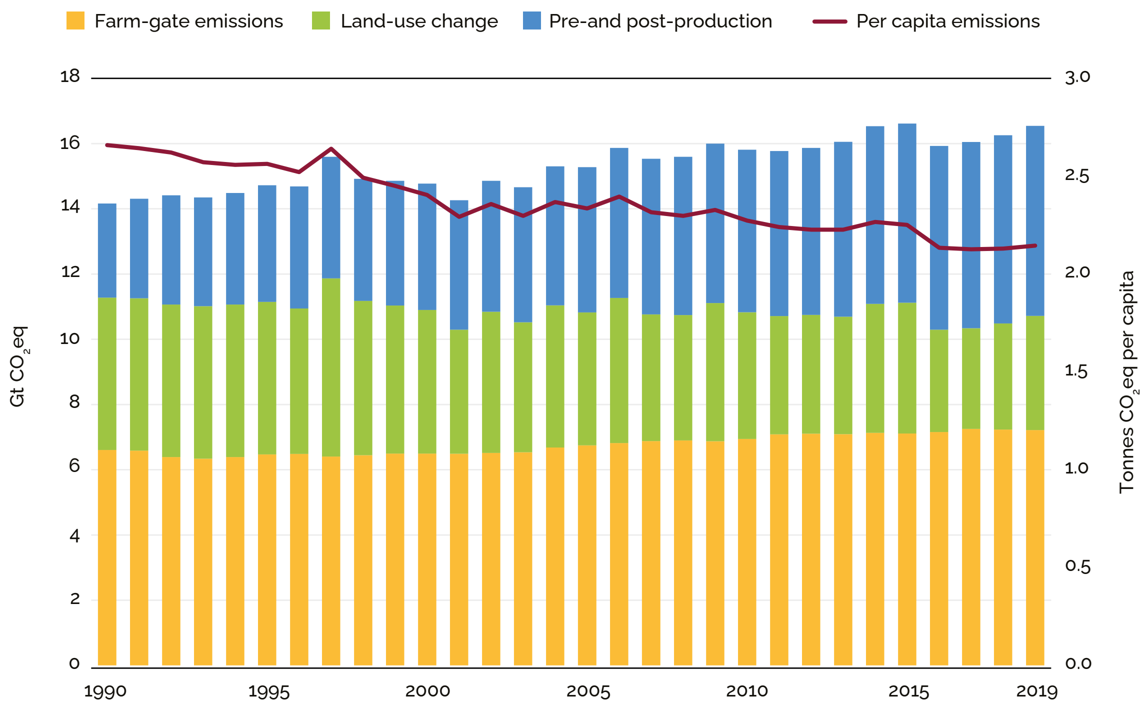
The impacts of climate change, from severe floods and droughts to persistent heat domes, are producing predicted and also surprising changes. Increasing evapotranspiration from cropland is anticipated, as is variable rainfall, leading to changes in land/crop suitability and reduced yields where temperature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

©FAO/Truls Brekke

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



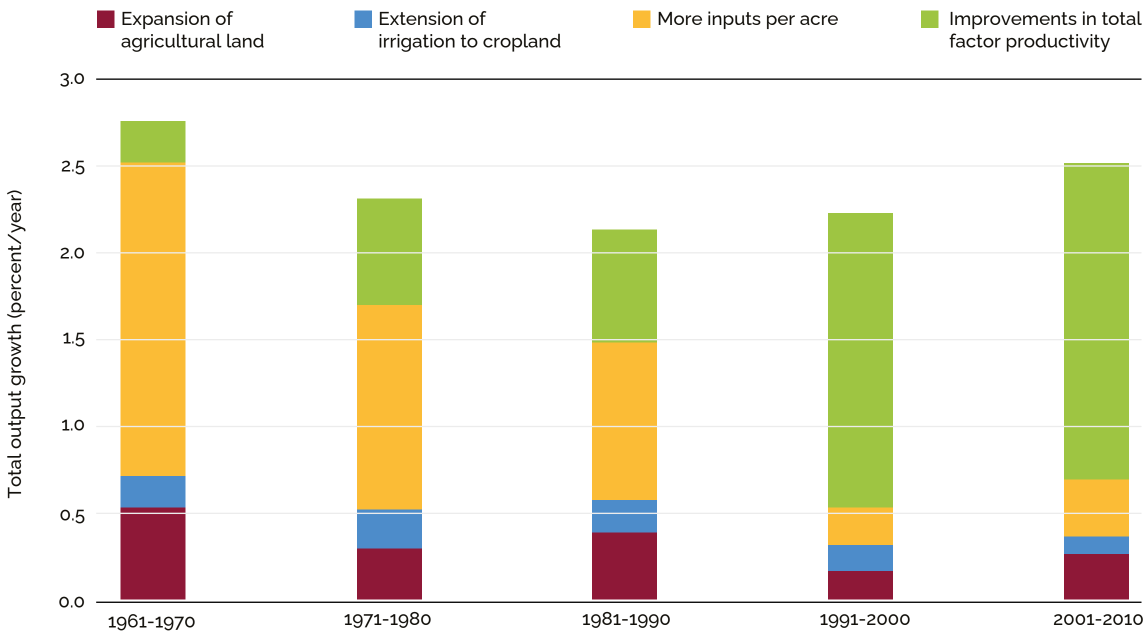
Source: FAO, 2021b.

1.1.5 Implications for agricultural productivity

©FAO/Giulio Napolitano

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**



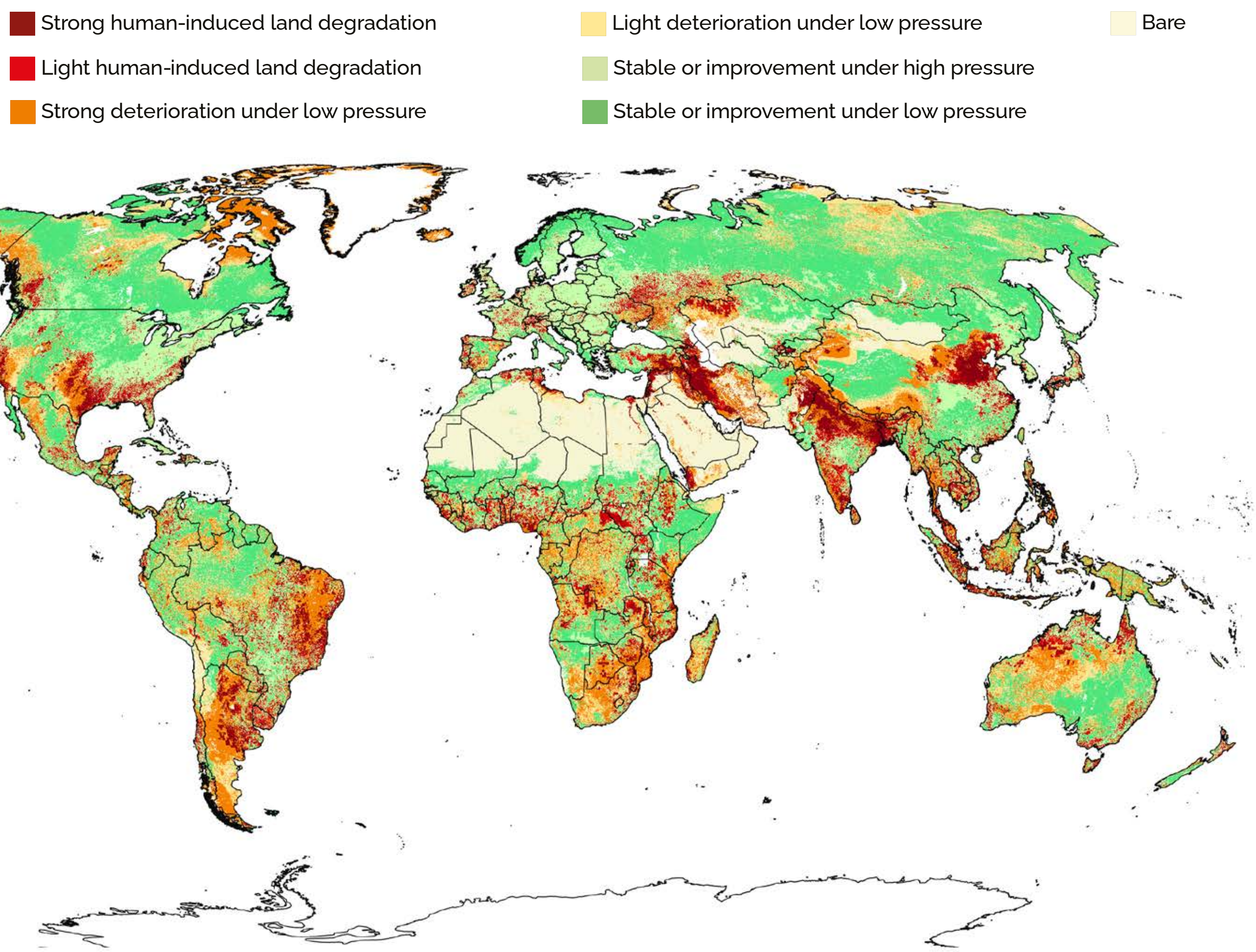
Source: USDA, 2021.

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.

©FAO/Salvator Ndabirorere

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.

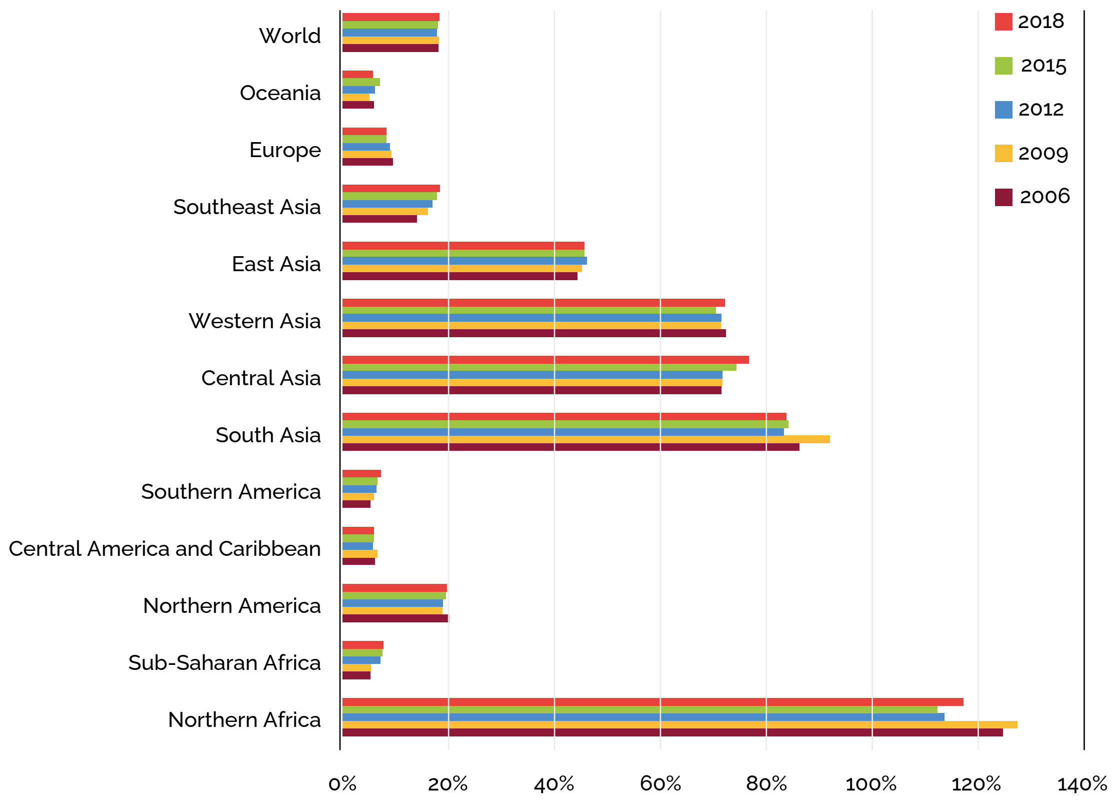
Grassland and shrub-covered areas that are used to graze animals or as sources of fodder have declined by 191 million ha over two decades to 3 196 million ha in 2019, and converted to cropland. Some 13 percent of the grassland area is degraded due to high anthropogenic pressures, and 34 percent has reduced 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 km³/year, and withdrawals (all sectors) exceed 4 000 km³/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

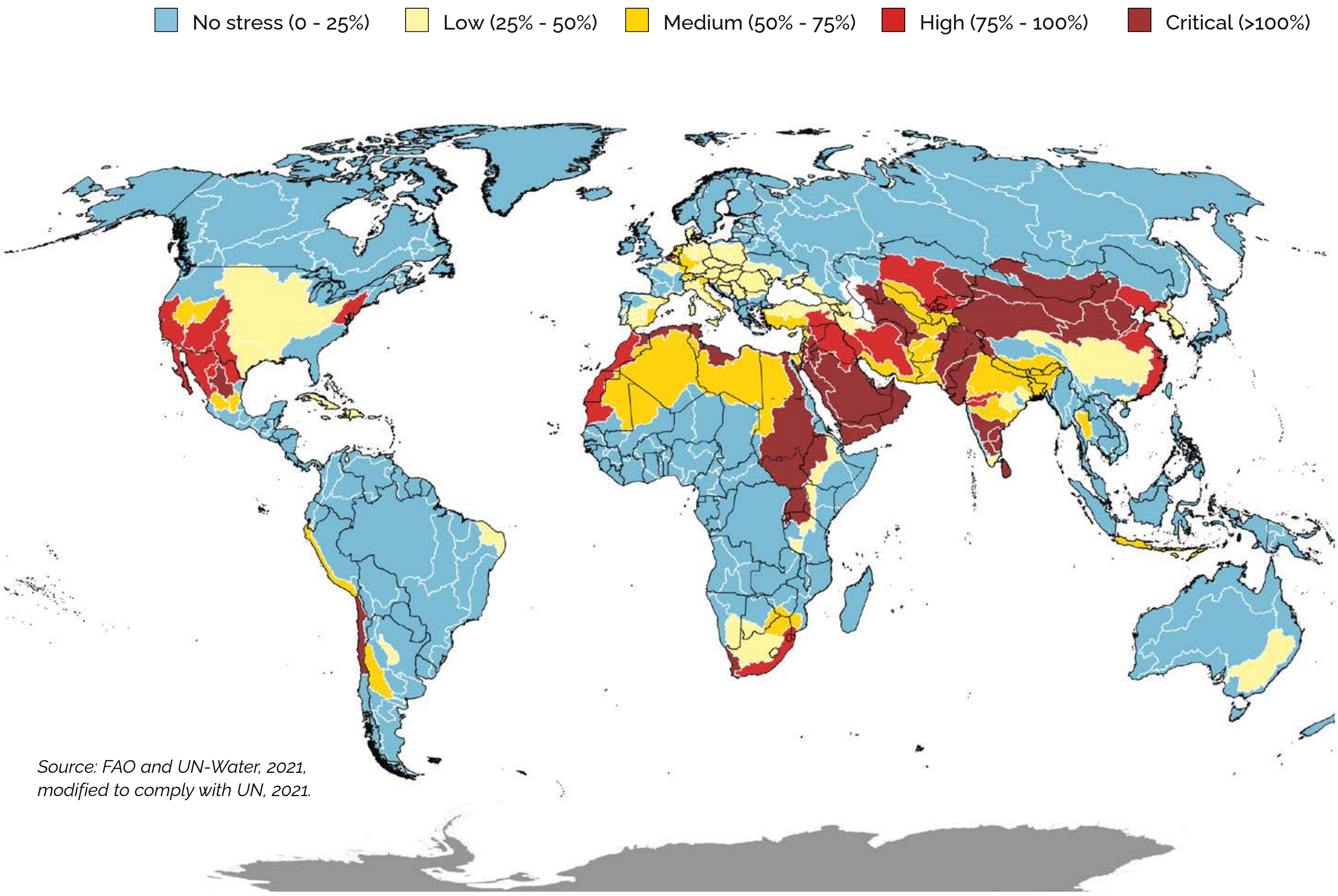
1 The SDG indicator 6.4.2 measures the level of water stress and is defined as the ratio of total fresh water withdrawn by all major sectors (agricultural, industrial and municipal) to total renewable freshwater resources, after considering environmental flow requirements. A ratio of 0–25 percent indicates 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.

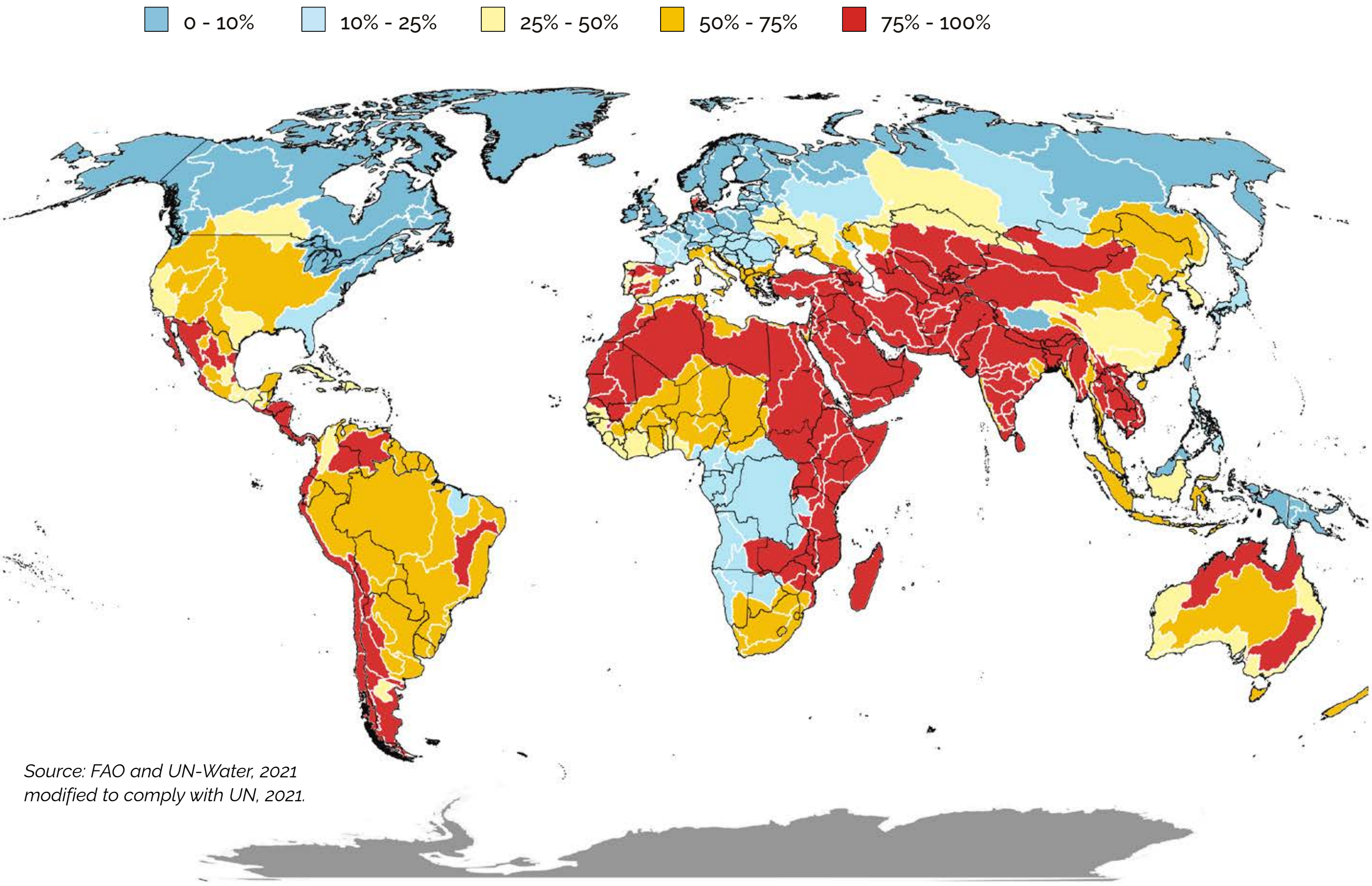
Agriculture is a significant contributor to water stress in countries with high levels of water stress. Agricultural withdrawals account for a substantial part of total withdrawals in Central Asia, the Middle East–Western Asia and Northern Africa (Map S.9). Water stress due to agricultural withdrawals 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.

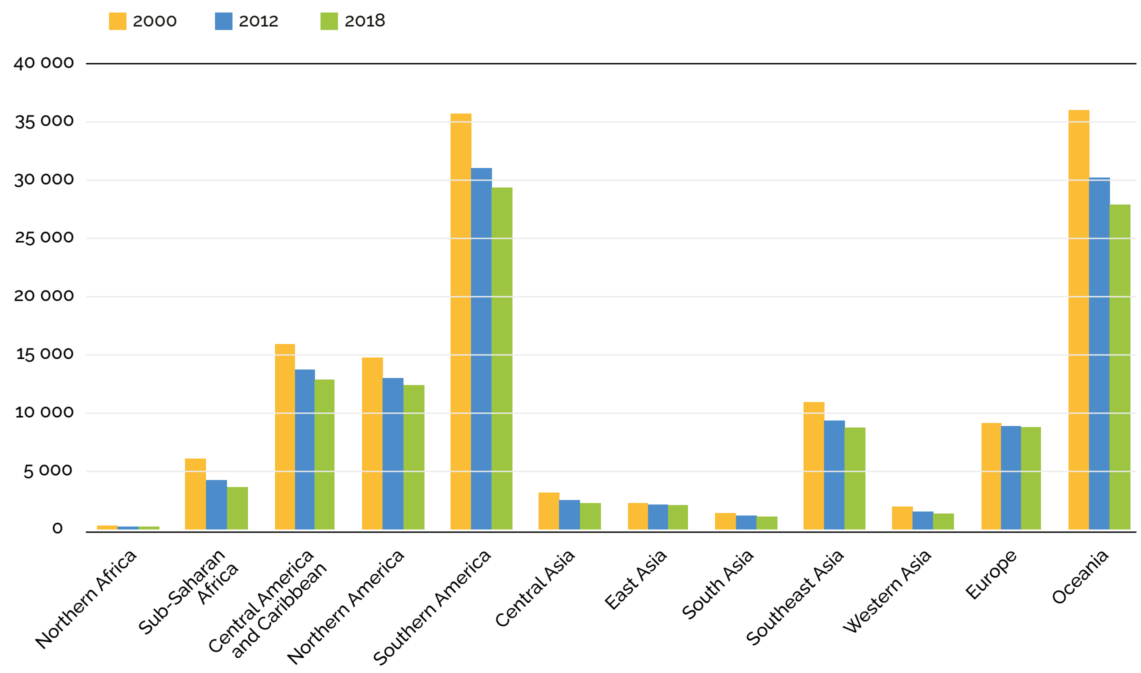
1.3.2 Per capita freshwater availability and withdrawals

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.

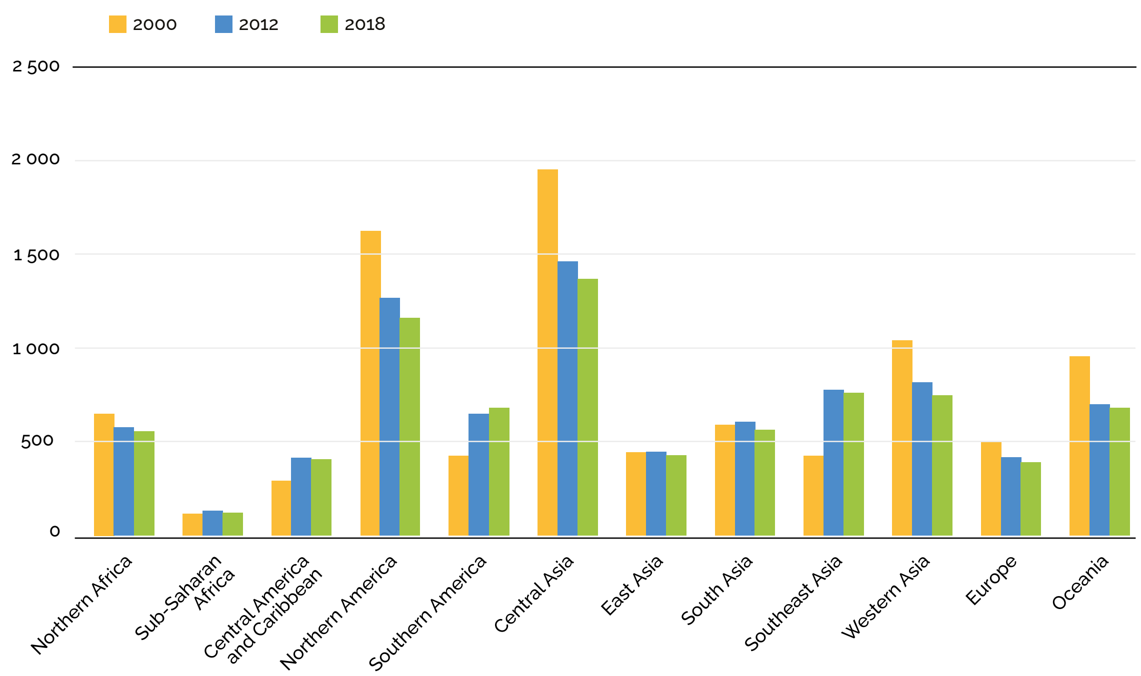
Total water withdrawals per capita declined from 2000 to 2018, except in Central America and the Caribbean, Southern America and Southeast Asia (Figure S.6). These trends are expected to persist as populations grow, partly due to overall increases in water productivity, including agriculture, and partly 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 (m^3/CAPITA)**



Source: FAO AQUASTAT, 2021.

FIGURE S.6 **TOTAL ANNUAL WATER WITHDRAWALS PER CAPITA BY GEOGRAPHICAL REGION, 2000, 2012 AND 2018 (m^3/CAPITA)**



Source: FAO AQUASTAT, 2021.

1.3.3 Groundwater depletion

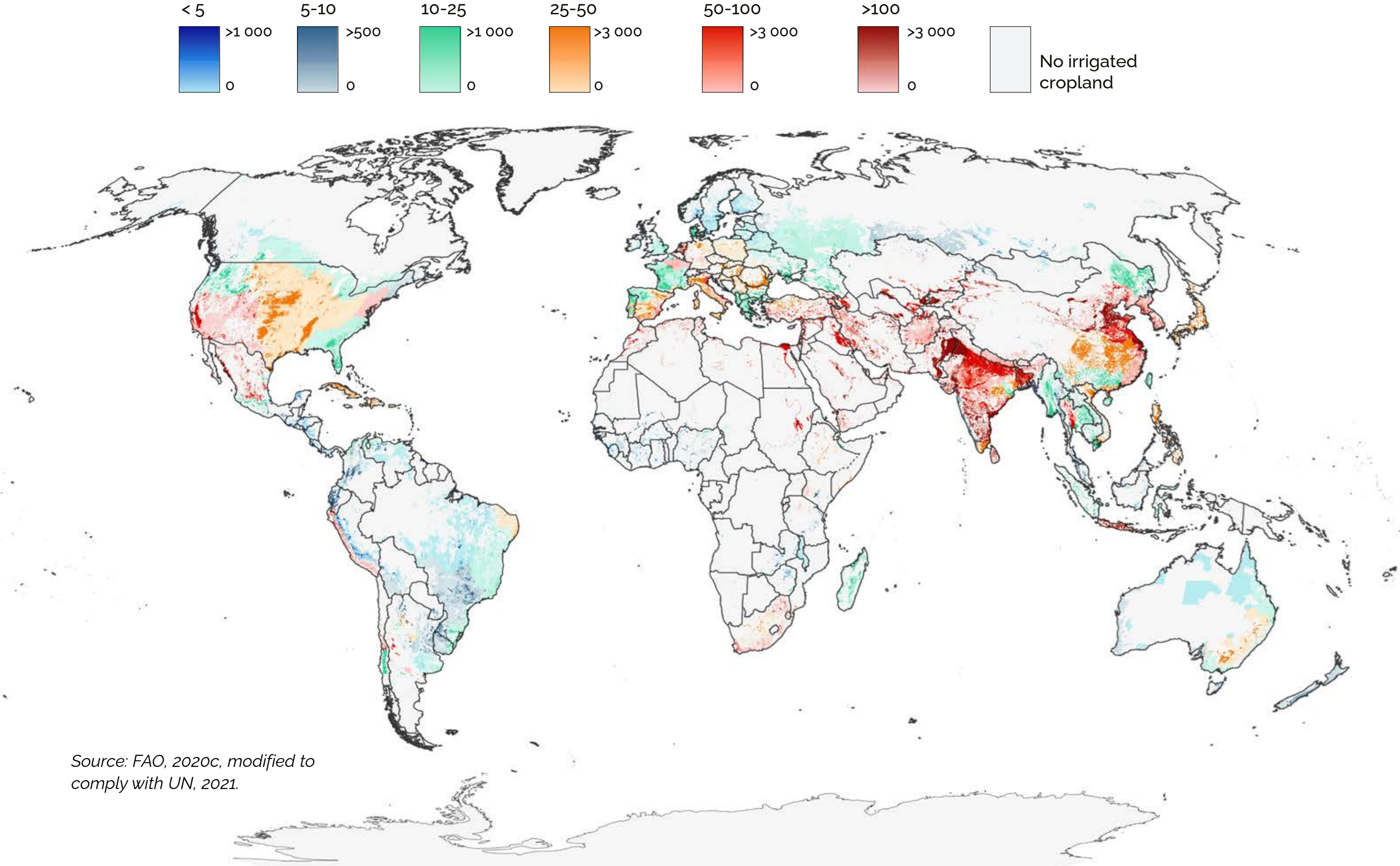
Global groundwater withdrawals for irrigated agriculture are estimated at 820 km³/year based on aggregated country-level reporting for 2018. This represents a 19 percent increase relative to 2010, when an estimated 688 km³ was withdrawn for irrigated agriculture. Groundwater withdrawals for irrigated 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.

©FAO/Giulio Napolitano

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

Extent (ha) of irrigated cropland by SDG indicator 6.4.2 level of water stress



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

©FAO/Asim Hafeez

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.

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.

©FAO/Asim Hafeez

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.

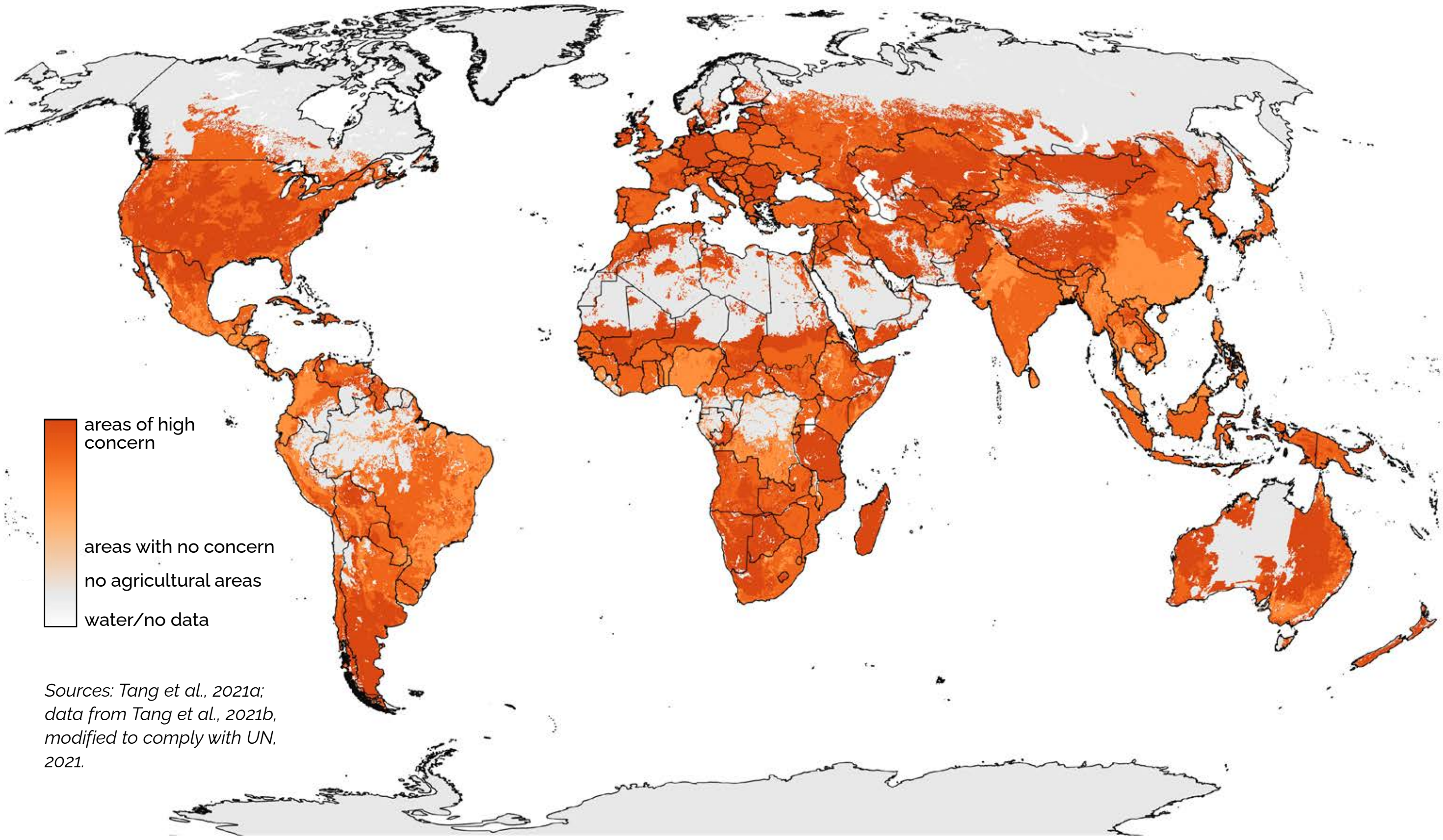
©FAO/Ivo Balderi

©FAO/Aamir Qureshi

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.

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.

©FAO/Giulio Napolitano

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.

©FAO/Olivier Thuillier

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

©FAO/Giulio Napolitano

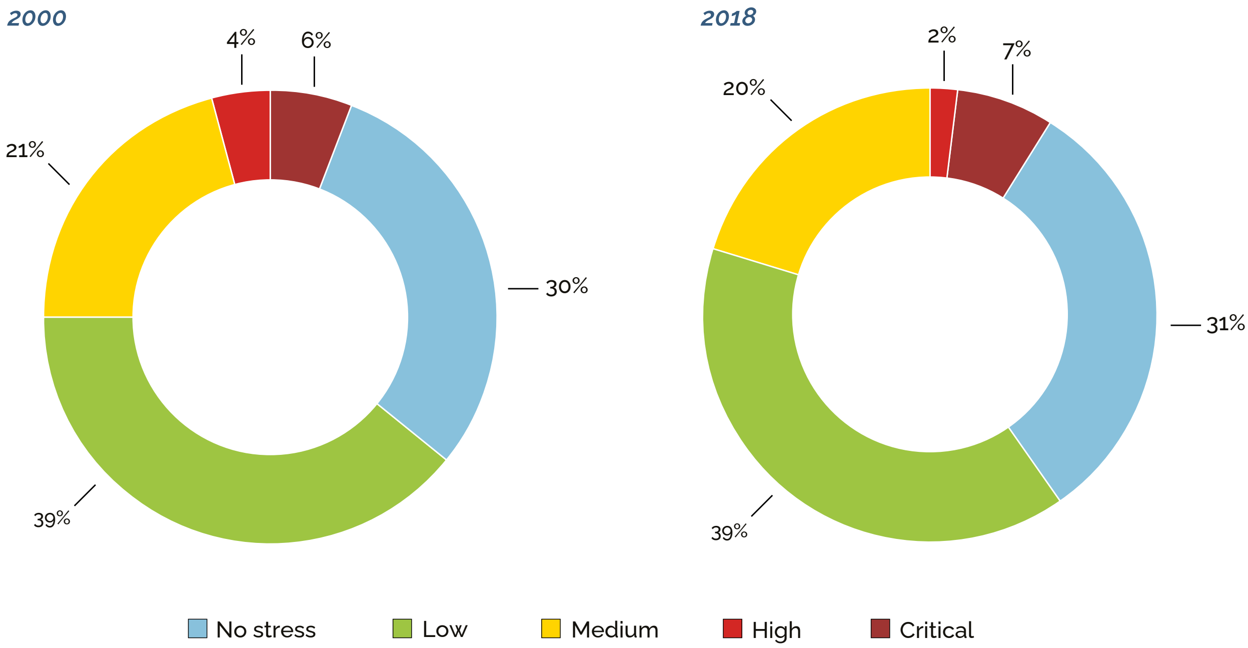
future climate risks. Responding to these risks has become an essential part of improving resilience strategies.

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.

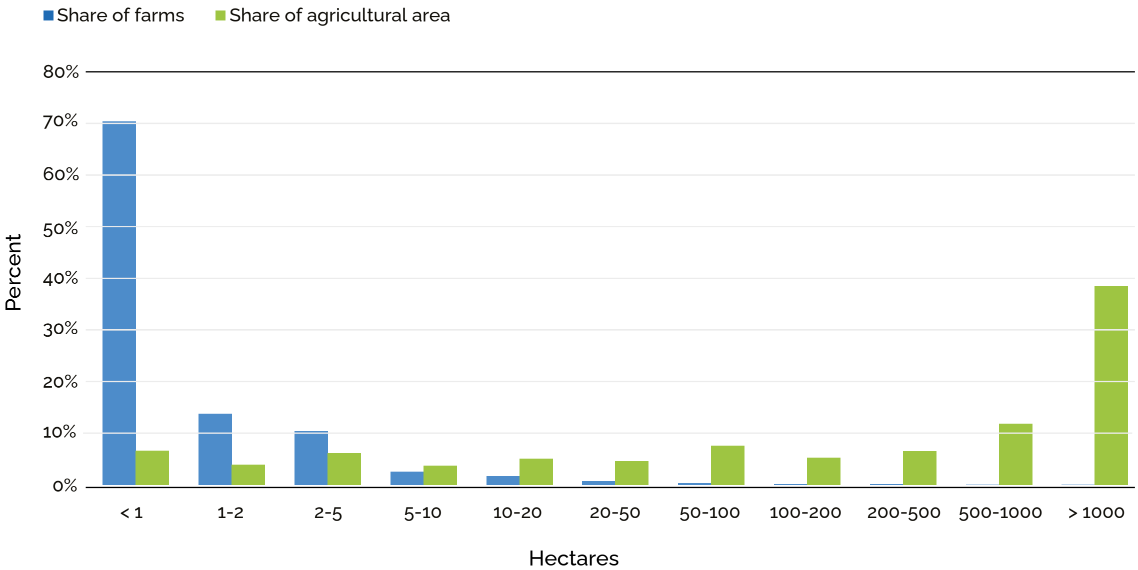
Increasing populations mean reduced natural resources available per capita. In sub-Saharan Africa, water availability per capita declined by 40 percent over the past decade, and agricultural land declined from 0.80 to 0.64 ha/capita between 2000 and 2017. Northern Africa, Southern Africa and Western 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.

©FAO/IFAD/WFP/Michael Tewelde

©Aneth David (SLU)

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.