Food and Agriculture Organization
of the United Nations

Enabling institutional environments conducive to livelihood improvement and adapted investments in sustainable land and water uses

SOLAW21 Technical background report

cirad
AGRICULTURAL RESEARCH
FOR DEVELOPMENT

Enabling institutional environments conducive to livelihood improvement and adapted investments in sustainable land and water uses

SOLAW21 Technical background report

by

Pierre Louis Mayaux, Caroline Lejars, Stefano Farolfi, Amandine Adamczewski-Hertzog, Emeline Hassenforder, Nicolas Faysse and Jean Yves Jamin

Centre de coopération internationale en recherche

Food and Agriculture Organization of the United Nations
Rome, 2022

Required citation:
Mayaux, L.P., Lejars, C., Farolfi, S., Adamczewski-Hertzog, A., Hassenforde, E., Faysse, N., Jamin, J.Y. 2022. *Enabling institutional environments conducive to livelihood improvement and adapted investments in sustainable land and water uses. SOLAW Background Thematic Report.* Rome, FAO. https://doi.org/10.4060/cc0950en

ISBN 978-92-5-136633-2

Cover photograph: ©FAO/Buletin Dorin Goian

Contents

Acknowledgment:

This report was prepared and coordinated by Pierre-Louis Mayaux and Caroline Lejars. An overall supervision was provided by Stefano Farolfi and Jean-Yves Jamin.

Amandine Adamczewski-Hertzog, Nicolas Faysse, Emeline Hassenforder, and Stefano Farolfi contributed and wrote the case studies. All authors are from CIRAD and its G-EAU Research unit.

Marcel Kuper (CIRAD) and François Molle (IRD) provided valuable comments and inputs. Pierre-Marie Bosc (FAO) provided guidance in terms of structure and content of the rep

Executive summary

This report reviews the main global trends in land and water uses, policies and investments that have taken place over the last decade and identifies the institutional arrangements that have been the most conducive to sustainable and equitable use of these resources.

The report focuses particularly on family farmers, who have limited access to key resources (land, water, credit and infrastructure). It pays special attention to their common challenges and needs, but also to their diverse conditions. It provides evidence-based information on the institutional conditions needed to ensure inclusive land and water programmes, and to upscale such programmes at local levels. It is based on a systematic review of official documents and academic papers and on detailed case studies, often grounded in the authors' own significant knowledge.

The report is organized in three main parts. The first section begins with a review of the main global trends affecting land and water uses over the last decade, and links them to the public policies and types of private investment that encouraged such trends. The main structural drivers of growing pressures on water resources and land availability are discussed, including population growth, diet changes, climate change, urbanization and biofuel development. The report discusses the direct effects of these drivers, including water scarcity, increased global competition for land use and the degradation of existing resources, on land and water availability. It then examines the main types of private investments and public policies that drive these trends: large-scale land acquisition, reassertion of large-scale infrastructure programmes for surface water irrigation, public subsidies and private initiatives that stimulate access to groundwater.

The second section of the report focuses on the impacts of global changes, policies and investments on farmers' livelihoods and water use. It reviews the numerous beneficial impacts of irrigation on poverty reduction emphasizing that they are highly contextual and unequally shared across social groups. It documents the widening gap between irrigated and rainfed areas, and the risks of a medium-term crisis for agricultural economies that are based on groundwater irrigation. It emphasizes that existing policies are poorly tailored to farmers' needs. Lastly, the section documents the complex relationship between migration and increased pressures on land and water.

The third section of the report charts the way forward for more sustainable and equitable management of land and water. It takes stock of policies inspired by the principles of integrated water resources management (IWRM). It documents some tentative steps toward more territory-based policies and reviews the experiences of integrating climate change into land and water policies. It then discusses the respective merits of universal versus targeted agricultural policies to improve family farmer livelihoods. Finally, the section reviews some promising experiences in terms of transboundary water governance and participatory approaches to land and water management.

Introduction

Over the past decade, global pressures on water resources and land availability have sharply intensified. This deeply worrisome trend is partly the result of processes beyond the direct control of national policy-makers, including population growth, dietary changes, urbanization and climate change. However, the trend is also the result, whether directly or indirectly, of development policies, including the reassertion of large-scale infrastructure programmes for surface water irrigation, and the many types of public subsidies for wells, boreholes and energy costs that have greatly stimulated groundwater abstraction on a global scale.

This report documents these trends and their complex socioeconomic implications for family farmers. Whereas the overall beneficial impacts of irrigation on poverty reduction are manifold and well documented, these impacts are also highly contextual and unevenly shared across social groups and along gender lines. Moreover, in many countries, a widening socioeconomic gap between irrigated and rainfed areas can be observed. Finally, the relationship between migration and increased pressures on land and water adds another layer of complexity to the current trends.

To address such challenges, the report highlights some promising experiences in terms of integrated, territory-based and participatory approaches to land and water management. Crafting land and water policies that are sustainable, equitable and that reduce poverty is possible, but is a time-consuming endeavor that requires strong state capacities, especially at the local and regional levels.

1. Main global trends, policies and investments affecting land and water access and uses over the last decade

Taking a global view, this section identifies the main socioeconomic and institutional changes that have occurred over the past decade, along with the environmental and socioeconomic consequences (including poverty alleviation) of past policy choices. It reviews the main global trends affecting land and water uses during this period and links them to the public policies and private investments that encouraged them. The main structural drivers of growing pressures on water resources and land availability are discussed, including population growth, dietary changes, climate change, urbanization and biofuel development. The section discusses the direct effects of these drivers on land and water availability, increased global competition for land-use and qualitative degradation of existing resources. The main types of private investments and public policies that have been driving these trends are examined, including large-scale land acquisition, reassertion of large-scale irrigation infrastructure projects, public subsidies and private initiatives that stimulate access to groundwater.

1.1. Main drivers of growing pressures on water resources and land availability

▪ Population growth

Despite Lutz, Sanderson and Scherbov foreseeing (in 2001) "the end of world population growth," the global population is still growing. Between 2010 and 2020, it grew by more than 800 million people to almost 7.8 billion, with an annual growth rate of 1.05 percent (UN, 2019). This rate was around 2 percent fifty years ago and it is slowly decreasing. Nevertheless, an additional 80 million people have to be fed every year.

Even though the numbers could be revised downward (Lancet, 2020), the world's population is still projected to reach 9.7 billion by 2050 according to the medium-growth projection scenario of the United Nations (UN, 2019). Most of the population growth will occur in Africa, +1.3 billion, or +108 percent of the present value, and in Asia, +0.75 billion, or +18 percent of the present value. Two-thirds of the global population will live in cities (UN, 2017).

▪ Dietary changes

Once based mostly on grains and carbohydrates, diets are changing to include larger proportions of meat, eggs, dairy, oils and other resource-intensive products.

Consumption patterns continue to change in many countries. Although growing numbers of consumers in developed countries are voluntarily increasing their share of plant-based proteins and reducing their intake of meat-based proteins, world meat consumption is increasing by 1.4 percent per year (Packaged Facts, 2020). "Global meat consumption increased by 58 percent over the 20 years to 2018 to reach 360 million tonnes. Population growth accounted for 54 percent of this increase and per-person consumption growth

accounted for the remainder. Per-person consumption was influenced most strongly by changing consumer preferences and income growth" (Whitnall and Pitts, 2019, p. 96). The consumption of meat, particularly poultry, is rising quickly in Africa and the Middle East. China is now the world's largest meat consumer, switching in 2009 from being a net corn exporter to being a net corn importer, to meet its demand for feed grain (Bai, Seale and Wahl, 2020).

However, the objective is not an across-the-board, indiscriminate reduction in meat consumption, but rather a sharp reduction for certain specific – mostly well-off – social groups, and stabilization for others.

- **Climate change**

As average temperatures rise (by 1–4°C depending on locations and forecasts) and rainfall decreases and/or increases in variability, climate change may increase water consumption and thereby create possible shortages and conflicts where water is scarce relative to demand. It may also increase soil erosion (from both rain and wind), desertification, and lower surface water availability for irrigation (less rain, more evaporation in reservoirs and increased evapotranspiration by natural vegetation).

A systematic, multicrop, global comparison between empirical and process-based crop models conducted by Moore, Lantz and Hertel (2017) showed that the differences between such responses may be smaller than generally believed. However, the number of empirical studies remains limited. The authors also pointed out that there is little evidence in the existing literature that farm-level adaptations will substantially reduce the negative impacts of climate change on yields. Many actions described as adaptation in yield modeling studies would raise yields both in the current and in the future climate, meaning they do not necessarily reduce the negative impacts of future warming.

It is important to keep in mind that the wide variability of projected impacts of climate change, both across and within countries, requires tailored approaches at subnational (territory) level rather than a one-size-fits-all approach.

- **Urbanization**

Population growth leads to a growing demand for food and stimulates urbanization, placing greater stress on agricultural land: most large cities were originally founded in fertile areas, and as they grow, they de velop on the surrounding fertile lands and use the surrounding water resources. The urbanization of agricultural lands is particularly problematic because peri-urban areas are usually fertile areas themselves. Managing rural-urban transition (in terms of jobs, housing and modes of social provision) is therefore a major challenge.

A growing population is not entirely bad for farmers. Large cities mean national markets for food products, which can help countries avoid overdependence on international commodity markets. It also means lower transportation costs, the development of urban and peri-urban agriculture (which may create some pollution issues), and a recycling and circular economy. However, to be able to meet urban demand, farmers need secure access to land, water and credit (for both investments and inputs).

▪ Biofuel development

Once celebrated as 'green,' biofuels (or rather agrofuels, since most of them are derived from crops), may not in fact contribute significantly to meeting energy demand "in a way that meets social and environmental sustainability goals" (German *et al.*, 2017, p. 806). Climate neutrality is not often achieved, employment benefits are disappointing and the associated risks (e.g. deforestation, food insecurity, biodiversity impacts, land right violations) are not sufficiently taken into account (Goetz *et al.*, 2017). One consequence is the impact of agrofuel development on large land acquisitions. For instance, in sub-Saharan Africa, an abundance of water resources and general business conditions, security and regulatory quality facilitate investments in land for agrofuel development (Giovannetti and Ticci, 2016). "The bio-economy, together with the Sustainable Development Goals, has inexorably exacerbated the practice of land-grabbing in sub-Saharan Africa" (Ashukem, 2020). According to Vivien *et al.* (2019), the bio-economy concept has been highjacked.

1.2. Global trends in water and land demand versus availability

▪ Global trends in water demand and water scarcity

Global water demand has increased by 600 percent over the past 100 years, more than twice the rate of population growth (Wada *et al.*, 2016). This corresponds to an annual increment rate of 1.8 percent. According to the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2018), the current annual growth rate is lower, around 1 percent, but most experts predict that this growth rate will accelerate in the near future to 2–3 percent per year (Boretti and Rosa, 2019). Global water demand for all uses, currently at around 4 600 km^3 per year, will increase by 20 to 30 percent by 2050, reaching 5 500 to 6 000 km^3 per year (Burek *et al.*, 2016). It is widely recognized, however, that such forecasts are problematic and only "the best we have" (Wada *et al.*, 2016, p. 176). In the Organization for Economic Co-operation and Development (OECD) countries, for example, where irrigation is not prominent, per capita consumption is now decreasing.

There is more than enough freshwater *globally* to meet current water demands. However, significant spatial and temporal variability exists in the distribution of water resources, coupled with a growing mismatch between water resources and populations. Consequently, a growing number of individual countries and regions need to urgently tackle the critical problems presented by water scarcity. Rodell *et al.* (2018) remind us that water scarcity can either mean inadequate availability due to physical shortage, or inadequate access, either due to the failure of institutions to ensure a regular supply or a lack of adequate infrastructure.

The 2018 edition of the United Nations World Water Development Report (WWDR) provided an update on present trends in clean water availability and future expectations (WWAP, 2018). The report states that 3.6 billion people (47 percent of the global population) are living in areas that suffer from water scarcity at least one month each year. That number is projected to reach 57 percent by 2050, affecting nearly 6 billion people.

▪ Trends in global land-use competition

Ten percent of the world is covered by glaciers and a further 19 percent comprises barren land deserts, dry salt flats, beaches, sand dunes and exposed rocks. The rest is so-called called habitable land. Half of all habitable land is used for agriculture (Ritchie and Roser, 2019), the other half is covered in forests and shrubs.

Current data provide no clear evidence on the global availability of productive land. Is there a finite stock of suitable land, inevitably leading to strict competition between land uses, or will increases in the price of goods produced from the land make it economically feasible to bring marginal land into use? The main friction points in global land use are expected to be between forests and agriculture; urban land use and intensive agriculture; tree plantations and natural forests; bioenergy, feed crops, and food crops; and intensive cropland and extensive agriculture (Lambin and Meyfroidt, 2014).

▪ Quantitative pressures on agricultural land and water

Increased crop production over the past 70 years has resulted from both the expansion of croplands and intensification. During the Green Revolution, agronomic improvements led to a threefold improvement in average yield ($t \cdot ha^{-1} \cdot y^{-1}$), i.e., land-use efficiency. However, instead of preventing land clearing, the increase in productivity brought about regionally-significant extensification (concentrated in Asia and Latin America), fueled by a more elastic global demand than expected (Pellegrini and Fernández, 2018). Nevertheless, it is recognized that only a small proportion of future increases in crop production will come from new land cultivation (about 20 percent); the main share is expected to come from intensification through increased yield (67 percent) and higher cropping intensity – more crops per year (12 percent) (Gregory and Ingram, 2014).

Irrigation schemes enable agricultural intensification or a switch to more profitable crops. Globally, water use for agriculture accounts for 70 percent of total withdrawals. According to FAO, the area equipped for irrigation has more than doubled in recent decades (from 139 million hectares – Mha – in 1961 to 320 Mha in 2012) (FAO, 2014). The world population doubled between around 1970 and 2015, but the production of cereals almost tripled, the production of vegetables increased fourfold, tomato production increased fivefold and soybean production increased eightfold (FAO, 2020). Although global estimates and projections are uncertain, it is forecast that food demand will increase by 60 percent by 2050 (WWAP, 2018).

A paper published in *Nature* analyzed the results of a NASA global freshwater availability study from 2002 to 2016 (Rodell *et al.*, 2018). It identified 19 water hotspots that experienced dramatic water depletion over those 14 years. The analysis suggested that northwestern China, northern and eastern India, North Africa and the northern Middle East are most likely to experience the greatest food and water threats by 2050. The study, however, also found some regions where freshwater availability *increased*. The evolution of water availability for agriculture is therefore highly uneven and will aggravate current disparities.

Of the four regions that are most likely to experience severe food and water challenges by 2050, the Middle East, specifically the northern part of the region encompassing Türkiye, Syrian Arab Republic, Iraq and Iran (Islamic Republic of), will be the most

threatened. This has been confirmed by the World Bank (World Bank, 2017), which states that the Middle East–North Africa region is a global hotspot for unsustainable water use. This especially involves groundwater, as more than half of current water withdrawals exceed natural rates of water recharge.

It should be noted that growing pressures on agricultural water also affect regions in developed countries. For instance, severe water restrictions occurred in California in 2017–2018, and in the Murray–Darling basin in Australia in 2019.

- **Demand from other economic sectors**

By 2050, water demand from industry is expected to increase everywhere around the world, with the possible exceptions of North America and Western Europe. Such demand is expected to increase by 800 percent in Africa, where current industrial use is negligible. It is set to increase by 250 percent in Asia. Global water demand for manufacturing is forecast to increase by 400 percent (Boretti and Rosa, 2019).

There has been a marked worldwide improvement in household access to drinking water and sanitation and this is expected to continue as countries strive to achieve Goal 6 of the Sustainable Development Goals (SDGs). However, there has been increasing pressure on domestic water as well, including a growing number of acute water crises (e.g. in São Paulo in 2014, Cape Town in 2017 and Chennai in 2019, just to mention a few of the most important).

- **Degradation of existing resources**

Although global attention has so far focused primarily on water quantity, water use efficiency and allocation issues, water pollution is now a global challenge (FAO, 2017a), worsening the water crisis. Global water scarcity is caused not only by the physical scarcity of the resource but also by the progressive deterioration of water quality in many countries, reducing the amount of water that is safe to use.

Lack of sanitation contributes to water pollution. In developing countries, 90 percent of sewage is discharged into water untreated (WHO and UNICEF, 2015). Every year, 730 million tonnes of sewage and other effluents are discharged into water. Industry discharges 300 to 400 megatonnes of waste into water every year (WWAP, 2017).

Agriculture, which accounts for 70 percent of water abstractions worldwide, is a rising source of water pollution. The global growth in crop production has mainly been achieved through an intensive use of inputs, such as pesticides and chemical fertilizers. Agriculture is the predominant source of nitrogen found in water and a significant source of phosphorus (UNEP, 2016). Although current levels of nitrogen and phosphorus pollution from agriculture may already exceed globally sustainable limits, by 2050 nitrogen and phosphorus effluents will increase by 180 percent and 150 percent, respectively (OECD, 2012).

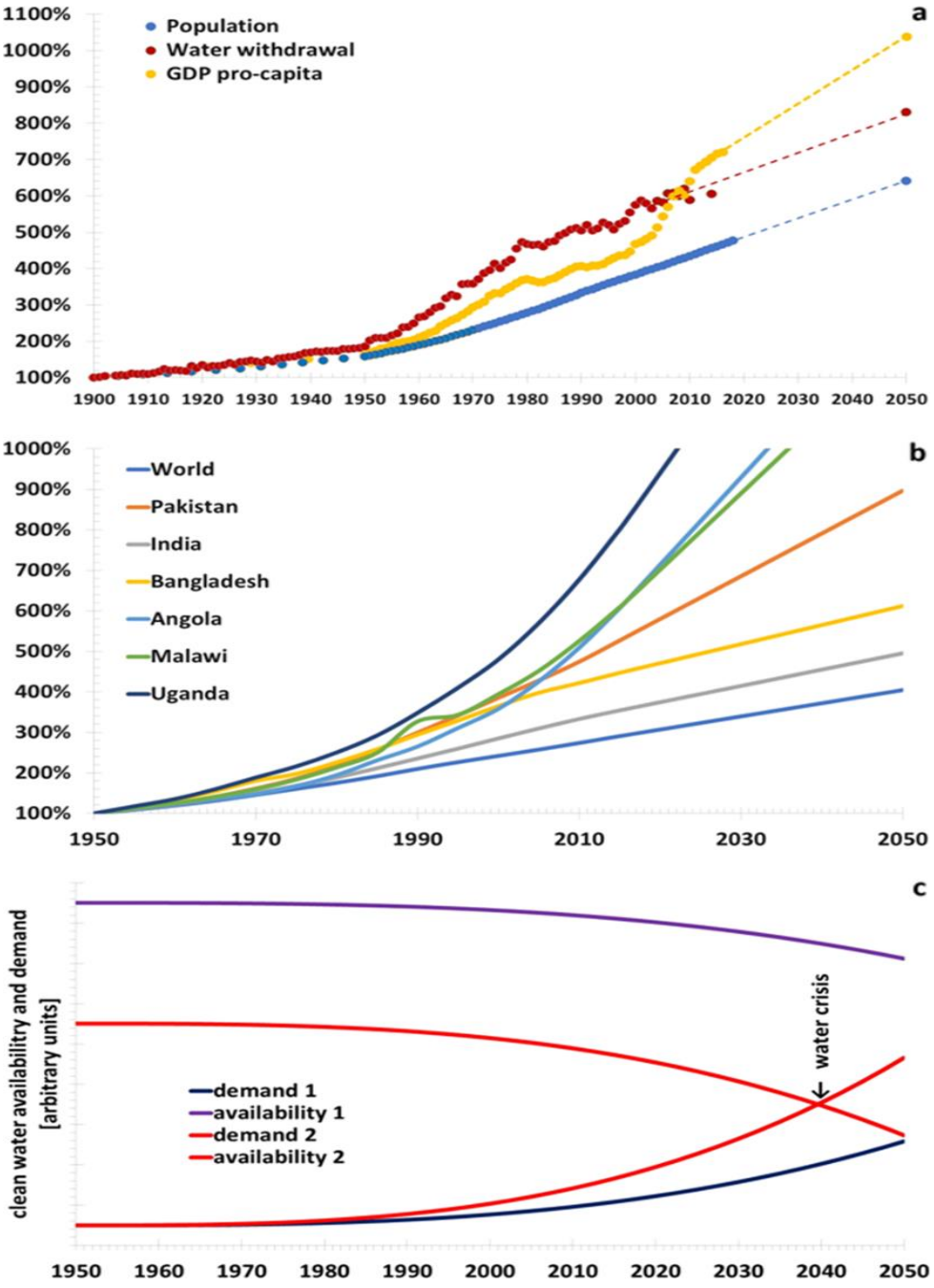
In the last 20 years, a new class of pollutants has emerged. Novel contaminants include pharmaceuticals, hormones, industrial chemicals, personal care products, flame retardants, detergents, perfluorinated compounds, caffeine, fragrances, cyanotoxins, nanomaterials and cleaning agents (WHO, 2012).

Major water salinity problems have been reported in Argentina, Australia, China, India, Sudan, the United States of America and many countries in Central Asia (FAO, 2011). In

2009, approximately 1.1 billion people lived in regions that had saline groundwater at shallow or intermediate depths (IGRAC, 2009).

Unsustainable land use and improper tillage and soil management in agriculture are increasing erosion and sediment runoff into rivers, lakes and reservoirs, with massive quantities of soil lost and transported to water bodies every year. The global rate of erosion in croplands is estimated at 10.5 tonnes per ha per year, which corresponds to 193 kilograms of soil organic carbon per ha per year (Boretti and Rosa, 2019).

Figure 1. Projections of the World Water Development Report



Source: Boretti and Rosa, 2019.

Major structural changes in the livestock sector are associated with the development of industrial and intensive livestock production systems, which often involve large numbers of animals concentrated in relatively small areas. These changes are exerting growing pressure on the environment and particularly on water quality. Most of the water used for livestock drinking and servicing returns to the environment in the form of liquid manure, slurry and wastewater.

In summary, the demand for water will increase by 2050, while water availability will decrease. Pollution will further reduce the amount of available clean freshwater. A business-as-usual approach is incapable of meeting growing needs and is not sustainable. However, the realities of global changes will display considerable variations between and within countries (Wada *et al.*, 2016), making a finer-grained view necessary.

1.3. Global trends in large-scale land acquisition and re-assertion of large-scale infrastructure for surface water irrigation

▪ Global trends in large-scale land acquisition

Both private investors and certain countries are seeking to acquire land throughout the world, the former to provide food and other commodities for international markets, the latter to secure their food supply. This has prompted an ever-growing demand for arable land in many countries. Developing countries are often targeted because they need foreign investments to develop their agriculture; targeted countries include South America, Southeast Asia and sub-Saharan Africa, which is the most sought-after region for large-scale land acquisitions; in Africa, large land contracts already cover 15 million hectares and 9 million more are coveted (Land Matrix, 2021).

On the one hand, investors aim to secure their capital and maximize their return on investment, so irrigated lands or lands that could be irrigated given the available water resources, are particularly targeted for their production potential. On the other hand, poor countries lack the funds to invest in the development of irrigation schemes to enhance their food security, and are turning to national and international investors, both private and public. Land acquisition often goes hand in hand with the acquisition of water rights, which has led to both land and water grabbing in some countries (Anseeuw, 2019).

Land tenure and water rights involve a wide array of actors, contracts and practices, often within incomplete and inconsistent legal frameworks. The most prominent actors are governments, local authorities, landowners, private national investors, foreign private investors and sovereign wealth funds. Land users, particularly tenants and sharecroppers, are often not part of such deals, since they do not have officially-sanctioned tenure.

Contracts may be informal arrangements or formal and very detailed. Beyond straightforward acquisition, diverse arrangements have been used to secure access to coveted land, such as contracts, rights of access and long-term leases. There is a push toward the privatization of public and collective land, but also toward land titling and 99-year lease contracts. Often, these arrangements are a complex mix of formal and customary law (e.g. in Mali, Morocco, Senegal). International donors may be involved, some of which favour public-private partnerships (e.g. The World Bank).

Nevertheless, the notion of land (and water) grabbing remains debated. The extent of the large land agreements phenomenon is obvious, with 80 million hectares involved worldwide. However, given the large array of stakeholders (governments, investors, landowners, land users, landless people), many different points of view are expressed about this phenomenon: considered as necessary investments leading to shared profitability for some, land and water grabbing can lead to the exclusion of the poor and foster social conflicts and corruption for others. The socioeconomic and political effects may also vary from one country to another, depending on national regulations as well as local needs for investments.

- **Reassertion of large-scale irrigation infrastructure projects**

Dams are typically designed to supply water and/or energy to industrial growth sectors and large-scale export agriculture and to serve the growing needs of megacities and urban zones. There are currently 57 985 large dams registered worldwide (ICOLD, 2020). An estimated 3 700 dams are currently planned or under construction worldwide, around 1 000 of which are large in size (Zarfi *et al.*, 2015).

With their present aggregate storage capacity of about 14 602 km^3, large dams clearly make a significant contribution to the efficient management of finite water resources, which are unevenly distributed and subject to large seasonal fluctuations. The worldwide 'concrete revolution' of large dam construction is one of the most notable trends in human-environment relations in the twentieth century (Sneddon, 2015).

After a drop in investment at the turn of the 21st century, the development of large-scale irrigation infrastructure has made a strong comeback worldwide. For example, after being criticized in the 1990s for its initial investment in ill-conceived dam and hydroelectric projects, the World Bank moved away from providing loans for large infrastructure projects. However, by 2003 it had returned to funding large dams and developing water transfer projects (Lynch, 2013). Funding for large dam development continues to increase (Ahlers *et al.*, 2015), but an increasing share is directly funded at the national level (e.g. in China, India, Iran (Islamic Republic of), Türkiye and Ethiopia, just to cite the most notable cases).

Large dams are not the only large-scale infrastructure projects on today's agenda. Recent technological advancements have allowed desalination to become more efficient and cost-competitive on a global scale (Darre and Toor, 2018). In 2013, there were over 17 000 active desalination plants, providing about 80 million m3 per day to 300 million people in 150 countries. However, there are still major desalination challenges, including the difficulty of further reducing desalination energy demands, and managing its waste products to prevent adverse environmental effects (Nair and Kumar, 2012). The progress of desalination between now and 2050 is therefore hard to predict, largely depending on economic and energy trajectories.

- **Current drivers of dam construction**

In many countries, particularly those that have not sufficiently invested in education to allow a shift in the labour force to non-agricultural sectors, providing access to water for rural populations is still a crucial political concern with implications for social stability. Access is generally provided through large-scale public infrastructure or slack enforcement of existing regulations (notably for groundwater). Such polices are still very much favoured, even in countries where resources are already overexploited (typically the

Middle East and North African region), and they tend to generate an imbalance between the available resource and the extent of the agricultural area that can make use of that resource (Barone and Mayaux, 2019).

The political motivation for large dam development has increasingly become linked to energy and climate policy, rather than driven by a strictly poverty alleviation or national development agenda. With the climate change agenda assuming increasing significance, strategies to limit greenhouse gas (GHG) emissions and meet the Paris 1.5℃ target require the use of clean technologies, and this has brought about a resurgence of hydropower development. Hydropower often emits less than a tenth of the emissions of coal or gas alternatives per kilowatt-hour generated.

This trend was also enabled by the recovery of financial capacity in many developing and emerging countries after two decades of hard budgetary constraints. This led to the creation of more subsidies for water-intensive crops in an overall push toward agricultural modernization, including monocropping in many places, and drip irrigation as a means of procuring 'more crop per drop' (e.g. in Senegal, Morocco, Bolivia (Plurinational State of), etc.). The political economy of large-scale infrastructure also has its dark side, involving huge corporate interests and often corruption.

Despite policy efforts, controversies surrounding the social impacts of large dams persist. Current estimates are that the total number of people displaced through infrastructure projects (including hydropower) during the period from 2000 to 2020, exceeded 10 million a year, or some 200 million overall (Cernea and Maldonado, 2018). These numbers only account for riverine populations directly impacted by dam construction; they do not include downstream users negatively affected by long-term impacts, such as habitat degradation or destruction, loss in downstream flow of sediment and nutrients, and prevention of fish migration (Beck, Claassen and Hundt, 2012). There is a large body of work documenting the social impact of large dams on local residents, especially dam-induced displacement and resettlement, and the various ways to mitigate negative impacts (Hay, Skinner and Norton, 2019). However, there have been fewer systematic analyses of the beneficiaries, especially the extent to which they include smallholders and local farmers.

1.4. The groundwater boom: The silent revolution led by private initiatives and investments

Groundwater is the world's most extracted raw material, with withdrawal rates currently estimated at 982 km^3/year (Margat and van der Gun, 2013). Groundwater provides almost half of all drinking water worldwide (Smith *et al.*, 2016). About 70 percent of groundwater worldwide is used for agriculture. Globally, around 38 percent of irrigated lands are equipped for irrigation with groundwater (Siebert *et al.*, 2010). The total volume of groundwater in the upper two kilometres of the Earth's continental crust (not including high-latitude North America or Asia) is approximately 22.6 million km^3, of which 0.1 million km^3 to 5.0 million km^3 is less than 50 years old (Gleeson *et al.*, 2016). Due to the rapid development of new wells and boreholes, the groundwater extraction rate multiplied ten times between 1958 and 2008 (Margat, 2008) and this groundwater boom has continued with unrelenting intensity over the past decade, especially in North Africa and Asia (Kuper *et al.*, 2016).

In many parts of the world, groundwater overexploitation has led to increasing concern about the sustainable use of this resource in the context of declining water tables, quality

degradation, land subsidence, biodiversity degradation and social inequity (Llamas and Martínez-Santos, 2005). These global trends have been documented in many arid and semi-arid countries, such as Algeria, Australia, China, India, Mexico, Morocco, Spain, Tunisia and the United States of America, where the irregular nature of surface water availability makes groundwater a strategic resource for irrigation (Changming, Jingjie and Kendy, 2001; Scott and Shah, 2004; Konikow and Kendy, 2005; Llamas and Martínez-Santos, 2005; Shah, 2009; Ross and Martínez-Santos, 2010; Kuper *et al.*, 2016; IWMI, 2020). Increased groundwater use is currently expected in other parts of the world, particularly in sub-Saharan Africa, due to increased food insecurity and easier access to technology (Altchenko and Villholth, 2015). In the semi-arid Sahel and East Africa regions, groundwater irrigation only affects a relatively small share of cultivated land, approximately 1 percent, as compared to 14 percent in Asia. Here, groundwater irrigation may have appreciable potential, especially for smallholders and for less intensive groundwater irrigation. However, data on the locations, thicknesses and hydraulic properties of aquifers are largely unavailable (Courtois *et al.*, 2010).

This groundwater-based agricultural boom, which started in the 1960s, was triggered in many semi-arid regions by a combination of easily accessible pumping and irrigation technologies, promoted by public policies through both direct and indirect subsidies.

Groundwater started to gain prominence through the action and investments of individual agents, leading Molle *et al.* (2003, p. 2) to qualify it as a "silent revolution;" it was only recognized as an important resource by states much later. Access to land and water often involves informal arrangements framed within locally-agreed rules, arrangements and regulations (Shah, 2009; López-Gunn, Rica and van Cauwenbergh, 2012; Kuper *et al.*, 2016; Lejars, Daoudi and Amichi, 2017). Informal networks around groundwater extraction extend well beyond the frontiers of the aquifer and actors operate in a context where access by farmers, not only to production factors (land, water, inputs) but also to markets, can be highly informal. While major uncertainties remain about the hydrological, social and ecological impacts of groundwater-based irrigation, countries have remained tolerant on illicit and informal practices around groundwater extraction, because the agricultural boom promotes economic growth (Petit *et al.*, 2017).

In many countries, the groundwater boom is also supported by public policies, through direct subsidies for irrigation equipment but also through energy and land policies that allow the development of new irrigated areas. Access to land and water is facilitated by laws enabling farmers without formal property rights over land or water to obtain such rights – by legalizing existing boreholes for example – and enabling new farmers using capital-intensive modes of production to establish themselves in local production areas. By providing subsidies for agriculture and irrigation equipment, States encourages and often finances the development of new technologies such as drip irrigation and the extension of irrigated lands.

Contrary to predictions associated with certain policy interventions, neither the total volume nor the share of water consumed by agriculture has decreased in most countries[71] (for example, California, the emblematic area of Elinor Ostrom's work (Ostrom, 2015); countries of the Middle East and North Africa, where drip irrigation allowed the expansion of irrigated areas rather than water saving; or the Beauce region of France, where the first water quotas were put in place).

Conclusion: A need for significant policy shifts towards less resource-intensive agricultural models

Over the past decade, countries have massively resumed their efforts to modernize their water and agricultural sectors. Financial support for large water infrastructure, irrigation equipment and drip irrigation has increased across the board, with a growing share being directly funded by national governments. Meanwhile, public subsidies for irrigation equipment and energy have generated and sustained a groundwater boom in many parts of the world.

There is much to celebrate in these efforts. Massive investments helped feed the 800 million people who joined the world population between 2010 and 2020. They also helped to satisfy changing diets, as global meat consumption increased by 58 percent over the 20 years to 2018.

However, these investments have come at the cost of increased pressures on land and water resources. Contrary to many predictions, the total volume of water consumed has increased, the share of water consumed by agriculture has not decreased, while both soil erosion and water quality have markedly worsened. Although these pressures vary considerably, both across and within countries, they are tendentially increasing especially under the effect of increased climate variability. In the coming years, governments will need to review their current level of political and financial commitment to their water and agricultural sectors, while making significant policy shifts towards less resource-intensive agricultural models.

2. Impacts of global changes, policies and investments on farmers' livelihoods and water use

This section of the report identifies the impacts of global changes and recent policies on farmers' livelihoods. It reviews the numerous beneficial impacts of irrigation on poverty reduction, while highlighting that they are highly contextual and unequally shared across social groups. It shows how policies handle the diversity of socioeconomic conditions on farms, and how investments in land and water management have significantly contributed to lifting people out of poverty. The section documents the widening gap between irrigated and rainfed areas, and the risks of a medium-term crisis for agricultural economies that are based on groundwater irrigation. It emphasizes the fact that existing policies are poorly tailored to farmers' needs. A range of perspectives are provided to compare the impacts of policies and investment programmes on large-scale industrial farming, family farms and new profile investors. Particular attention is paid to the impacts of recent land and water policies on migration, as limited access to water and land has become a driver of migration and migration affects access to, and sustainable management of, land and water.

2.1. The impacts of concentrating investments on irrigated (versus rainfed) agriculture: Benefits and disadvantages

▪ The beneficial impacts of irrigation on poverty reduction are numerous and well documented

The primary, direct impact of irrigation is increased crop output through increased in yield (Namara, Giordano and Bassini, 2019). Beyond the overall effect of additional water availability, irrigation increases yield (a measure of land productivity) in multiple ways:

- Irrigation offers more precise control over both the quantity and timing of water availability, supporting crop establishment, growth and yield.
- Water supplies from irrigation also increase the productivity of complementary inputs including seeds and fertilizers (Gebregziabher, Namara and Holden, 2012).
- Irrigation can make crop production possible in places where rainfall and soil moisture are otherwise insufficient and can make it possible to intensify production through a second, and sometimes a third crop per year (Hussain and Hanjra, 2004).

For example, in India, areas with investment in surface irrigation have seen higher yields, changed cropping patterns, larger gross cropped areas, and a transition from a single-cropping system to double-cropping, compared to areas that wholly depend on rainfed agriculture (Jagadeesan and Kumar, 2015). In the district of Ashoknagar (with 12 900 ha of command area rehabilitated by the Madhya Pradesh Water Sector Restructuring Project by 2014), Ranu *et al.* (2019) calculated that wheat yields rose by 31 percent due to irrigation investment.

Unsurprisingly, studies have found that crops show the greatest yield increases when cultivation shifts from rainfed to surface irrigation in semi-arid regions (Elliott *et al.*, 2014).

Importantly, studies have also illustrated the potential for infrastructure investments to disconnect economic growth from rainfall variability (Damania *et al.*, 2017).

Irrigation also benefits poor consumers (Lipton, Litchfield and Faurès, 2003). It fosters food price reductions, which are particularly beneficial to the poor since they spend a large proportion of income on food. Many poor producers are also net buyers of food, so they also benefit in this way.

Many positive economic and social impacts are attributed to groundwater irrigation, which has boosted economic growth and transformed rural economies in many countries in Europe; in Latin America and Asia through the Green Revolution (Shah, 2009); and, more recently, in North Africa (Kuper *et al.*, 2016; Lejars, 2017). In sub-Saharan Africa, groundwater irrigation supports rural livelihoods by promoting poverty alleviation, food security, land and labour productivity, as well as rural employment and general economic development (Villholth, 2013).

Beyond direct production, consumption and income effects, irrigation also affects poverty through indirect mechanisms, including: i) increased labour demand, particularly during planting and harvesting periods; ii) improved nutrition and health; and iii) economy-wide multiplier effects. Irrigation contributes to the availability of energy and protein (Pingali, 2012) and can provide increased incomes or purchasing power to support dietary diversity. Small-scale irrigation in Africa has been associated with increases in vegetable production, with direct benefits for nutritional status, particularly for women and children (von Braun, Puetz and Webb, 1989). However, the nature and extent of these impacts are also i) highly contextual and ii) unequally shared across social groups.

Studies examining the role of investments in water-related infrastructure and water institutions tend to use national, regional and global datasets to make assertions at regional and country levels. These studies often overlook impacts on a sub-basin or sub-national scale, as data at this level are typically not available (Narayanamoorthy, 2018).

After reviewing over 500 articles, Namara, Giordano and Bassini (2019) noted that irrigation impacts, both positive and negative, were socially, spatially and temporally unequal: "virtually every study we reviewed that was designed to measure differential impacts, in whatever dimension, found them to be significant (p. 3)."

The nature and extent of poverty impacts can vary greatly, depending on factors such as relative or absolute land size, relative location within an irrigation system (e.g. head or tail end), and structural issues related to the overall institutional and social-economic environment, such as those related to gender, caste and class. For example, the impact of irrigation on employment might benefit the landless poor, but there could be also growth in inequality if increased production depresses prices received by poor farmers operating under rainfed conditions. Irrigation may also worsen poverty if it reinforces processes of land consolidation in which poor households lose rights, converting marginal and poor farmers to landless labourers (Chambers, 1988), or if it is associated with the replacement of labour by mechanization or herbicide use.

There is growing evidence linking the expansion of groundwater-based agriculture with increasing socioeconomic inequalities in a context of declining water tables and rapid agrarian change. Many farmers have become involved in the groundwater economy, from family farmers to new agricultural entrepreneurs and investors. A large share of the rents from groundwater irrigation development can be captured by powerful agricultural

lobbies. The boom in the groundwater economy has benefited entrepreneurial and well-endowed farmers, who have made intensive use of groundwater, while the effects of their overexploitation of groundwater have fueled the marginalization of family farmers (Ameur *et al.*, 2017). Capital has replaced land ownership as the dominant production factor. Capital is not only required to obtain access to groundwater, but also to deal with the highly intensive, more risky agriculture frequently conducted in the groundwater economy. This leads to the exclusion of small family farmers, who may quit the groundwater economy poorer than they entered it. Some family farmers, for example, attracted by the potentially high economic returns of the groundwater economy, shifted from a traditional mode of farming to intensive (but riskier) forms of agriculture. Attracted by apparently easy profits, these farmers sometimes sold their livestock to try their luck with high-risk investments, which in some cases can indeed be very profitable, but in most cases end in bankruptcy. These general trends vary under the influence of contextual factors such as property rights, social organization, the role and weight of the state, the type of aquifer system and the dominant agricultural model.

The development of irrigation can have off-site environmental impacts that are particularly important for the poor. Irrigation is often associated with soil salinization, quantitative pressures on water, and the heavy use of fertilizers and pesticides. Irrigation may also reduce environmental services upon which the poor rely, related to inland and marine fisheries, for example.

In India, the construction of dams and reservoirs to support irrigation has been associated with displacement costs that disproportionately fall on the poor (Duflo and Panda, 2005) and Indigenous communities.

A wide range of literature highlights the importance of gender considerations to resource management outcomes in general (Meinzen-Dick, Kovarik and Quisumbing, 2014). The importance of gender in irrigation outcomes and impacts is no less important. The production of particular crops is gendered, the uses made of agricultural water are gendered (e.g. field crops versus home gardens), and access to inputs is gendered (e.g. land titles, credits), as is the use of revenue from irrigated output. However, while well over half of food production in developing countries is attributed to women (Domenech, 2013), irrigation interventions are often made without explicit inputs from women and without consideration for gendered constraints to adoption (Zwarteveen, 2006). Yet, the gendered impacts of irrigation are highly variable. For example, irrigation may reduce work for women in some circumstances, but increase work in others (van Koppen and Hussain, 2007).

Irrigation may also influence overall governance structures in complex and mixed ways. The rationale for the Green Revolution was both increased food production and social and political modernization in Asia and Latin America (Latham, 2011), although the impacts may not always have been as hoped for. Niazi (2004), for example, argued that the arrival of more productive seeds and irrigation in Pakistan hampered wider political reform (Niazi, 2004).

- ### A widening gap between irrigated and rainfed areas

Rainfed farming investments have been neglected compared to irrigated farming. This trend was encouraged by the fact that it is easier and more rewarding in the short term – for countries and international donors alike – to invest in large-scale infrastructure than in

introducing new practices at the plot level, such as plant cover, rainwater harvesting or precision agriculture, or new varieties that are resistant to drought.

Nevertheless, 80 percent of cultivated area worldwide is rainfed. Rainfed agriculture produces around 60 percent of global crop output in a wide variety of production systems.

Irrigated and rainfed systems should not be viewed in isolation from each other, as there are many conjunctive uses of water resources: e.g. rainwater harvesting, surface water, shallow wells, deep tube-wells and drainage water. For example, in India, Ranu *et al.* (2019) found that investments in irrigation had little to no effect on crop yields in low-rainfall areas. This led them to believe that crop yields in these districts are still, to some extent, linked to rainfall variability. It also indicates some reliance on rainfed and groundwater irrigation by farmers in these districts, despite rehabilitated surface irrigation systems.

Increased efforts and investments in irrigation have led to intensification and expansion and have resulted in an increase in energy consumption (Bazilian *et al.*, 2012). For example, in Morocco, Doukkali and Lejars (2015) showed that irrigated agriculture had increased the energy import bill and energy dependency of the country, concluding that, taking into account the multiplier effects of agriculture, investment in rainfed agriculture would be more profitable for the Moroccan economy than investment in irrigation (Doukkali and Lejars, 2015).

▪ A medium-term crisis for agricultural economies based on groundwater irrigation

The groundwater boom created high vulnerability in the medium term, through overexploitation and depletion of the water table, salinization, and the loss of resilience with more water-intensive crops. There are many warnings about, on the one hand, the degradation of the biodiversity of groundwater-dependent ecosystems and, on the other hand, social inequity or even a social crisis (Mukherji, 2006). Some authors have even predicted the social and economic 'collapse' of societies that depend on an eroded resource base such as groundwater, preceded by a period of environmental decline (Petit *et al.*, 2017).

Despite the benefits linked to groundwater economies, the social, economic and environmental sustainability of an economic model based on agricultural intensification, high value, year-round crops, affordable and easy-to-use technologies often led by entrepreneurial farmers, can be questioned. Awareness of the vulnerability of groundwater economies remains low in the political sphere, as it does among most stakeholders, and may explain why policies continue to be based on water supply logic: mobilizing new water resources.

2.2. Policy design often struggles to integrate farmer diversity, especially that of family farmers

- **Existing official farm typologies are often limited by several factors:**
  - By types of water use: as many uses of water resources tend to be combined in pragmatic and evolving ways: e.g. rainwater harvesting, surface water, shallow wells, deep tube-wells, drainage water.
  - By broad types of farming organization: as the line between family farming and agribusiness is often blurred (e.g. regular employment of day labourers by family farms, mixed model of family business, pluri-activity, etc.).
  - By farm size: as per capita land endowment is no longer a relevant measure of rural wealth, as high incomes can be achieved on small areas with highly intensified practices.
  - By tenure systems: as diversity and complexity are probably increasing worldwide: diversification in farming contracts, new profiles of investors (e.g. Maghreb, Asia, etc.).
  - By diversified types of activity systems: as the complexity of subnational (regional) economies has increased, which makes it harder to assess the impact of investments.

This often leads to policies that are poorly tailored to farmers' needs. Many instruments, regulations and policies are not correlated with the type of support that small farmers need.

The agricultural intensification that the Green Revolution launched in Latin America and Asia during the 1950s and 1960s was enormously successful in increasing key crop yields. The yields in developing countries of the three major cereal crops (rice, maize and wheat) more than doubled between 1960 and 2000 (Pingali, 2012). The impacts were enormous, including for smallholder farmers, reducing hunger and malnutrition for billions of people (FAO, 2017b).

However, from an equity perspective, many have argued that the Green Revolution and similar approaches are biased toward higher and middle-income farmers and can make the poorest people relatively and, in some cases, even absolutely worse off (Ickowitz *et al.*, 2019). Intensification has often led to the consolidation of small farms, creating a class of landless, agricultural labourers in place of small- and medium-sized family farm enterprises (Bernstein, 2010) and a 'corporate food regime' dominated by transnational agrifood corporations (McMichael, 2005). For example, in Rwanda, farmers report that the strict rules of the Crop Intensification Programme of the government's Strategic Plan for the Transformation of Agriculture, has made it difficult for them to produce the crops they need to maintain dietary diversity (Isaacs, 2016). In Morocco and Tunisia, many instruments, regulations and policies do not provide the type of support that small farmers need. The national banking system delivers loans to small farmers working at least 5 ha of land, for example, while most small farmers work on 2–3 ha on average. Moreover, informal contracts and arrangements, which are highly supportive of small farmers' livelihoods in developed countries, are generally poorly considered in public policies.

2.3. Land, water and migration

▪ Limited access to water and land as significant drivers of migration

Water stress, such as droughts, dry spells, changing rainfall variability and extremes that result in declining smallholder and subsistence agricultural production, may accelerate or amplify migration patterns (Nawrotski and Bakhtsiyarava, 2017). Findings from various studies indicate that the likelihood of migration is low immediately after a water shock, but increases as households cycle through the various adaptation strategies available to them. If the shock is not repeated for an extended period, migration rates stabilize (Wrathall *et al.*, 2018). However, migratory responses to water stress are context-dependent and can vary from region to region.

In Africa, rural migrants are mostly young people, most of whom come from farming families. Around 60 percent of them are between 15 and 34 years old. Most migrants are men; however, in some countries, such as Mozambique, the Democratic Republic of the Congo and Burkina Faso, most migrants are women (FAO and CIRAD, 2017).

Agricultural adaptation strategies affect people's need to migrate and should be explicitly incorporated into relevant policies, including for climate change adaptation. A delayed migration reaction to water stress allows time for intervention. Investments in agricultural adaptation techniques and technologies and the development of rural livelihood diversification programmes can be used to diminish the economic imperatives that drive vulnerable people to migrate. However, agricultural development programmes and migration policies can only result in desirable outcomes when they prioritize human rights and security, and attack the roots of environmentally forced migration, i.e., deficits in the protection of human rights, no guarantee of entitlements, and lack of support for human agency and freedom (Tanner *et al.*, 2015).

▪ A massive influx of migrants can increase pressures on land and water

Various studies show that migration can create water stress through impacts on the ecosystem services that support water provisioning, water distribution systems, flood management systems and safe drinking water (Selby *et al.*, 2017; Wrathall *et al.*, 2018). These papers conclude that when environmental displacement and/or conflict-induced displacement cause migrants (or refugees) to live in informal settlements, those involved can be locked into future water stress (Runfola and Napier, 2015). Typical examples are refugee camps in Lebanon and Jordan, populated first by Palestinians and now by Syrians. This is especially the case where informal settlements involve forms of land use that are water-intensive or destructive to local water cycles. The literature identifies three mechanisms whereby this may occur. First, migrants can decide, or be forced, to settle on marginal or fragile lands increasing risk of water stress. Second, land tenure systems that incentivize water conservation may be disrupted. Third, the construction of new settlements or the expansion of existing ones may damage local water flows as land uses change and land degradation occurs.

- **Impact of migratory patterns on women**

As Davison has shown in case studies in *Agriculture, women and land: the African experience* (2019), women are more affected by changes in migratory patterns than are men. In Africa, their importance as primary producers of food does not protect them if specific innovations and policies are not in place. In Nepal and parts of India, men often migrate to pursue non-agricultural livelihoods (Sunam, 2017), leaving women with greater responsibilities for agriculture (the so-called 'feminization of farming'), without necessarily having the resources to meet those responsibilities.

Based on the International Monetary Fund's World Economic Outlook Database (IMF, 2017) and cross-sectional, time-series data from 1981 to 2010, Eastin (2018) showed that in developing countries, "gendered disparities in climate change vulnerability not only reflect pre-existing gender inequalities, they also reinforce and strengthen them (p. 289)." Women with lower socioeconomic status who rely on agriculture as a means of subsistence and production are likely to be acutely vulnerable. In Africa, women are responsible for between 50 and 80 percent of agricultural production but hold less than 20 percent of agricultural land (FAO, 2016). This disparity can create acute hardships for women when climate change undermines agricultural livelihoods: ownership increases access to formal credit markets, which can enable individuals to cope with lost harvests, invest in new livelihood strategies, or purchase agricultural inputs that can reduce production volatility.

- **Migration as an adaptation strategy and vector for innovation transfer**

Migrants may stimulate innovation, thereby promoting job creation and enhancing productivity (Jensen, 2014). Migration also fuels transfer of knowledge and can also provide most on-farm workers (e.g. such as in the Algerian oases, the United States of America, Andalusia, etc.) (Naouri, Hartani and Kuper, 2017).

In some countries, migration is used as an adaptation strategy and is part of a process of socioeconomic transformation, where people leave to cope with or adapt to environmental changes or to optimize their livelihoods. This can be misunderstood if migration is considered purely from an economic standpoint. Some examples show that migration can facilitate the transition from family-based subsistence farming to commercial production (Szelc and Fekih, 2020). As such, it is an integral part of a strategy for looking for additional resources needed for agricultural development.

However, the link between climate change and rural migration can be complex. Although environmental challenges can influence migration, the decision to migrate is also determined by social, economic and political factors.

Conclusion: Water and agricultural policies should be more 'territorialized' to take into account the growing diversity of farmers' structures, needs and strategies

Farm diversity is expected to increase by 2050. Small farms are set to become more numerous, but also more diverse in size, land tenure type, cropping patterns and market strategies. There is also growing evidence linking the expansion of irrigated agriculture to increased socioeconomic inequalities in a context of declining water resources. Complexity is further increased by migration patterns partly caused by increased pressures on access to water and land.

Policy designs often struggle to take this diversity into consideration. The limitations of existing official typologies often lead to policies that are poorly tailored to farmers' actual needs. Specifically, many instruments, regulations and policies are not in phase with the type of support needed by the most vulnerable farmers. More broadly, insufficient attention is generally paid to issues of policy implementation, in terms of the organizational capacity required and the understanding of local social dynamics.

To tackle these shortcomings, governments are showing renewed interest in approaches that enable them to adapt their intervention more effectively to the diversity of local contexts. Territory-based approaches allow a better connection of water and land policies to other policy domains and help to improve the ability of stakeholders to coordinate their interventions to implement policy decisions. However, some major questions remain unanswered regarding the appropriate scaling of public intervention and its legitimacy.3. Which way forward for sustainable land and water management?

This section reviews a range of options for creating a conducive environment to support sustainable land and water management. It takes stock of policies inspired by the principles of integrated water resources management. It documents some tentative steps toward more territory-based policies and reviews the experiences of integrating climate change into land and water policies. The section focuses on new approaches to comanaging common property resources, cross-sectoral cooperation and transboundary cooperation. It then discusses the respective merits of universal versus targeted agricultural policies to improve family farmer livelihoods. Finally, it reviews some promising experiences in terms of water governance and participatory approaches to land and water management.

3.1. The need for more effective and integrated policies within countries

▪ Taking stock of integrated water resources management: a need for financial, technical and environmental support

Since its heyday in the 1990s and 2000s, when integrated and participatory management became a real mantra in the world of water resources, the dissemination of integrated water resources management (IWRM) principles and the accompanying institutional packages (e.g. river basin agencies, river basin master plans and local management plans, inclusion of all relevant stakeholders in the formal decision-making process, aquifer contracts, user-pays and polluter-pays principles, etc.) has had mixed results (Barone and Mayaux, 2019).

Many water agencies have found it hard to access the necessary human, financial and logistical resources to adequately function (e.g. in Brazil, Indonesia, etc.). Meanwhile, several developing and emerging countries have opted to keep water management within their traditional policy and bureaucratic systems. In South Africa, and in Africa more generally, many hurdles and limitations in terms of financial capacity, lack of skills, institutional conflicts and rigidity, have hampered the successful establishment of water management agencies following the decentralization principles of IWRM (see the case study on South Africa in the annex). Nevertheless, in some cases (Morocco, Brazil), IWRM has had some major successes in producing knowledge, identifying problems and building institutional capacity.

However, there is a glaring gap between the complexity of the issues and the weakness of the resources allocated to administering the sector, particularly regarding the staff of the water police (with examples in Morocco, Mexico, Brazil and France). In addition to the lack of technical and financial resources, schemes related to water politics often relegate environmental issues to the background. Water institutions are often marginalized in the decision-making system.

Finally, the effectiveness of water policies (are they really implemented?) and their efficiency (do they achieve their objectives?) are rarely assessed. Such assessments of policy impact could reinforce trust between authorities and citizens.

▪ Toward more coherent cross-sectoral and 'territorialized' policies

Coordination challenges are perceived to be more complex than ever with the emergence of the WELF (water, energy, land, and food) nexus paradigm (Wichelns, 2017). Policies on water, land energy and food are mostly developed in silos, despite the fact that the interdependencies between them are numerous and substantial. These interdependencies i) are complex to understand, ii) highly variable across states, and iii) are often not recognized in policy-making. Whatever the scale, information to support policy-making should include second order consequences through feedback loops. Some recent conceptual frameworks bring these interdependencies to the forefront (e.g. virtual water, ecosystem services, etc.), but they are not yet used (or not even useful) to operationalize a nexus vision.

In 2006, the need for territory-based approaches gave rise to the New Rural Paradigm (OECD, 2006). The OECD showed that governments are increasingly aware of the need to improve, or sometimes abandon, traditional sectoral policies and replace them with more appropriate instruments. Governments are also concerned about the modest positive impact of agricultural subsidies on overall economic performance, even in areas that depend heavily on agriculture. In this context, OECD governments are showing a growing interest in territorial approaches to rural policy, that focus on investment rather than on subsidies and can integrate different sectoral policies and improve the coherence and efficiency of public spending in rural areas.

In some countries, central government involvement is evolving from direct intervention toward a 'territorialized' policy. For example, in France and Tunisia, such policies have created space for involving local communities in decision- and policy-making. Local planning authorities are becoming more autonomous and can push for a participatory territorialized approach (see, for example, Case Study 4 on Tunisia or PTGE in France in the annex) (Loubier *et al.*, 2019). These experiments have had mixed results, as important questions remain unanswered regarding the appropriate level of public intervention, its legitimacy, and the capacity of local planning authorities to capture the necessary resources and implement adequate planning processes.

- **Taking climate change into account in public policies**

From the mid-2000s onward, countries started adopting national strategies for climate change adaptation (CCA) that included agriculture (e.g. France, Spain and Senegal in 2006, California in the United States of America and the Western Cape Province in South Africa in 2008 – interestingly, in the latter two cases, subnational plans preceded national plans). However, climate change is typically not considered in river basin planning in most countries (Sanchis-Ibor, Molle and Kuper, 2020).

Partey *et al.* (2018) stated that "adopting climate-smart agriculture seems to be a suitable strategy to achieving food security while also mitigating and adapting to climate-related risks (p. 285)". In West Africa, Zougmoré *et al.* (2018, p. 2) cited "agroforestry, conservation agriculture, crop diversification, climate information services, etc." as "emerging climate-smart agriculture options to improving farm productivity, rural livelihoods and the adaptive capacity of farmers and production systems in sub-Saharan Africa."

Vaughan *et al.* (2019) analyzed the effects of weather and climate services. They showed that access to, and use of, these services vary considerably and that their impact is conditioned on a number of characteristics of the service, the user, and the context. Similarly, for Southeast Asia and Latin-America, Jat *et al.* (2016, p. 128) stated that:

> [C]onservation and climate-smart agriculture (CSA), judicious utilization of available water for agriculture through micro-irrigation and water saving technologies, developing multiple stress-tolerant crop cultivars and biotypes through biotechnological tools, restoration of degraded soils and waters, promoting carbon sequestration through alternate production technologies and land use, and conservation of biodiversity must be promoted at regional and country level to ensure durable food and nutritional security.

Torquebiau *et al.* (2019) observed that close links between agro-ecology and climate change give cause for hope in developing countries and they provide different successful

technical examples. The authors acknowledge that agro-ecology is "unfortunately mentioned explicitly only very rarely" in the Nationally Determined Contributions (NDCs) presented by countries at the time of the Paris Agreement in 2015 (COP 21)"… but that "some of its components do find inclusion: conservatory water management, improved pastoralism, agroecological fish farming, landscape approach, biological corridors, 'low carbon' farming practices, etc. (p. 10)." National adaptation plans (NAP) and domestic planning processes designed to identify, address and review evolving national adaptation needs may also include some of these components.

On the Climate-Smart Agriculture Prioritization Framework (CSA-PF) process in Mali, Andrieu *et al.* (2017) concluded:

> [T]here is global momentum to better understand how to achieve agricultural development that considers productivity, resilience, and mitigation. Given this, it is critical that policy-makers, planners, and implementers identify processes for prioritizing investments in agriculture that match with the institutional, biophysical, and socioeconomic realities, and also push for inclusive decision-making to ensure equitable, effective, and sustainable solutions for agricultural systems and stakeholders in the long-term (p. 13).

A few innovative instruments for climate change adaptation have been implemented. Many are informational instruments, i.e., supporting research and innovation, setting up information systems, fostering the regular publishing of reports at different levels (national and subnational, e.g. by European Union countries).

Some actual incentives have also been designed (e.g. subsidies for restructuring vineyards in Spain and southern France, however, with limited funding so far). Regulatory instruments are gaining in significance too (e.g. quotas and restrictions on irrigation water in France), although not for public interventions in cropping patterns.

However, policy innovation has so far remained limited. For example, many planning documents (either for water and/or agriculture) do not yet consider the predicted effects of climate change. In addition, in many cases, traditional policy instruments have simply been relabeled as instruments for climate change adaptation (e.g. crop-yield insurance against natural disasters, subsidies for agro-ecological practices or drip irrigation, support for precision agriculture, dam building, inter-basin transfers, for example in Spain, Brazil and North Africa.

There still appears to be a major need for research to provide climate-smart solutions to help farmers and, moreover, the "Climate Smart Agriculture focus on adaptation, mitigation, and food security needs to be assessed in terms of science-based practices (Torquebiau *et al.*, 2018, p. 2)."

3.2. Universal versus targeted agricultural policies to improve the livelihoods of poor farmers

Looking ahead to prospects for 2050, based on the twenty-first century experience, Hazell (2019) foresees a growing differentiation within the agricultural sectors in developing countries under a business-as-usual scenario. Small farms will become smaller and more numerous. There will be more part-time farmers, particularly among smallholders, for whom agriculture provides a modest and diminishing share of household income. There

will also be a growing gap between large and small farms, commercial and non-commercial farms, young and elderly farmers, and geographically well-situated regions (both rural and urban) and isolated, marginal rural areas.

What type of agricultural strategy is required to avoid such a fate? Which policies have been successful in avoiding growing farm differentiation? In their effort to synthesize strategic insights from the agricultural and rural development experiences of the 1960s–1980s, Tomich, Kilby and Johnston (1995) built the case for the feasibility and desirability of a broad-based agricultural development strategy aiming for a 'unimodal' agrarian structure (the distribution of farms by size). Recognizing differences across farms and within households, the point nevertheless was that a single agricultural strategy could raise productivity on the vast majority of farms in a country, drive economy-wide growth multipliers, including growth in income and employment in the rural non-farm economy, and thereby create a growth dynamic that would tighten labour demand and dramatically reduce poverty.

Arguments for universal agricultural strategies emphasize that there is no necessary trade-off between production efficiency and social equity, since there is evidence of an inverse relationship between farm size and productivity (often proxied by crop yields), especially in sub-Saharan Africa (Barrett *et al.*, 2017).

At the same time, Hazell (2019) argued that strategies aimed at poverty reduction must consider a range of different smallholder types with very different resources, connections to markets and economic prospects. To these categories, we should also add the culturally-mediated roles of gender and marital status, which influence access to education and health services, and to land, irrigation water, forests, and other resources, affecting both labour market participation and wages. systematically disadvantaging women and girls and making them more likely to experience poverty (Sen, 2001).

3.3. Intensifying cross-country cooperation

Managing transboundary water resources is expected to be one of the greatest challenges facing human development over the coming decades (UN Water, 2008). The world's 286 transboundary river basins support the socioeconomic well-being of more than 40 percent of the global population, as well as the ecosystems on which they depend (UNEP-DHI and UNEP, 2016). More than 90 percent of the world lives in countries with basins that cross international borders (Leb *et al.*, 2018). Target 6.5 of the SDGs, adopted in September 2015, calls on the world community to implement integrated water resources management at all levels, "including through transboundary cooperation as appropriate," recognizing the greater benefits that can be achieved in transboundary basins through coordinated versus unilateral action. In the absence of cooperation frameworks, in a business-as-usual scenario, conflicts are expected to escalate because of the growing world population, industrial development, and increasing urbanization, as well as the negative consequences of climate change (Tayia, 2019).

▪ Characterization of transboundary water management

Many studies conceptualize conflict and cooperation as opposing ends of a spectrum. For example, on the Basins at Risk (BAR) project, Yoffe, Wolf and Giordano (2003) measured

water events on a scale of conflict and cooperation. Their dataset compiled every reported interaction between two or more nations – whether conflictive or cooperative – that involved water as a scarce and/or consumable resource or as a quantity to be managed. Where water was the driver of an event, the BAR scale determined +7 as the highest level of cooperation, and -7 as the highest level of conflict of a "formal declaration of war over water (p. 1111)."

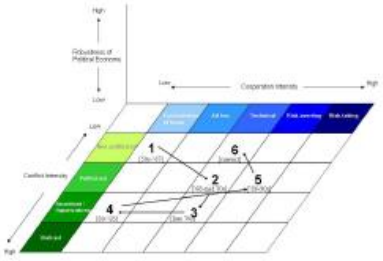
Countries have achieved significant mutual economic benefits through cooperation in the Columbia Basin in North America (Altingoz, 2018). The cooperative regime established by the United States of America and Canada under the 1961 Columbia River Treaty (CRT) included developing reservoirs in the upper basin and coordinating cascade operations with already existing dams downstream. In terms of prevented flood damage, it is estimated that the flow regulation provided by new upstream dams in 1972, 1974, 1996, and 1997 prevented damage amounting to USD 260 million, USD 306 million, USD 227 million, and USD 379 million respectively (USACE, 2013).

Likewise, in the La Plata Basin (shared by Argentina, Bolivia (Plurinational State of), Brazil, Paraguay and Uruguay), cooperation on hydropower development on the common river stretches of the Paraná River have generated significant benefits from electricity production. The Itaipu Dam, jointly developed by Brazil and Paraguay and managed by an entity co-owned by their respective power companies, Eletrobras and the Administración Nacional de Electricidad (Ande), provides almost 75 percent of the electricity consumed in Paraguay and about 15 percent of the electricity consumed in Brazil. Since Paraguay only uses about 5 to 10 percent of the electricity produced in Itaipu, it sells the remainder of its share to Brazil and receives an annual compensation payment of around USD 360 million for the use of its share of the hydraulic resource (Kramer *et al.*, 2012).

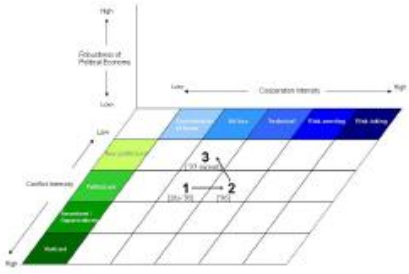
At the conflictual end of the spectrum lies the management of the Tigris and Euphrates rivers. The construction of 22 dams in Türkiye over the last 30 years has decreased the flow of freshwater into Iraq and Syrian Arab Republic (Lovelle, 2018). Those two countries have been hit by severe drought and the decreased water flow in the Tigris and Euphrates rivers has exacerbated the lack of water availability, leading to an increased reliance on groundwater for the irrigation of crops and domestic water needs, and widespread devastation in Iraq.

This notion of a linear continuum between conflict and cooperation has been criticized. The Transboundary Waters Interaction NexuS (TWINS) framework highlights the simultaneous coexistence of conflict and cooperation in transboundary water interactions (Eynon, 2016). On the one hand, the level of cooperation intensity in each instance is determined by the existence or absence of four factors among the water-sharing states: common goals, joint action mechanisms, the will to participate in joint action mechanisms, and confidence in the other parties' will to participate in collective action. On the other hand, four levels of conflict may exist in each instance: non-politicized, politicized, securitized and violated. The TWINS framework analyses the patterns of transboundary water interactions at any point of time based on these coexisting levels of cooperation and conflicts. It can also trace changes in the intensity of cooperation and conflict in transboundary water relations over time (see Figure 2). More recently, an improvement has been made to TWINS by adding the degree of robustness of the political economy context as a third determinant of transboundary water interaction patterns (Mirumachi and Allan, 2013).

Figure 2. Characterization of two transboundary trajectories according to the TWINS framework



Trajectory of Lesotho-South Africa relation over the upper Senqu/Orange



Trajectory of Nepal-India relation over the upper Ganges

Source: Mirumashi and Allan, 2013,

It should be noted, however, that there is generally a lack of access to the data and the decision-making processes involved in transboundary water interactions, making the precise characterization of interactions difficult (Mirumachi and Allan, 2007).

- **Mechanism for enhancing cooperation**

Despite agreement on important component principles, there is no consolidated and agreed international integrated framework for the joint management of freshwater.

Optimization approaches are widely used by academics, but are rarely used in real-world situations, as they do not consider the fact that international water resource allocation and management take place in circumstances of asymmetric power such as asymmetric economic positions, unequal network of international alliances, upstream vs. downstream positions, etc.

The Danube River, Nile Basin, Ganges River Basin, Caspian Sea and the Nestos River have been analysed using different optimization techniques, including multiobjective, multiparticipant optimization, linear programming and dynamic programming (Leb *et al.*, 2018). These techniques focus on identifying possible conflict settlement under ideal conditions.

The Alternative Dispute Resolution (ADR) is more sensitive to real-world power asymmetries. The ADR aims to reshape the process of negotiations from distributive, or zero-sum, negotiations into collaborative negotiations (Delli Priscoli and Wolf, 2009). Here, all parties cooperate to optimize the overall outcome of the process, allowing every party to gain from negotiations. Most frameworks rely on four main principles: defining the problem; focusing negotiations on interests, not on positions; bringing parties together to generate new options; and providing objective criteria for allocating gains among parties. However, the ADR does not provide a concrete conceptualization of the criteria that determine optimal results. It should therefore be considered as a partial conflict resolution mechanism, which can serve as a process facilitation tool but not as a resolution mechanism that can guide the participants towards the best resolution.

As a general conclusion, most transboundary water conflict resolution mechanisms offered in the academic literature lack the analytical capacity to deal with all dimensions of transboundary water conflicts.

- **General lessons learned**

Effective transboundary water governance remains rare because transboundary water management exists in a context of asymmetric power. In such circumstances, the hegemonic riparians dictate the pace of cooperative adaptation and engage in fake cooperation that disguises domination as cooperation. Hydro-hegemons can choose to diminish the effectiveness of the regional public good (Warner *et al.*, 2017). For example, according to a former minister of Jordan's Ministry of Water and Irrigation, it was difficult for the Jordanian government to stop Syrian violations of the 1987 bilateral treaty over the Yarmuk River for this reason. The Syrian state is upstream and Jordan downstream; the geopolitical alliances and objectives of the two countries were very different; the transit trade through Syrian Arab Republic for the benefit of Jordan was strategic for the Jordanian government. Important interests in the other sectors, especially trade, was the main reason why the Jordanian government never took any action against the Syrian violations, apart from releasing statements condemning them.

Effective cooperation is built over a long period of time. Using 1948–2008 data from the Basins at Risk project, Schlomi *et al.* (2019) investigated whether basins governed by treaties witness fewer tensions and/or more effective cooperation over shared water relative to those basins not governed by treaties (Shlomi *et al.*, 2019). It also evaluated basins pre- and post-treaty enactment. The results provide only limited evidence that the presence of a general treaty promotes cooperation but provide stronger support for the claim that more specific treaties that target a given problem in the basin elicit increased cooperation.

Strong and diverse economies can more readily install the very expensive institutions of transboundary water governance. They can also avoid the stressful relations that riparians endure when they do not have the options of advanced socioeconomic development.

3.4. Participatory approaches toward land and water co-management

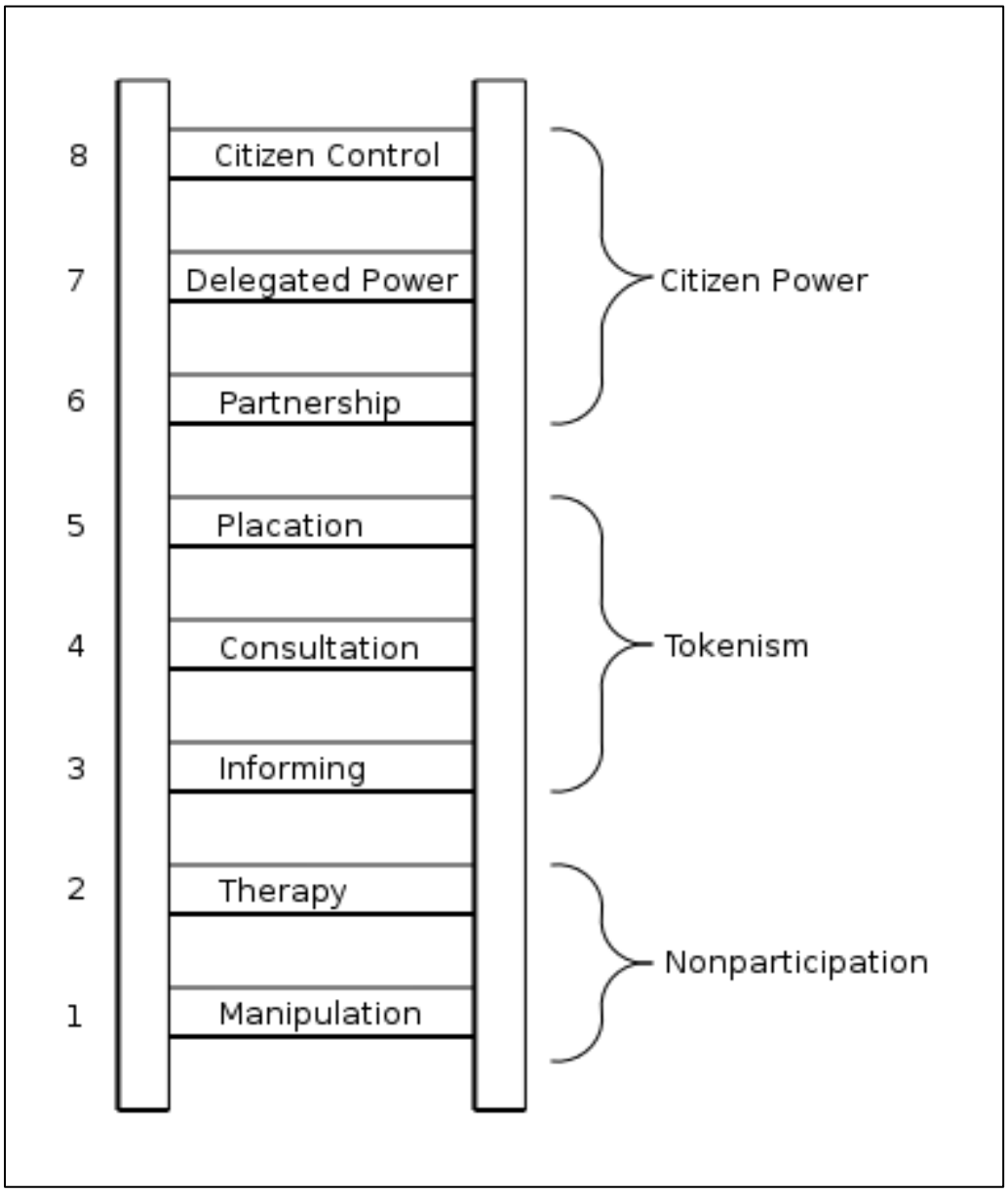
Participatory approaches to integrated natural resource planning and use have been widely promoted in recent decades. Public participation is one of the key principles of IWRM (Snellen and Schrevel, 2004). It is also one of the principles of good governance, along with consensus-orientation, accountability, transparency, responsiveness, equity and inclusiveness, effectiveness and efficiency, and consistency with the rule of law (Dasgupta and Roy, 2011). Public participation is also targeted by the SDGs (SDG Target 16.7 among others) (UN, 2020) and promoted by the commons approach (Venot, 2014). Finally, public participation is advocated by international donors, governments and by individual stakeholders themselves. It increasingly conditions donor funding of development projects. In North Africa, the Arab Spring renewed the demand for more participation and transparency in public policies. In Europe, the implementation of the Water Framework Directive and other directives promoting participation is an ongoing process. Since the 1980s, public participation has mostly taken place at subnational levels: e.g. water basin agencies, water users associations, municipalities (Gurney *et al.*, 2016), although with highly variable levels of participation (from non-participation to citizen power, see Figure 3).

The past decade has witnessed the boom of civic technologies and citizen science. Civic technologies are "information and communication technology (ICT) platforms designed to

amplify citizen voices to improve service delivery" (Peixoto and Sifry, 2017). In Kenya, for example, citizens can lodge complaints or feedback about water services through a website, MajiVoice (http://www.majivoice.com/). Citizen science initiatives are research programmes engaging individuals – many of whom are not trained scientists – in collecting, categorizing, transcribing, or analyzing scientific data (Bonney *et al.*, 2014).

These trends present both opportunities and risks. On the positive side, they allow more participatory approaches, with more numerous and diverse participants, and enable greater transparency of public policies and greater accountability of decision-makers. But these trends also present risks of exclusion, marginalization and corruption if participation is not implemented in a genuine manner.

Figure 3. The ladder of citizen participation



source: Arnstein, S.R.1969. A ladder of citizen participation, Journal of the American Institute of Planners, 35:4, 216-224, DOI: 10.1080/01944366908977225

While participatory approaches have lived up to their promise in many cases, obstacles remain, which can limit their implementation and impact.

- Participatory approaches are not always carried out in a genuine manner: many decision-makers still think little of farmers' knowledge and do not understand the added-value of public participation (Williams, 2004).
- Governments rarely have the means to involve the most marginal and disadvantaged people, because it requires going to see them individually, and setting up appropriate participatory methods. Governments therefore often rely on associations or farmer representatives' (who are often farmers with more means and interests that are not necessarily aligned with those of the poorest people). There is also often a lack of political will to implement participatory approaches.

- The evaluation of participatory approaches is fundamentally deficient in most countries (Abelson and Gauvin, 2006). While it sometimes includes a procedural evaluation (e.g. number of participants, representativeness, etc.), it rarely includes the assessment of social impacts (learning, changes in practices, etc.) or environmental performance (Newig *et al.*, 2017). Moreover, evaluations undertaken five or ten years after the end of the process are anecdotal, including at the global level. There is an urgent need to invest more resources in evaluation, particularly to inform reports such as SOLAW.
- Decision-support systems are not necessarily operational or well used. They are often hosted in developed countries because developing countries do not have broadband or servers powerful enough to run the systems; data are often entered in the systems for monitoring and accountability purposes rather than to support participatory decision-making, and they are rarely, if ever, used by lay stakeholders (Giupponi and Sgobbi, 2008).
- Large-scale participation, especially in a rural context, raises issues of data storage, aggregation, analysis and sharing (Bright and Margetts, 2016; Karim *et al.*, 2020; Tang and Liao, 2019): human, time and financial resources are not always available to transcribe handwritten notes onto computers and analyse data.
- There is often a discrepancy between the participatory process and investment timelines. A participatory diagnosis must be allowed to unfold at its own pace, while there is often pressure to spend an annual or project budget quickly. In addition, budgeting requirements are often incompatible with genuine participatory approaches: the former usually require financed activities to be predefined, while these often can only be identified once a diagnosis of the main problems and issues has been made.
- It remains difficult to integrate plurality, conflict and hybridity into participatory planning approaches (Brown *et al.*, 2017; Murray, Shaffer and Lovan, 2004). Often, participatory planning processes 'smooth out' disagreements to the benefit of the majority.

To overcome these obstacles, a set of recommendations has been proposed in the literature:

- Establish multilevel participatory approaches, i.e. approaches that do not consist solely in devolving responsibilities to the local level, but which also strengthen and support public participation in regional and national decision-making and create connections between the different levels (Daniell and Barreteau, 2014; Newig, Schulz and Jager, 2016). Some participatory methods – such as role-playing games or strategic planning – make it possible to strengthen the interactions between multiple levels of governance (Hassenforder *et al.*, 2021). Such multilevel participation requires the early involvement of stakeholders in the process, and training and awareness-raising of decision-makers and experts regarding the added-value of participation. In Tunisia, the Climate Change Adaptation Programme for Vulnerable Territories (2018–2022) seeks to strengthen multilevel participatory planning through the creation of multi-stakeholder platforms and capacity-building for territorial facilitators.
- Develop a culture of participation, in governments and administrations, among elected officials, territorial managers and technicians. The aim is that the different actors see participation as an opportunity to build more transparent public policies, based on more diverse opinions and closer proximity to citizens, farmers and users. Participation must adapt to the cultural context, but the context must also adapt to participation requirements (Maleki and Bots, 2013).
- Implement participation charters and participation warrants, which contribute to the transparency and accountability of public policies. Participation charters formalize the

rules, principles and values underlying the participatory process. Participation warrants are the individuals responsible for ensuring that participation charters are respected and that the process is equitable and transparent. Participation charters can be co-redacted with different actors during the engineering phase of the process. Increasingly, participatory processes are co-engineered with the participants themselves. This means that participants decide who will participate, when, with what methods, and with what roles each will play (Daniell *et al.*, 2010; Hassenforder *et al.*, 2020).

- Establish meaningful monitoring and evaluation and decision-support systems, which include qualitative and quantitative data, and which assess the multiple impacts of participation (learning, institutional and relational changes, justice and equity, behavioral change, etc.). Diverse approaches have been developed to such systems (Ferrand and Daniell, 2006; Blundo Canto *et al.*, 2018; Hassenforder *et al.*, 2016). These approaches promote the involvement of different stakeholders in designing the evaluation process, in collecting and analyzing data, and in sharing results (Chouinard, 2013). The objective is to move from a vision of evaluation as a control tool to an evaluation that contributes to the impact of the approach.
- Finally, take more systemic approaches to participation, accounting for the complexity of the socioenvironmental system within which participation unfolds (Chilvers, Pallett and Hargreaves, 2018; Jager *et al.*, 2020). Some existing theoretical and operational participatory approaches enable this complexity to taken into account, such as participatory modeling and simulation, systemic thinking, etc.(van Muuren, van Meerkerk and Tortajada, 2019). These approaches are often based on a critical view of prevailing participatory narratives and practices; in particular their time inconsistencies, since very distinct temporalities (that of participatory arrangements themselves, that of policy-makers, of researchers and of donors) are often poorly articulated. Such a critical perspective is presented by some authors as a prerequisite for ensuring a transformative change of the systems at hand (Blühdorn and Deflorian, 2019).

Conclusion: Strengthen participatory approaches to improve water and land governance arrangements and policy design

Participatory approaches to integrated natural resource planning and use have been widely promoted in recent decades. Public participation is one of the basic principles of IWRM. The past decade has also witnessed growing interest in civic technologies and citizen science. These approaches and technologies allow for more numerous and diverse participants, and for greater transparency and accountability in public policies. However, if participation only takes place in superficial or partial ways, it risks reproducing pre-existing forms of social exclusion, marginalization and corruption.

While participatory approaches have lived up to their promise in a number of cases, several obstacles remain that limit their implementation and impacts. The evaluation of participatory approaches is fundamentally deficient in most countries; decision-support systems are either lacking or poorly used; there is often a lack of political will to widen participation. Lastly, it has proven difficult to integrate plurality, conflicts, and hybridity into participatory planning approaches. Often, participatory planning processes 'smooth out' disagreements to the benefit of the majority.

If these obstacles are to be overcome, participatory processes and their evaluation need to be improved. Possible improvements include the establishment of multilevel participatory approaches, i.e., approaches that do not consist solely in granting a voice at local level, but which also strengthen and support public participation in regional and national decision-making processes. Another important step is the establishment of interlinkages between these different levels. Furthermore, participatory processes need to be co-engineered with the participants themselves. This means that future participants should jointly decide who will participate, when, with what methods, and what their roles should be.

Conclusion

What major conclusions can we draw from this study?

First, the trends are clear for water and land uses: the pressures on quantity and quality have greatly increased and have fed back on each other, even though strong variations do exist and have probably been amplified. Countries have massively resumed their efforts to modernize their water and agricultural sectors, and there is much to celebrate in these efforts. However, these investments have also led to more water stress, degradation of water quality, fewer farms available for family farmers, and soil erosion. In the coming years, governments will need to renew their current level of political and financial commitment to their water and agricultural sectors, while making significant policy shifts towards less resource-intensive agricultural models.

Second, policy designs often struggle to take into consideration the growing diversity of farms. The limitation of official typologies often lead to policies that are poorly tailored to farmers' needs. Specifically, many instruments, regulations and policies are not in line with the type of support that the most vulnerable farmers need.

If these deficiencies are to be tackled, water and agricultural policies will need to be more territorialized to consider the growing diversity of farmers' structures, needs and strategies. Territory-based policies could also enable a better connection between water and land policies and other policy domains, integrating them into rural policy and improving cross-sectoral policy coherence. However, some major questions remain unanswered regarding the appropriate scaling of public intervention, its legitimacy, and the capacity of regional planning authorities to bring into play the necessary resources to implement effective planning.

Third, there is a need to strengthen participatory approaches to improve water and land governance arrangements and policy design. While participatory approaches and IWRM have lived up to their promise in some cases, obstacles remain that limit their implementation and ultimate impacts. The evaluation of participatory approaches is fundamentally deficient in most countries; decision-support systems are either lacking or poorly used; there is often a lack of political will to widen participation.

Finally, it has proven difficult to integrate plurality, conflicts, and hybridity into participatory planning approaches. To overcome these obstacles, there is a need to improve participatory processes and their evaluation. Possible improvements include the establishment of multilevel participatory approaches, i.e., approaches that strengthen and support public participation in local, regional and national decision-making processes. Another important need is to establish interlinkages between these different levels. Some recent cases have shown that large-scale local participation is possible, even in a context where there are few or no functional intermediary organizations, low digital penetration rates and high rates of illiteracy, and that the territory-based approaches are appropriate for identifying these enabling conditions.

Annex. Case studies

Case study 1. Catchment management agencies (CMA) and water users' associations (WUA) in South Africa: A non-linear process showing the difficulties of a decentralization effort based on IWRM principles

Following inclusion of the principle of access to water and sanitation in South Africa's Constitution (1996), the 1998 South African Water Act established nineteen water management areas (WMAs). Within each WMA, the law established the gradual creation of catchment management agencies (CMAs), subcatchment entities (catchment management committees-or CMCs) to provide advice to the CMAs on defined issues (Anderson, 2005) and water users associations (WUAs) (Mutondo, Farolfi and Dinar, 2016).

In 2012, the Department of Water and Sanitation (DWS) decided to reduce the 19 planned CMAs to nine; the minister approved the establishment of nine CMAs in the newly delineated nine WMAs. Currently, seven of the nine CMAs are in the process of being established. These proto-CMAs are managed by the respective regional offices of the DWS (Meissner, Stuart-Hill and Nakhooda, 2017).

Referring to the Incomati WMA, Denby *et al.* (2016) argued that the decentralization and integration aspects of IWRM have somewhat failed to take off. Brown (2013) concluded that there might be fundamental weaknesses in the participatory model often used and its underlying assumptions. These weaknesses are, for instance, due to the lack of voice in the participatory processes by certain groups such as the smallholder farmers or the representatives of disadvantaged communities (Farolfi *et al.*, 2008). The approaches to decentralization may actually reinforce inequitable outcomes rather than achieving equity, efficiency, and sustainability in the use of water and other resources.

In 2010, a study was conducted in the Incomati CMA to understand the factors affecting the decentralization process and performance of water resource management in South Africa (Mutondo, Farolfi and Dinar, 2016).

Four groups of factors were identified to explain the situation and performance of water governance decentralization in the CMA.

The first group of factors concern context and initial conditions. This included the level of economic development in the country and in the catchment at the time decentralization started. The situation was considered relatively favourable in the Incomati CMA. However, the distribution of access to water was very skewed. This was pointed out as having potentially negative consequences for the decentralization process and performance.

For the second group of factors – the characteristics of the decentralization process – efforts to involve local stakeholders in the process from the beginning were more evident in South Africa than in other southern countries of the region. This resulted in a more diversified composition of the catchment boards and in more active participation by local representatives. The size and composition of the CMA Governing Board is recommended

by the Advisory Committee (a group of stakeholder representatives brought together by the Department of Water Affairs and Forestry (DWAF) regional office and with the assistance of local consultants, (Anderson, 2005), while the individuals are nominated by the institutions and by the groups represented (Pegram and Bofilatos, 2005).

The third group of factors concern central government/basin-level relationships and capacities. Here, the devolution of power was found to be relatively low in the catchment, triggering, among other consequences, a lack of financial autonomy of the river basin organization.

Finally, the fourth group of factors relate to the configuration of basin-level institutional arrangements. The presence of basin-level governance institutions and a well-structured hierarchy of managing organizations was seen as a potentially positive factor for the water decentralization process and performance. Information sharing is critical, as it reduces asymmetries among stakeholders and fosters cooperation. Efforts to establish forums and support for information dissemination and sharing have been observed. At the same time, the use of the English language and Western protocols and practices during council meetings seems to marginalize disadvantaged community representatives.

At the water users' association level, Madigele, Snowball and Fraser (2015) drew a critical picture of the South African landscape. The WUAs are seen as one of the key institutions driving IWRM in South Africa, since they are designed to allow stakeholders at local levels have a say in the allocation and management of this important public good. However, WUAs in South Africa have mostly not been a success and are currently being reviewed at the national level. For the most part, black farmers and rural communities still do not have equal access to water, or play a meaningful role in decision-making, and there are significant supply and allocation issues for municipal users too.

Examples of innovative approaches, including participatory methods and modeling (Farolfi *et al*., 2008. Farolfi, Müller and Bonte, 2010) to support the establishment and development of WUAs are numerous in South Africa. They have shown the advantages and the shortcomings of this type of 'action-research' methods and processes when confronted with real-life complex situations.

Key messages for decision-makers/land users/practitioners

Decentralizing water management is a long and complex process, often involving radical transformations, power conflicts and political clashes. The South African case bears witness to the difficulty of decentralizing water management, particularly in African countries. South Africa benefits from a higher development level than neighbouring countries in the region but suffers from a heavy legacy of divisions and contrasts dating from the apartheid period. These factors have contrasting influences in the process of water management decentralization in the country. Difficulties occur on different levels, from local WUAs to the CMAs.

Interesting new findings that could be applicable to other areas or communities with similar challenges

Participatory methods and tools to foster the participation of local stakeholders in managing water resources have been widely tested in the South African context. These methods can be applied at local levels, such in the WUAs, and on higher scales, such as the CMAs, or even at national (see Photo 1) and international/transboundary levels.

However, according to several observers, these tools can worsen inequity levels in the communities where they have been implemented, if they are not used in the right way.

Photo 1. Officers from the South African Department of Water Affairs (DWA) testing a participatory interface during a training workshop in Pretoria

©StefanoFarolfi/CIRAD

Case study 2. Evolving farm structures: a major – and still largely overlooked – driver of changes in Thailand

In many areas of Thailand, farm structures are becoming more and more fragile. Many farms are increasingly trapped in a situation of low profitability making them less attractive to younger generations. This has already had major impacts on land management. To date, public policies have paid limited attention to farm structures. In Thailand, as in other newly industrialized Asian countries, placing the issue of farm structures at the core of future policies will be key to building capacities to move toward sustainable agricultural production, land and water management.

In several newly industrialized countries in Asia, farm structures face major changes. First, the involvement of young people in agricultural production has been decreasing over at least the past two decades. The trend has been particularly rapid in Thailand. According to the 2003 and 2013 agricultural censuses, the number of farm holders under 45-years-old decreased from 2.6 million in 2003 to 1.4 million in 2013, i.e., a decrease of 46 percent. Studies have shown that other types of engagement by young people in farming (e.g. as a part-time activity) is also decreasing (Ruiz-Salvago *et al.*, 2019). In many areas of Thailand, farming has become an activity for elder people. Second, in many rural areas, farming is losing its status as the main provider of household income. A de-agrarianization process is taking place, which, for various reasons, has not yet led to an increase in average farm size (Rigg, Salamanca and Thompson, 2016).

In Thailand, increasing numbers of farms have become trapped in a vicious circle where farms are yielding lower profits, reducing their attractiveness to younger people low farm profitability and leading to the 'greying' of agriculture as older people are forced to take up the slack (Faysse *et al.*, 2020a). Some farmers try to escape from this trap by making changes to their farming systems. For example, farms that used to focus on rice production are investing in secure access to irrigation water during the dry season, or to protect their fields from floods. This enables them to start growing crops that are more profitable than rice (Faysse, Phiboon and Filoux, 2019; Salaisook, Faysse and Tsusaka, 2020). However, in some areas only a minority of farmers have been able to make changes to their farming systems due to various constraints (Faysse and Phiboon, 2019). For example, short-term land rental contracts, which were not much of an issue for rainfed rice farming, become a major impediment for farmers wishing to invest in more productive and more sustainable farms (Faysse *et al.*, 2020b).

So far, Thai agricultural policies have paid little attention to these changes (Faysse, Phiboon and Filoux, 2019), although they have already had several impacts. For example, in the northeast region, public extension systems promote many sustainable land management practices. However, many farmers seek to maintain their farming system while limiting their efforts to run the farm (Salaisook, Faysse and Tsusaka, 2020). These farmers are not interested in spending time and effort in implementing sustainable land management practices, even when knowledge and support are available. In the long term, there is no guarantee that economically sustainable farm structures will emerge 'on their own,' and agricultural production could face major disruptions. Such a risk is also on the cards for other Asian countries (Bhandari and Mishra, 2018).

Management and outcome

Newly industrialized Asian countries would benefit from public policies that pay greater attention to farm structures, including farm size and profitability, as well as to the way farming is incorporated into broader livelihood strategies, and land tenure security. This could involve defining the various farm types that are likely to be relevant in the coming decades. Such farm types may not necessarily be based on full-time farming (Phiboon, Cochetel and Faysse, 2019). Public policies could then organize support to help develop or maintain these types of farms.

Photo 2. Young farmer in Thailand

©KassirinPhiboon/CIRAD

Case study 3. Assessing highly diverse tenure arrangements at the local level in Senegal.

As in many developing countries, the government in Senegal has been targeting food security and self-sufficiency for decades. Senegal has called on support from international donors to develop irrigated family farming, but the irrigation expansion rate does not match the country's ever-growing food needs. Half of the rice consumed nationally is imported. Successive Senegalese governments, as well as international donors, have stressed the urgent need to modernize agriculture through the introduction of intensified practices in terms of labour, capital and water consumption for irrigation. Following international guidelines, Senegal has gradually liberalized its rice market since the late 1990s in the hopes of boosting its agricultural sector.

Several laws and programmes have supported the development of this policy and facilitated the opening up of the sector to foreign investors. Starting in the early 2000s, the

government has implemented a process of political and institutional reforms, guided by a vision of rural development that is based on a highly productive irrigation sector and the promotion of agro-industrial investors (Chouquer, 2012). Several different national initiatives, including President Wade's Great Agriculture Offensive for Food in the 2000s and President Sall's Plan for an Emerging Senegal in 2019 (Presidency of Senegal, 2019) promoted rapid rice and horticultural production growth. These initiatives were closely linked to the president and were based on two pillars: the modernization of family farming, on the one hand, by developing more efficient irrigated areas; and the development of the agro-industrial sector, on the other, by ensuring an appropriate legal and financial environment.

The government and international donors, led by the World Bank, envisaged several projects to facilitate the installation of international and national investors as part of a new deal in the agro-industrial sector. Far from opposing family farming and private agriculture, these projects aimed to promote middle-scale initiatives and the integration of new actors, mainly city dwellers, in the agricultural sector. Family farmers are also expected to gain from this new deal, through better integration in agricultural value chains. The most targeted area of the country is the Senegal River Delta in the Saint Louis region. A wide range of actors converge in this area: family farmers, small private farmers, medium-size agricultural companies, large-scale national investors and large foreign companies.

Access to irrigated land is very competitive in this region, where the government has transferred public land governance from the state to rural communities since the late 1990s. Thus, land markets based on a wide diversity of arrangements and practices behind closed doors have increased, as has occurred in many rural areas in African countries that have adopted land reforms in recent decades (Deininger *et al.*, 2014; Boone, 2018; Chimhowu, 2019).

In the Senegal River Delta, the various actors responsible for private agricultural projects use many different legal, informal and customary ways of accessing land and water resources. A study was conducted between 2019 and 2021 to understand the variety of land deals between private actors, and local land authorities in the area (the Vallagri project, in progress). The practices involve either local, supralocal, or national middlemen, thus modifying the governance of land and water at different levels.

An in-depth analysis of formal and informal arrangements between stakeholders, their strategies and regulating rules, provides a picture of the new issues involved in decision-making for land and water management. Furthermore, the analysis sheds light on the consequences of this new deal and the related development of new irrigation projects in terms of their social, economic and environmental impacts.

Taking advantage of a lack of supervision by rural communities in charge of land management, investors deploy innovative ways of formalizing customary rights to gain access to land. The way they proceed is project-specific. The closer the relationship is between investors and local representatives, the lower is the risk of conflict. Ethnographic research suggests that foreign investment projects can also be locally appropriated, resulting in positive impacts through social investments (schools, medical structures, roads, etc.) and preferential employment of the local population.

In addition to social sustainability, an ongoing issue is the relationship between highly diverse types of agriculture at the local level. Synergies exist and can be developed

between large-scale and middle-scale investment projects and family farming. Recent insights from research in the Senegal River Delta reveal interesting strategies, such as:

- combining family transhumant breeding with agro-industrial projects through the utilization of by-products, or fodder production;
- increasing technical skills of seasonal or permanent employees, who also manage family-owned rice and vegetable farms.

Photo 3. Utilization of by-products: synergies between breeding and agro-industrial investors in the Senegal River Delta, October 2019

©AmandineAdamczewskiHertzog/CIRAD

These novel forms of synergies should guide local authorities in their supervision of investors to ensure positive impacts and long-term effects of the 'new deal' in the Senegalese agricultural sector.

Case study 4. A multi-level participatory process for territorial planning in rural Tunisia

Climate change and globalization are important drivers for social-ecological systems in many developing countries. By affecting resource stocks and accessibility, they can exacerbate competition between users and generate conflicts over land and water. These issues are particularly relevant in rural Tunisia, where poverty-led, short-term resource management strategies combine with changing climatic conditions to threaten water resources, soils and biodiversity. At the same time, the democratic transition and decentralization processes that got underway in 2011 has yet to create space for involving local communities in decision- and policy-making.

Attempting to respond to these multidimensional challenges, the Climate Change Adaptation Programme for Vulnerable Rural Territories (PACTE) supports experiments on the joint management of natural resources, funds the development of sustainable agrosylvopastoral value chains, and promotes local governance mechanisms. The PACTE programme is implemented in six intervention areas located in the governorates of Bizerte, Siliana, El Kef, Kairouan and Sidi Bouzid. These areas are characterized by high vulnerability to climate change, high rates of poverty and rural exodus, and a predominance of small-scale family farms and pluriactive households.

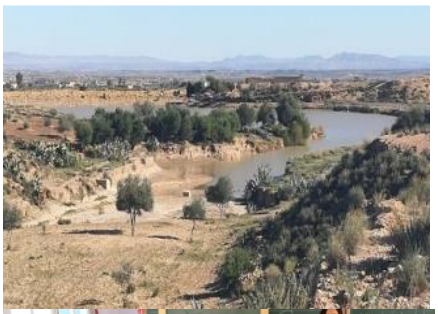
To engage with local communities, staff from the regional agricultural administration have been trained as facilitators, capable of conducting territorial diagnoses and guiding local actors through a concerted planning process. After an initial phase devoted to awareness raising among local communities, the facilitators conducted a participatory territorial diagnosis in each community in the intervention areas. This phase involved individual interviews and focus groups, participatory mapping and transect walks over a period of eight months. The following phase – the planning process itself – included diagnosis feedback workshops, the identification and prioritization of the major land and water issues in each local territory and a proposal for action. Next, expert consultations took place to better characterize the actions proposed by the population (i.e., resource requirements and potential impacts). At the same time, territorial committees have been established, including representatives of local communities, as well as elected councils and key civil society and private sector actors. With assistance from the facilitators, these committees will draw up strategic plans for each intervention area, based on the most appropriate and innovative actions.

The strategic plans will be funded and implemented locally. Throughout the process, monitoring and evaluation provides data for adapting the processes to local conditions and uncertainty, and for reflecting on the applicability of the approach to other areas with similar challenges. Ultimately, this monitoring and evaluation system will be fueled in part through information and communication technologies (i.e. information system and associated information services). To sum up, the PACTE process involves multiple levels of governance: i) the central level with ministerial departments, national experts, financial institutions and teaching and research organizations, ii) the regional level with the agricultural services of the governorate, other administrative services (equipment, health, education, etc.) and the regional council, and iii) the local level centered around the territorial committees.

The approach enables the creation of multistakeholder platforms. These platforms are designed as collaborative networks that bring together a diversity of actors for public dialogue on territorial development stakes, integrated planning of actions and impact monitoring and evaluation. So far, the stages of mobilization (in 2018), diagnosis (2019) and the beginning of planning – i.e. collection of action proposals from the population – have resulted in large-scale participation, with more than 100 public events, more than 4 000 direct participants and more than 11 000 action proposals collected in total.

Photo 4. PACTE Programme in Tunisia

PACTE intervention areas in Tunisia



©EmelineHassenforder/CIRAD

Conclusion and key messages

The key messages for decision-makers, land users and practitioners are:

- Large-scale local participation is possible, even in a context characterized by few or no functional intermediary organizations, low digital penetration rates and high rates of illiteracy.
- There is a need to train a new generation of facilitators that are qualified in participatory approaches and territorial development.
- Participatory approaches make it possible to respond to issues considered as a priority by the population and to produce integrated and multiscale land-use and water management plans.
- These approaches must be supported by replicable engineering and participatory evaluation processes.

References

Abelson, J. & Gauvin, F.P. 2006. *Assessing the impacts of public participation: Concepts, evidence and policy implications*. Ottawa, Canadian Policy Research Networks (CPRN). https://www.researchgate.net/profile/Julia_Abelson/publication/5100037_Assessing_the_Impacts_of_Public_Participation_Concepts_Evidence_and_Policy_Implications/links/5447fdfe0cf2d62c30529dbf.pdf

Ahlers, R., Budds, J., Joshi, D., Merme, V. & Zwarteveen, M. 2015. Framing hydropower as green energy: Assessing drivers, risks and tensions in the Eastern Himalayas. *Earth System Dynamics* 6(1): 195–204.

Altchenko, Y. & Villholth, K.G. 2015. Mapping irrigation potential from renewable groundwater in Africa: A quantitative hydrological approach. *Hydrology an Earth System Science,* 19: 1055–1067. https://doi.org/10.5194/hess-19-1055-2015

Altingoz, M., Belinskij, A., Brethaut, C., do Ó, A., Gevinian, S., Hearns, G., Keskinen, M., McCracken, M., Ni, V., Soininen, N. & Wolf, A.T. 2018. *Promoting development in shared river basins: Case studies from international experience*. Washington, DC, World Bank. https://openknowledge.worldbank.org/handle/10986/29449

Allan, J.A.T. & Mirumachi, N. 2013. Why negotiate? Asymmetric endowments, asymmetric power and the invisible nexus of water, trade and power that brings apparent water security. In: *Transboundary Water Management*, pp. 26–39. Abingdon, UK, Routledge.

Ameur, F., Amichi, H., Kuper, M. & Hammani, A. 2017. Specifying the differentiated contribution of farmers to groundwater depletion in two irrigated areas in North Africa. *Hydrogeology Journal*, 25: 1579–1591. https://doi.org/10.1007/s10040-017-1569-1

Anderson, A. 2005. Engaging disadvantaged communities: Lessons from the Inkomati CMA establishment process. Workshop presentation at African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, 26-28 January 2005. Johannesburg, International Water Management Institute (IWMI).

Andrieu, N., Sogoba, B., Zougmore, R., Howland, F., Samake, O., Bonilla-Findji, O., Lizarazo, M., Nowak, A., Dembele, C. & Corner-Dolloff, C. 2017. Prioritizing investments for climate-smart agriculture: Lessons learned from Mali. *Agricultural Systems,* 154: 13-24

Anseeuw, W., Hertzog-Adamczewski, A., Jamin, J.Y. & Farolfi, S. 2019. Large-scale land and water acquisitions: What implications for food security? In: S. Dury, P. Bendjebbar, E. Hainzelin, G. Thierry & B. Nicolas, eds. *Food systems at risk. New trends and challenges*, pp.67–69. Rome, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) & Food and Agriculture Organization of the United Nations (FAO). https://doi.org/10.19182/agritrop/00095

Arnstein, S.R. 1969. A ladder of citizen participation. *Journal of the American Institute of Planners*, 35:4, 216-224.

Ashukem, J.C.N. 2020. The SDGs and the bio-economy: Fostering land-grabbing in Africa. *Review of African Political Economy*, 47(164): 275–290. https://doi.org/10.1080/03056244.2019.1687086

Bai, J., Seale, J. & Wahl, T. 2020. Meat demand in China: To include or not to include meat away from home? *The Australian Journal of Agricultural Economics*, 64(1): 150–170. https://doi.org/10.1111/1467-8489.12362

Barone, S. & Mayaux, P.L. 2019. *Les politiques de l'eau*. Paris, LGDJ. https://www.lgdj.fr/les-politiques-de-l-eau-9782275060033.html

Barrett, C., Christiaensen, L., Sheahan, M., & Shimeles, A. 2017. *On the structural transformation of rural Africa*. Policy Research Working Paper No. 7938. Washington, DC, World Bank. https://doi.org/10.1596/1813-9450-7938

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D. & Yumkella, K.K. 2012. Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy*, 39(12): 7896–7906.

Beck, M.W., Claassen, A.H. & Hundt, P.J. 2012. Environmental and livelihood impacts of dams: Common lessons across development gradients that challenge sustainability. *International Journal of River Basin Management,* 10(1): 73–92. https://doi.org/10.1080/15715124.2012.656133

Bernstein, H. 2010. *Class dynamics of agrarian change*. Halifax, Fernwood Publishing.

Bhandari, H. & Mishra, A.K. 2018. Impact of demographic transformation on future rice farming in Asia. *Outlook on Agriculture*, 47(2): 125–132.

Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J., & Parrish, J.K. 2014. Next steps for citizen science. *Science*, 343(6178): 1436–1437. https://doi.org/10.1126/science.1251554

Boone, C. 2018. Shifting visions of property under competing political regimes: changing uses of Côte d'Ivoire's 1998 Land Law. *The Journal of Modern African Studies*,56 (2): 189 – 216. https://doi.org/10.1017/S0022278X18000198

Boretti, A. & Rosa, L. 2019. Reassessing the projections of the World Water Development Report. *npj Clean Water* 2, 15. https://doi.org/10.1038/s41545-019-0039-9.

Bright, J. & Margetts, H. 2016. Big data and public policy: Can it succeed where e-participation has failed? *Policy and Internet*, 8(3): 218–224.

Brown, G., Kangas, K., Juutinen, A. & Tolvanen, A. 2017. Identifying environmental and natural resource management conflict potential using participatory mapping. *Society & Natural Resources,* 30(12): 1458–1475. https://doi.org/https://doi.org/10.1080/08941920.2017.1347977

Brown, J. 2013. Can participation change the geography of water? Lessons from South Africa. *Annals of the Association of American Geographers,* 103(2): 271–279.

Blühdorn, I. & Deflorian, M. 2019. The collaborative management of sustained unsustainability: On the performance of participatory forms of environmental governance. *Sustainability,* 11(4): 1189. https://doi.org/10.3390/su11041189

Blundo Canto, G., Barret, D., Faure, G., Hainzelain, E., Monier, C., Triomphe, B. & Vall, E. 2018. *ImpresS* ex ante*. An approach for building* ex ante *impact pathways.* https://doi.org/https://doi.org/10.19182/agritrop/00013

Burek, P., Satoh, Y., Fischer, G., Kahil, M.T., Scherzer, A., Tramberend, S., Nava, L.F. & Wada, Y. 2016. *Water futures and solution: Fast track initiative (final report).* IIASA Working Paper. Laxenburg, Austria, International Institute for Applied Systems Analysis (IIASA).

Cernea, M.M. & Maldonado, J.K. 2018. *Challenging the prevailing paradigm of displacement and resettlement risks, impoverishment, legacies, solutions*. Routledge, Abingdon, UK and New York, USA.

Chambers, R. 1988. *Managing canal irrigation: Practical analysis from South Asia*. Cambridge, UK, Cambridge University Press.

Changming L., Jingjie Y. & Kendy, E. 2001. Groundwater exploitation and its impact on the environment in the North China Plain. *Water International,* 26(2): 265–272.

Chilvers, J., Pallett, H. & Hargreaves, T. 2018. Ecologies of participation in sociotechnical change: The case of energy system transitions. *Energy Research and Social Science*, 42: 199–210. https://doi.org/10.1016/j.erss.2018.03.020

Chimhowu, A. 2019. The 'new' African customary land tenure. Characteristic, features and policy implications of a new paradigm. *Land Use Policy* (81): 897-903, https://doi.org/10.1016/j.landusepol.2018.04.014.

Chouinard, J.A. 2013. The case for participatory evaluation in an era of accountability. *American Journal of Evaluation,* 34(2): 237–253. https://doi.org/10.1177/1098214013478142

Courtois, N., Lachassagne, P., Wyns, R., Blanchin, R., Bougaïré, F.D., Somé, S. & Tapsoba, A. 2010. Large-scale mapping of hard-rock aquifer properties applied to Burkina Faso. *Ground water*, 48(2):269–283. https://doi.org/10.1111/j.1745-6584.2009.00620.x

Damania, R., Desbureaux, S., Hyland, M., Islam, A., Moore, S., Rodella, A.S. & Zaveri, E. 2017. *Uncharted waters: The new economics of water scarcity and variability*. Washington, DC, World Bank.

Daniell, K.A., & Barreteau, O. 2014. Water governance across competing scales: Coupling land and water management. *Journal of Hydrology,* 519(C): 2367–2380. https://doi.org/10.1016/j.jhydrol.2014.10.055

Daniell, K.A., White, I.M., Ferrand, N., Ribarova, I., Coad, P., Rougier, J.E., & Burn, S. 2010. Co-engineering participatory water management processes: Theory and insights from Australian and Bulgarian interventions. *Ecology and Society,* 15(4).

Davison, J., ed. 2019. *Agriculture, women and land: the African experience*. New York, Routledge. https://doi.org/10.4324/9780429044045

Darre, N. & Toor, G. 2018. Desalination of water: A review. *Current Pollution Reports*, 4, 104–111. https://doi.org/10.1007/s40726-018-0085-9

Dasgupta, S. & Roy, I. 2011. *Good agricultural governance. A resource guide focused on smallholder crop production*. Rome, FAO. http://www.fao.org/3/ba0113e/ba0113e00.pdf

Deininger, K., Hilhorst, T., Songwe, V. 2014.Identifying and addressing land governance constraints to support intensification and land market operation: Evidence from 10 African countries. *Food Policy*,

(48): 76-87. https://doi.org/10.1016/j.foodpol.2014.03.003.

Delli Priscoli, J. & Wolf, A.T. 2009 Water conflict management: Theory and practice. In: J. Delli Priscoli, & A.T. Wolf, eds. *Managing and transforming water conflicts,* pp. 33–49. Cambridge, UK, Cambridge University Press.

Denby, K., Movik, S., Metha, L. & Van Koppen, B. 2016. The 'trickle down' of IWRM: a case study of local-level realities in the Inkomati water management area, South Africa. *Water Alternatives*, 9(3): 473–492. https://doi.org/10.1080/00045608.2013.754685

Domenech, L. 2013. *The impact of irrigation on nutrition, health, and gender: A review paper with insights for Africa south of the Sahara*. Vol. 1259. Washington, DC, International Food Policy Research Institute (IFPRI).

Doukkali, M.R. & Lejars, C. 2015. Energy cost of irrigation policy in Morocco: A social accounting matrix assessment. *International Journal of Water Resources Development* 31(3): 422–435.

Duflo, E., & Pande, R. 2005. *Dams*. Working Paper No. 11711. Cambridge, USA, National Bureau of Economic Research. https://ssrn.com/abstract=796170

Eastin, J. 2018. Climate change and gender equality in developing states. *World Development,* 107: 289–305

Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D. & Wisser, D. 2014. Constraints and potentials of future irrigation water availability on agricultural production under climate change. *Proceedings of the National Academy of Sciences (PNAS)*, 111(9): 3239–3244.

Eynon, K., 2016. *Powerful water: A literature review of transboundary water interaction in the Nile Basin*. Cape Town, South Africa, University of Cape Town.

Food and Agriculture Organization of the United Nations (FAO). 2011. *The State of the World's Land and Water Resources for Food and Agriculture.* Rome, FAO and London, Earthscan.

FAO. 2014. AQUASTAT: Area equipped for irrigation. In: *FAO* [online]. Rome. Cited 09 June 2016. http://www.fao.org/nr/water/aquastat/ infographics/Irrigation_eng.pdf.

FAO. 2016. Gender and land rights database. In: *FAO* [online]. Rome. Cited 22 may 2018. http://www.fao.org/gender-landrights-database/data-map/statistics/en/?sta_id=982

FAO. 2017a. *Water pollution from agriculture: a global review*. Colombo, FAO & IWMI.

FAO. 2017b. *Nutrition-sensitive agriculture and food systems in practice: Options for intervention*. Rome. http://www.fao.org/3/a-i7848e.pdf.

FAO. 2018. AQUASTAT. In: *FAO* [online]. Rome. Cited 07 June 2020. www.fao.org/nr/aquastat/

FAO. 2020. FAOSTAT. In: *FAO* [online]. Rome. Cited 12 November 2021. http://faostat3.fao.org/browse/R/RP/E

FAO & CIRAD. 2017. *Rural Africa in motion. Dynamics and drivers of migration south of the Sahara*. Rome, FAO &CIRAD. https://www.fao.org/3/i7951en/I7951EN.pdf

Farolfi, S., Gumede, H., Rowntree, K. & Jones, N. 2008. Local water governance in South Africa: To which extent participatory approaches facilitate multi-stakeholder negotiations? The Kat River Valley experience. Conference paper for the XIII World Water Congress, 1–4 September 2008. Montpellier, France. http://dx.doi.org/10.13140/2.1.3468.8008

Farolfi, S., Müller, J.P. & Bonte, B. 2010. An iterative construction of multi-agent models to represent water supply and demand dynamics at the catchment level. *Environmental Modelling and Software*, 25(10): 1130–1148.

Faysse, N. & Phiboon, K. 2019. Building capacities for change: Farmers moving away from conventional rice farming in Prachinburi Province, Thailand. *Journal of Community Development Research (Humanities and Social Sciences)*, 12(4): 57–67.

Faysse, N., Phiboon, K. & Filloux, T. 2019. Public policy to support young farmers in Thailand. *Outlook on Agriculture*, 48(4): 292–299.

Faysse, N., Aguilhon, L., Phiboon, K., & Purotaganon, M. 2020a. Mainly farming… but what's next? The future of irrigated farms in Thailand. *Journal of Rural Studies*, 73: 68–76.

Faysse, N., Phiboon, K., Aguilhon, L. & Srisawaluck, E. 2020b. *Land rent conditions for rice farmers in Thailand: connecting policies and practices to enable the transformation of farming systems*. Report from the DOUBT (Deltas Dealing with Uncertainty) project. http://deltasoutheastasia-doubt.com/

Ferrand, N. & Daniell, K.A. 2006. *Comment évaluer la contribution de la modélisation participative au développement durable?* Lille, France, Séminaire DDT.

Lovelle, M. 2018. *The natural and artificial causes of the drought in Southern Iraq*. Dalkeith, Australia, Future Directions International. http://www.futuredirections.org.au/publication/natural-artificial-causes-drought-southern-iraq/

Gebregziabher, G., Namara, R.E. & Holden, S. 2012. Technical efficiency of irrigated and rainfed smallholder agriculture in Tigray, Ethiopia: A comparative stochastic frontier production function analysis. *Quarterly Journal of International Agriculture,*51(3): 203.

German, L., Goetz, A., Searchinger, T., Oliveira, G., Tomei, J., Hunsberger, C. & Weigelt, J. 2017. *Sine qua nons* of sustainable biofuels: Distilling implications of under-performance for national biofuel programs. *Energy Policy*, 108: 806–817. https://doi.org/10.1016/j.enpol.2017.04.013

Giovannetti, G. & Ticci, E. 2016. Determinants of biofuel-oriented land acquisitions in sub-Saharan Africa. *Renewable Sustainable Energy Re*view, 54(C): 678–687.

Giupponi, C. & Sgobbi, A. 2008. Models and decision support systems for participatory decision-making in integrated water resource management. In: P. Koundouri, ed. *Coping with water deficiency*, pp. 165–186. Environment & Policy, Vol. 48. Dordrecht, the Netherlands, Springer. https://doi.org/10.1007/978-1-4020-6615-3_7

Gleeson, T., Befus, K.M., Jasechko, S., Luijendijk, E. & Cardendas, M.B. 2016. The global volume and distribution of modern groundwater. *Nature Geoscience*, 9(2): 161–167.

Goetz, A., German, L., Hunsberger, C., Schmidt C.O. & Oscar, C. 2017. Do no harm? Risk perceptions in national bioenergy policies and actual mitigation performance. *Energy Policy*, 108: 776–790. https://doi.org/10.1016/j.enpol.2017.03.067

Gregory, P.J. & Ingram, J.S.I. 2014. Food production and land use. In: Seto, K.C. & A. Reenburg. *Rethinking global land use in an urban era.* MIT Press Scholarship Online. https://doi.org/10.7551/mitpress/9780262026901.003.0003

Gurney, G.G., Cinner, J.E., Sartin, J., Pressey, R.L., Ban, N.C., Marshall, N.A. & Prabuning, D. 2016. Participation in devolved commons management: Multiscale socioeconomic factors related to individuals' participation in community-based management of marine protected areas in Indonesia. *Environmental Science & Policy*, 61: 212–220. https://doi.org/https://doi.org/10.1016/j.envsci.2016.04.015

Hassenforder, E., Pittock, J., Barreteau, O., Daniell, K.A. & Ferrand, N. 2016. The MEPPP framework: A framework for monitoring and evaluating participatory planning processes. *Environmental Management Journal*, 57(1): 79–96. https://doi.org/10.1007/s00267-015-0599-5

Hassenforder, E., Barreteau, O., Daniell, K.A., Ferrand, N., Kabaseke, C., Muhumusa, M. & Tibasiima, T. 2020. The effects of public participation on multi-level water governance, lessons from Uganda. *Environmental Management*, 66: 770–784. https://doi.org/10.1007/s00267-020-01348-8

Hassenforder, E., Girard, S., Ferrand, N., Petitjean, C. & Fermond, C. 2021. La co-ingénierie de la participation : Une expérience citoyenne sur la rivière Drôme. *Natures Sciences Sociétés,* 2(29).

Hay, M., Skinner, J. & Norton, A. 2019. *Dam-induced displacement and resettlement: A literature Review*. FutureDAMS Working Paper 004. Manchester, UK, University of Manchester.

Hazell, P. 2019. Urbanization, agriculture, and smallholder farming. In: R. Serraj & P.L. Pingali, eds. Agriculture *and food systems to 2050*: Global *t*rends, *c*hallenges and *o*pportunities. Hackensack, USA, World Scientific.

Hussain, I. & Hanjra, M.A. 2004. Irrigation and poverty alleviation: Review of the empirical evidence. *Irrigation and Drainage*, 53(1): 1–15.

Ickowitz, A., Powell, B., Rowland, D., Jones, A. & Sunderland, T. 2019. Agricultural intensification, dietary diversity, and markets in the global food security narrative. *Global Food Security,* 20: 9–16.

International Commission on Large Dams (ICOLD). General synthesis. In: *ICOLD* [online]. Paris. Cited 6 May 2020. https://www.icold-cigb.org/GB/world_register/general_synthesis.asp

International Groundwater Resources Assessment Centre (IGRAC). 2009. *Global overview of saline groundwater occurrence and genesis*. Report no. GP2009-1. Utrecht, the Netherlands.

International Monetary Fund (IMF). 2017. World Economic Outlook Database. In: *IMF* [online]. Washington, DC.

http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/index.aspx.

International Water Management Institute (IWMI). 2020. Groundwater governance in the Arab World. In: *IWMI* [online]. Cited 6 August 2021 http://gw-mena.iwmi.org/outputs/

Isaacs, B., Snapp, S.S., Chung, K. & Waldman, K.B. 2016. Assessing the value of diverse cropping systems under a new agricultural policy environment in Rwanda. *Food Security,* 8(3): 491–506.

Jagadeesan, S. & Kumar, D.M. 2015. *The Sardar Sarovar project: Assessing economic and social impacts*. New Delhi, Sage Publications.

Jager, N.W., Newig, J., Challies, E. & Kochskämper, E. 2020. Pathways to implementation: Evidence on how participation in environmental governance impacts on environmental outcomes. *Journal of Public Administration Research and Theory,* 30(3): 383–399. https://doi.org/10.1093/jopart/muz034

Jat, M.L., Dagar, J.C., Sapkota, T.B., Yadvinder-Singh, Govaerts, B., Ridaura, S.L., Saharawat, Y.S. *et al.* 2016. Climate change and agriculture: Adaptation strategies and mitigation opportunities for food security in South Asia and Latin America. In: D.L. Sparks, ed. *Advances in agronomy*, *Vol. 137*, pp. 127–135. Amsterdam, Elsevier. https://doi.org/10.1016/bs.agron.2015.12.005

Jensen, P.H. 2014. Understanding the impact of migration on innovation policy forum: Immigration and the economy. *The Australian Economic Review,* 47(2): 240–250.

Karim, A., Siddiqa, A., Safdar, Z., Razzaq, M., Gillani, S.A., Tahir, H., & Imran, M. 2020. Big data management in participatory sensing: Issues, trends and future directions. *Future Generation Computer Systems*, 107: 942–955. https://doi.org/https://doi.org/10.1016/j.future.2017.10.007

Konikow, L.F. & Kendy, E. 2005. Groundwater depletion: A global problem. *Hydrogeology Journal,* 13(1): 317–320.

Kramer, A., Hensengerth, O., Mertens, A., & Carius, A. 2012. *Assessment of RBO-level mechanisms for sustainable hydropower development and management*. Bonn, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Kuper, M., Faysse, N., Hammani, A., Hartani, T., Marlet, S., Hamamouche, M.F. & Ameur F. 2016. Liberation or anarchy? The Janus nature of groundwater use on North Africa's new irrigation frontiers. In: T. Jakeman, O. Barreteau, R. Hunt, J.D. Rinaudo & A. Ross, eds. *Integrated groundwater management*, pp. 583–615. Dordrecht, the Netherlands, Springer.

Lambin, E.F. & Meyfroidt, P. 2011. Trends in global land-use competition. *PNAS*, 108(9): 3465–3472. https://doi.org/10.1073/pnas.1100480108

Lancet. 2020. World population likely to shrink after mid-century, forecasting major shifts in global population and economic power. In: *The Lancet*, 14 July 2020 [online]. Cited 22 February 2021. http://www.healthdata.org/news-release/lancet-world-population-likely-shrink-after-mid-century-forecasting-major-shifts-global

Land Matrix. 2021. Public database on land deals. In: *Land Matrix* [online]. [DATE OF CITATION]. https://landmatrix.org/

Latham, M.E. 2011.*The right kind of revolution: Modernization, development, and US foreign policy from the Cold War to the present.* Ithaca, USA, Cornell University Press.

Leb, C., Henshaw, T., Iqbal, N., & Rehberger Bescos, I. 2018. *Promoting development in shared river basins: Tools for enhancing transboundary basin management*. Washington, DC, World Bank.

Leb, C., Taylor, H., Nausheen, I., & Rehberger Bescos, I. 2018. *Promoting development in shared river basins: Tools for enhancing transboundary basin management*. Washington, DC, World Bank.

Lejars, C., Daoudi, A. & Amichi, H. 2017. The key role of supply chains actors in the development of groundwater irrigation in North Africa. *Hydrogeology Journal*, 25: 1595–1603. https://doi.org/10.1007/s10040-017-1571-7

Llamas, M.R. & Martínez-Santos, P. 2005. Intensive groundwater use: Silent revolution and potential source of social conflicts. *Journal of Water Resources Planning and Management*, 131(5): 337–341.

Lipton, M., Litchfield, J. & Faurès, J.M. 2003. The effects of irrigation on poverty: A framework for analysis. *Water Policy,* 5: 413–427

López-Gunn, E., Rica. M. & Van Cauwenbergh, N. 2012. Taming the groundwater chaos. In: L. de Stefano & M.R. Llamas, eds. *Water, agriculture and the environment in Spain: Can we square the circle?* pp. 227–240. Boca Raton, USA, CRC Press.

Loubier, S., Garin, P., Hassenforder, E., Lejars, C., & Robichon, S. 2019. *Analyse économique et financière des projets de territoire pour la gestion de l'eau (PTGE) à composante agricole. Principes méthodologiques*. Montpellier, France, IRSTEA, UMR G-EAU Ministère de la Transition Ecologique.

Lutz, W., Sanderson, W. & Scherbov, S. 2001. The end of world population growth. *Nature,* 412: 543–545.

Lynch, B. 2013. Rivers of contention: Scarcity discourse and water competition in highland Peru. *Georgia Journal of International & Comparative Law*, 42: 69–92.

Madigele P., Snowball J. & Fraser G. 2015 Water, water everywhere: Is integrated water resource management the right institutional prescription for South Africa's water management challenges? Conference presentation at the Economic Society of South Africa (ESSA), 2–4 September 2015, Capetown, South Africa, University of Cape Town. http://2015.essa.org.za/programme.

Maleki, A. & Bots, P.W.G. 2013. A framework for operationalizing the effect of national culture on participatory policy analysis. *Journal of Comparative Policy Analysis: Research and Practice*, 15(5): 371–394. https://doi.org/10.1080/13876988.2013.846959

Margat, J. 2008. *Les eaux souterraines dans le monde*. Cachan, France, Laviosier.

Margat, J. & van der Gun, J. 2013. *Groundwater around the world*. Leiden, the Netherlands, CRC Press/Balkema.

McMichael, P. 2005. Global development and the corporate food regime. In: F.H. Buttel & M. McMichael, eds. *New directions in the sociology of global development*, pp. 265–299. Bingley, UK, Emerald Group Publishing Limited.

Meinzen-Dick, R., Kovarik, C. & Quisumbing, A. 2014. Gender and sustainability. *Annual Review of Environment and Resources*, 39: 29–55. http://dx.doi.org/10.1146/annurev-environ-101813-013240

Meissner, R., Stuart-Hill, S. & Nakhooda, Z. 2017. The establishment of catchment management agencies in South Africa with reference to the Flussgebietsgemeinschaft Elbe: Some practical considerations. In: E. Karar, ed. *Freshwater governance for the 21st century. Global issues in water policy*, *Vol 6*. Berlin, Germany, Springer.

Mirumachi, N. & Allan, J.A. 2007 Revisiting transboundary water governance: Power, conflict cooperation and the political economy. In: *Proceedings of the CAIWA International Conference on Adaptive and Integrated Water Management: Coping with Scarcity*, Basel, Switzerland, 12–15 November 2007.

Molle, F., Shah, T. & Barker, R. 2003. The groundswell of pumps: multilevel impacts of a silent revolution. Conference paper for the International Commission on Irrigation and Drainage/Asia Regional Workshop: Management and Operation of Participatory Irrigation Organizations. 10–12 November, 2003. Taipei (CHN).

Moore, F.C., Lantz, U.L. & Hertel, T. 2017. Economic impacts of climate change on agriculture: A comparison of process-based and statistical yield models. *Environmental Research Letters*, 12(6). https://doi.org/10.1088/1748-9326/aa6V

Mukherji, A. 2006. Political ecology of groundwater: The contrasting case of water-abundant West Bengal and water-scarce Gujarat, India. *Hydrogeology Journal*, 14(3): 392–406. https://doi.org/10.1007/s10040-005-0007-y

Murray, M., Shaffer, R. & Lovan, W.R. 2004. *Participatory governance: Planning conflict mediation and public decision-making in civil society*. Belfast, Ashgate Publishing.

Mutondo, J., Farolfi, S. & Dinar, A. 2016. *Water governance decentralization in Africa: Between myth and reality.* Leiden, the Netherlands, Springer.

Nair, M. & Kumar, D. 2012. Water desalination and challenges: The Middle East perspective: A review. *Desalinisation & Water Treatment*, 51: 10–12.

Namara, R.E., Giordano, M.F. & Bassini, E. 2019. *The impacts of irrigation: A review of published evidence*. Washington, DC, World Bank. http://documents.worldbank.org/curated/en/132251561407498546/The-Impacts-of-Irrigation-A-Review-of-Published-Evidence

Naouri, M., Hartani, T. & Kuper, M. 2017. The 'innovation factory': User-led incremental innovation of drip irrigation systems in the Algerian desert? In: J.P. Venot, M. Kuper & M. Zwarteveen, eds. *Drip irrigation for agriculture. Untold stories of efficiency, innovation and development*. Oxfordshire, UK, Routledge.

Narayanamoorthy, A. 2018. Financial performance of India's irrigation sector: An historical analysis. *International Journal of Water Resources Development*, 34(1): 116–131.

Nawrotski, R.J. & Bakhtsiyarava, M. 2017. International climate migration: Evidence for the climate inhibitor mechanism and the agricultural pathway. *Population, Space and Place*, 23(4).

Newig, J., Challies, E., Jager, N.W., Kochskaemper, E., & Adzersen, A. 2017. The environmental performance of participatory and collaborative governance: A framework of causal mechanisms. *Policy Studies Journal,* 46(2): 269–297. https://doi.org/10.1111/psj.12209

Newig, J., Schulz, D. & Jager, N. W. 2016. Disentangling puzzles of spatial scales and participation in environmental governance: The case of governance re-scaling through the European Water Framework Directive. *Environmental Management*, 58: 998–1014. https://doi.org/10.1007/s00267-016-0753-8

Niazi, T. 2004. Rural poverty and the Green Revolution: The lessons from Pakistan. *Journal of Peasant Studies*, 31(2): 242–260.

Organisation for Economic Co-operation and Development (OECD). 2006. *The new rural paradigm: Policies and governance*. Paris.

OECD. 2012. *OECD Environmental Outlook to 2050*. Paris. www.oecd.org/env/indicators-modelling-outlooks/oecdenvironmentaloutlookto2050theconsequencesofinaction-keyfactsandfigures.htm

Ostrom, E. 2015. *Governing the commons: The evolution of institutions for collective action.* Cambridge, UK, Cambridge University Press.

Packaged Facts. 2020. *Global meat & poultry trends*. Rockville, USA. https://www.packagedfacts.com/Global-Meat-Poultry-Trends-13012951/

Partey, S.T., Zougmoré, R.B., Ouédraogo, M. & Campbell B.M. 2018. Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. *Journal of Cleaner Production,* 187: 285–295. https://doi.org/10.1016/j.jclepro.2018.03.199

Pegram, G. & Bofilatos, E. 2005 Considerations on the composition of the CMA governing boards to achieve representation. Draft paper for proceedings of international workshop, African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, 26-28 January 2005. Gauteng, South Africa.

Peixoto, T. & Sifry, M.L. 2017. *Civic tech in the global south: Assessing technology for the public good*. Washington, DC, World Bank. https://openknowledge.worldbank.org/handle/10986/27947

Pellegrini, P. & Fernández R.J. 2018. Crop intensification, land use, and on-farm energy-use efficiency during the worldwide spread of the green revolution. *PNAS*, 115 (10): 2335–2340

Presidency of Senegal. 2019. *Plan of Emerging Senegal.* Dakar. Cited 28 January 2020. http://www.presidence.sn/en/pse/emerging-senegal

Petit, O., Lopez Gun, A., Kuper, M., Rinaudeau, J.D., Lejars, C. & Douadi, A. 2017. Resilience or collapse? Looking at agricultural groundwater economies under stress, *Hydrogeology Journal*, 25: 1549–1564. https://doi.org/10.1007/s10040-017-1567-3

Phiboon, K., Cochetel, C. & Faysse, N. 2019. Support programmes and the diversity of young farmers in Thailand: A good match? *Outlook on Agriculture,* 8(4): 300–308.

Pingali, P.L. 2012. Green Revolution: Impacts, limits, and the path ahead. *PNAS*, 109(31): 12302–12308.

Ranu, S., Gilmont, M., Hope, R. & Dadson, S., 2019. Understanding the effectiveness of investments in irrigation system modernization: Evidence from Madhya Pradesh, India. *International Journal of Water Resources Development*, 35(5): 847–870. https://doi.org/10.1080/07900627.2018.1480357

Rigg, J., Salamanca, A. & Thompson, E.C. 2016. The puzzle of East and Southeast Asia's persistent smallholder. *Journal of Rural Studies.* 43: 118–133. https://doi.org/10.1016/j.jrurstud.2015.11.003

Ritchie, H. & Roser, M. 2019. Land use. In: *Our World in Data* [online]. Cited 12 June 2020. https://ourworldindata.org/land-use

Rodell, M., Famiglietti, J.S., Wiese, D.N., Reager, J.T., Beaudoing, H.K., Landerer, F.W. & Lo, M.H. 2018. Emerging trends in global freshwater availability. *Nature,* 557: 651–659. https://doi.org/10.1038/s41586-018-0123-1

Ross, A. & Martinez-Santos, P. 2010. The challenge of groundwater governance: Case studies from Spain and Australia. *Regional Environment Change,* 10(4): 299–310. https://doi.org/10.1007/s10113-009-0086-8

Ruiz Salvago, M., Phiboon, K., Faysse, N., & Nguyen, T.P.L. 2019. Young people's willingness to farm under present and improved conditions in Thailand. *Outlook on Agriculture*, 48(4): 282–291.

Runfola, D.M. & Napier, A. 2015. Migration, climate, and international aid: Examining evidence of satellite, aid, and micro-census data. *Migration and Development*, *5*(2): 275–292. https://doi.org/10.1080/21632324.2015.1022969

Salaisook, P., Faysse, N. & Tsusaka, T. W. 2020. Reasons for adoption of sustainable land management practices in a changing context: A mixed approach in Thailand. *Land Use Policy*, 96: 104676.

Sanchis-Ibor, C., Molle, F. & Kuper, M. 2020. Irrigation and water governance. In: M. Zribi, L. Brocca, Y. Tramblay & F. Molle, eds. *Water resources in the Mediterranean*, pp. 77–106. Amsterdam, Elsevier.

Scott, C. & Shah, T. 2004. Groundwater overdraft reduction through agricultural energy policy: Insights from India and Mexico. *Water Resource Development*, 20(2): 149–164.

Selby, J., Dahi, O., Fröhlich, C. & Hulme, M. 2017. Climate change and the Syrian civil war revisited: A rejoinder. *Political Geography,* 60: 253–255.

Sen, A. 2001. The many faces of gender inequality. *The New Republic*.

Shah, T. 2009. *Taming the anarchy: Groundwater governance in South Asia.* Washington, DC, Resources for the Future.

Shlomi, D., Katz, D., De Stefano, L., & Blankespoor, B. 2019. Do treaties matter? Climate change, water variability, and cooperation along transboundary river basins. *Political Geography*, 69: 162–172

Siebert, S., Burke J., Faures, J.M., Frenkenn, K., Hoogeveen, J., Doll, P. & Portmann, F.T. 2010. Groundwater use for irrigation – a global inventory. *Hydrology and Earth Systems Science*, 14(10): 1863–1880.

Smith, M., Cross, K., Paden, M. & Laban, P. 2016. *Spring – managing groundwater sustainability*. Gland, Switzerland, International Union for Conservation of Nature (IUCN).

Sneddon, C. 2015. *Concrete revolution: Large dams, Cold War geopolitics, and the US Bureau of Reclamation*. Chicago, USA, University of Chicago Press.

Snellen, W.B. & Schrevel, A. 2004. IWMR: *For sustainable use of water 50 years of international experience with the concept of integrated water management. Background document to the FAO Netherlands Conference on Water for Food and Ecosystems*. http://www.fao.org/ag/wfe2005/docs/IWRM_Background.pdf

Sobczak Szelc, K. & Fekih, N. 2020. Migration as one of several adaptation strategies for environmental limitations in Tunisia: Evidence from El Faouar. *Comparative Migration Studies*, 8. https://doi.org/10.1186/s40878-019-0163-1

Sunam, R. 2017. In search of pathways out of poverty: Mapping the role of international labour migration, agriculture and rural labour. *Journal of Agrarian Change*, 17: 67–80. https://doi.org/10.1111/joac.12136

Tang, M. & Liao, H. 2019. From conventional group decision making to large-scale group decision making: What are the challenges and how to meet them in big data era? A state-of-the-art survey. *Omega*, 100. https://doi.org/10.1016/j.omega.2019.102141

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S. & Alaniz, R. 2015. Livelihood resilience in the face of climate change. *Nature Climate Change*, 5(1): 23.

Tayia, A. 2019. Transboundary water conflict resolution mechanisms: Substitutes or complements. *Water*, 11(7): 1337. https://doi.org/10.3390/w11071337

Tomich, T., Kilby, P. & Johnston, B. 1995. *Transforming agrarian economies: Opportunities seized, opportunities missed*. Ithaca, USA, Cornell University Press, Ithaca.

Torquebiau, E., Rosenzweig, C., Chatrchyan, A., Andrieu, N. & Khosla, R. 2018. Les agricultures face au changement climatique. *Cahiers Agriculture*. 27(2).

Torquebiau, E., Roudier, P., Demenois, J., Saj, S., Hainzelin, É. & Maraux, F. 2019. Agroecology and climate change: Close links which give cause for hope. In : X.F. Côte, E. Poirier-Magona, S. Perret, P. Roudier, B. Rapidel & M.C. Thirion, eds. *The agroecological transition of agricultural systems in the Global South*, pp. 239–249. Versailles, France, Éditions Quae.

United Nations (UN). 2017. *World population prospects: Key findings and advance tables – the 2017 revision.* Working Paper No. ESA/P/WP/248. New York USA. www.esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.

UN. 2019. 2019 Revision of world population prospects. In: *UN Department of Economic and Social Affairs* [online]. New York, USA. Cited 12 June 2020. https://population.un.org/wpp/

UN. 2020. Information for integrated decision-making and participation. In: *Sustainable Development Goals Knowledge Platform* [online]. Cited 21 July 2020. https://sustainabledevelopment.un.org/topics/information-integrated-decision-making-and-participation

United Nations Environment Programme (UNEP). 2016. *A snapshot of the world's water quality: towards a global assessment*. Nairobi. uneplive.unep.org/media/docs/assessments/unep_wwqa_report_web.pdf.

UNEP-DHI & UNEP. 2016. *Transboundary river basins: Status and trends*. Nairobi, UNEP.

UN Water. 2008. *Transboundary waters: Sharing benefits, sharing responsibilities*. Zaragoza, Spain.

United States Army Corps of Engineers (USACE). 2013. Effect of reservoir regulation on flood peaks and damages: Columbia River Basin. http://www.nwd-wc.usace.army.mil/PB/PEB_08/docs/WaterMan/WaterMan01/-Table%2018.pdf

Van Koppen, B. & Hussain, I. 2007. Gender and irrigation: Overview of issues and options. *Journal of Irrigation and Drainage*, 56: 1–10.

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P. & Carr, E. 2019. Evaluating agricultural weather and climate services in Africa: Evidence, methods, and a learning agenda. *WIREs Climate Change*, 10(4): e586. https://doi.org/10.1002/wcc.586

Venot, J.P. 2014. Rethinking commons management in sub-Saharan West Africa: Public authority and participation in the agricultural water sector. *Water International,* 39(4): 534–548.

Villholth, K.G. 2013. Groundwater irrigation for smallholders in sub-Saharan Africa: A synthesis of current knowledge to guide sustainable outcomes. *Water International* 38(4): 369–391.
https://doi.org/10.1080/02508060.2013.821644

Vivien, F.D., Nieddu, M., Béfort, N., Debref, R. & Giampietro, M. 2019. The hijacking of the bioeconomy. *Ecological Economics*, 159: 189–197.

Van Buuren, A., van Meerkerk, I. & Tortajada, C. 2019. Understanding emergent participation practices in water governance. *International Journal of Water Resources Development*, 35(3): 367–382.

Von Braun, J., Puetz, D. & Webb, P. 1989. *Irrigation technology and commercialization of rice in the Gambia, effects on income and nutrition*. Washington, DC, IFPRI.

Wada, Y., Flörke, M., Hanasaki, N., Eisner, S., Fischer, G., Tramberend, S., Satoh, Y. *et al.* 2016. Modelling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches. *Geoscientific Model Development*, 9: 175–222

Warner, J., Mirumachi, N., Farnum, R.L., Grandi, M., Menga, F. & Zeitoun, M. 2017. Transboundary 'hydro-hegemony': 10 years later. *WIREs Water*, 4.

Whitnall, T. & Pitts, N. 2019. Global trends in meat consumption. *Agricultural Commodities* 9: 96–99.

Wichelns, D. 2017. The water-energy-food nexus: Is the increasing attention warranted, from either a research or policy perspective? *Environmental Science and Policy*. 69: 113–123.

Williams, G. 2004. Evaluating participatory development: Tyranny, power and (re)politicization. *Third World Quarterly*, 25(3): 557–578. https://doi.org/10.1080/0143659042000191438

Wolf, A.T, Yoffe, S.B. & Giordano, M. 2003, International waters: Identifying basins at risk, *Water Policy*, 5 (1): 29–60.

World Bank. 2017. *Beyond scarcity: Water security in the Middle East and North Africa*. Washington, DC.

World Health Organization (WHO). 2012. *Animal waste, water quality and human health.* Geneva, Switzerland.

WHO & United Nations Children's Fund (UNICEF). 2015. *Progress on sanitation and drinking water: 2015 update and MDG assessment*. New York, USA, WHO.

Wrathall, D., von den Hoek, J., Waters, A. & Devenish, A. 2018. *Water stress and human migration: A global, georeferenced review of empirical research*. Land and Water Discussion Paper 11. Rome, FAO. http://www.fao.org/3/I8867EN/i8867en.pdf

United Nations World Water Assessment Programme (WWAP). 2017. *The United Nations World Water Development Report 2017. Wastewater: The untapped resource.* 2017. Paris, UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2017-wastewater-the-untapped-resource/

WWAP. 2018. *The United Nations World Water Development Report 2018*. Paris, UNESCO. www.unwater.org/publications/world-water-development-report-2018/).

Yoffe, S.B., Wolf, A.T. & Giordano, M. 2003, Conflict and cooperation over international freshwater resources: Indicators of basins at risk. *Journal of the American Water Resources Association*, 39(5): 1109–1126.

Zarfl, C., Lumsdon, A.E., Berlekam, J., Tydecks, L. & Tockner, K. 2015. A global boom in hydropower dam construction. *Aquatic Sciences 77*(1): 161–170.

Zougmoré, R.B., Partey S.T., Ouédraogo, M., Torquebiau, M. & Campbell, B.M. 2018. Facing climate variability in sub-Saharan Africa: Analysis of climate-smart agriculture opportunities to manage climate-related risks. *Cahiers Agricultures*, 27(3): 34001. https://doi.org/10.1051/cagri/2018019

Zwarteveen, M.Z. 2006. Wedlock or deadlock? Feminists' attempts to engage irrigation engineers. Wageningen, the Netherlands, Wageningin University. PhD dissertation.

This report reviews the main global trends in land and water uses, policies and investments that have taken place over the last decade and identifies the institutional arrangements that have been the most conducive to sustainable and equitable use of these resources. It focuses particularly on family farmers, who have limited access to key resources (land, water, credit and infrastructure). It pays special attention to their common challenges and needs, but also to their diverse conditions. It provides evidence-based information on the institutional conditions needed to ensure inclusive land and water programmes, and to upscale such programmes at local levels. It is based on a systematic review of official documents and academic papers and on detailed case studies, often grounded in the authors' own significant knowledge.

ISBN 978-92-5-136633-2
9 789251 366332
CC0950EN/1/07.22