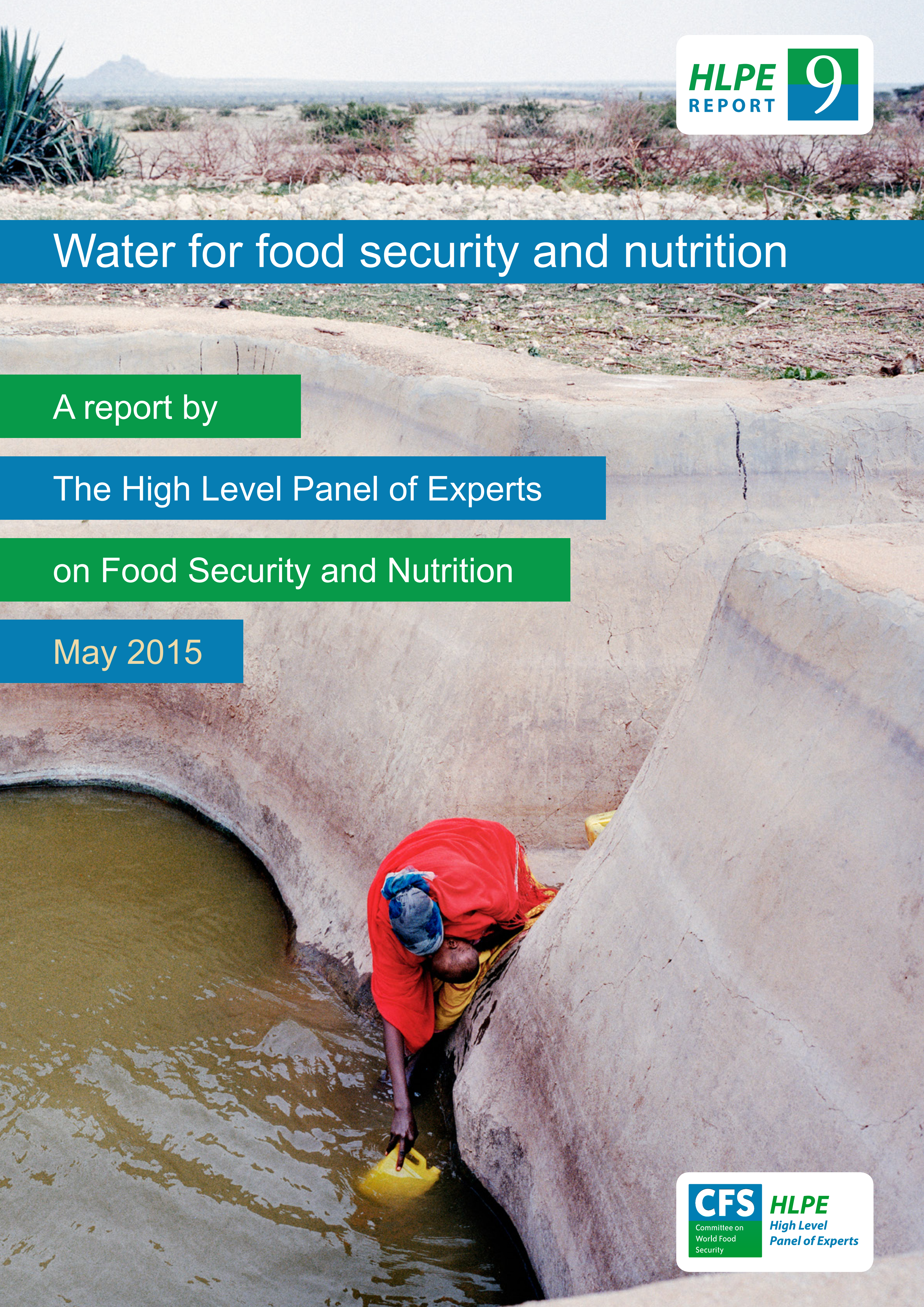
HLPE REPORT 9

Water for food security and nutrition



A report by

The High Level Panel of Experts

on Food Security and Nutrition

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HLPE Reports series

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FOREWORD

Water is key to human life. It is key to human food security and nutrition. Safe drinking water and sanitation are fundamental to the good nutrition, health and dignity of all. According to the latest estimates by WHO/UNICEF, in 2011, 36 per cent of the world's population – 2.5 billion people – lacked improved sanitation facilities, and 768 million people had to rely on unsafe drinking water sources. Water of sufficient quantity and quality is essential for agricultural production and for the preparation and processing of food. Irrigated agriculture accounts for 70 percent of all water withdrawals globally (surface and groundwater). 40 percent of irrigation uses groundwater sources, some of them non-renewable at human time scale. Climate change will alter the geographic and seasonal patterns of precipitations, with impacts on agriculture.

How can the world ensure food and nutrition security given increasingly scarce water resources, especially in some regions, and the increasing competition for water uses?

This policy-oriented report from the High Level Panel of Experts on Food Security and Nutrition (HLPE) presents a synthesis of existing evidence on the multiple relations between water and food security and nutrition, from global levels to household levels.

The aim of this report, given the diversity of contexts, is to help all concerned actors to improve water management, and management of agricultural and food systems for water, and to improve water governance, given the overarching need to ensure provision and access to safe drinking water for all, good sanitation, and maximize the contribution of water to food security and nutrition for all, now and in the future.

The HLPE was created in 2010 to provide the United Nations' Committee on World Food Security (CFS) with evidence-based and policy-oriented analysis to underpin policy debates and policy formulation. As specific policy interventions need to be based on context-specific understanding, HLPE reports provide all stakeholders with evidence relevant to the diversity of contexts, and recommendations expected to be useful to guide context-specific policy interventions.

The HLPE works on topics identified by the CFS. This is the ninth HLPE report to date.

The HLPE has a very noble and important mission which is to produce reports which serve as starting points for debates, at CFS, between actors having many different perspectives, points of view, and often, objectives. We also hope that these reports are useful on the ground, for policy-makers, for practitioners, when it comes to decide to do the right thing to improve food security and for better nutrition. They are available for all, for action, as public goods.

The Steering Committee of the HLPE consists of 15 members including a Chair and a Vice-Chair. In addition, the HLPE includes a wide range of researchers who work on the various reports. I have been very glad to serve as chair of the HLPE during two years, succeeding to M. S. Swaminathan. The HLPE Steering Committee will be renewed in October 2015 and I wish to the new members all the success in their important mission.

I would like also to pay my tribute to all the experts who worked for the elaboration of this report, and especially to the Project Team Leader Lyla Mehta (from Austria), and to Project Team Members Oscar Cordeiro-Netto (from Brazil), Theib Oweis (from Jordan), Claudia

Ringler (from Germany), Barbara Schreiner (from South Africa) and Shiney Varghese (from India), who worked very hard on this report.

The report also benefited greatly from comments and suggestions by the external peer reviewers and a large number of experts and institutions who commented extensively both on the terms of reference and on a first draft of the report. I would also like to thank the HLPE Secretariat for its tremendous contribution and permanent support to our work.

Last but not least, I would like to thank the resource partners who support, in a totally independent way, the work of the HLPE.

Safeguarding water for the dignity, health, food and nutrition security of everyone on the planet is one of the biggest challenges that humanity currently faces. It is a fundamental dimension of the sustainable development agenda. We hope that this report will help policy makers and actors around food, agriculture, water and all concerned sectors worldwide to overcome this challenge.

Per Pinstrup-Andersen

Chairperson, Steering Committee of the HLPE, 12 May 2015

SUMMARY AND RECOMMENDATIONS

Water is key to food security and nutrition. However there are many challenges for water, food security and nutrition, now and in the future, in the wider context of the nexus between water, land, soils, energy and food, given the objectives of inclusive growth and sustainable development.

In this context, in October 2013, the Committee on World Food Security (CFS) requested the High Level Panel of Experts on Food Security and Nutrition (HLPE) to prepare a report on Water and Food Security, to feed into CFS's 42nd Plenary session in 2015.

This report explores the relations between water and food security and nutrition, from household level to global level. It investigates these multiple linkages, in a context of competing demands, rising scarcities, and climate change. It explores ways for improved water management in agriculture and food systems, as well as ways for improved governance of water, for better food security and nutrition for all, now and in the future. The report is deliberately oriented towards action. It provides examples and options to be implemented by the many stakeholders and sectors involved, given regional and local specificities.

Main findings

What follows is a summary of the main observations and findings of the report:

Water is central to Food Security and Nutrition (FSN)

1. Water is life. Water is essential to food security and nutrition. It is the lifeblood of ecosystems, including forests, lakes and wetlands, on which depend the food security and nutrition of present and future generations. Water of appropriate quality and quantity is essential for drinking and sanitation, for food production (fisheries, crops and livestock), food processing, transformation and preparation. Water is also important for the energy, industry and other economic sectors. Water streams and bodies are often key ways for transport (including inputs, food and feed). All in all, water supports economic growth, and income generation, and thus economic access to food.
2. Safe drinking water and sanitation are fundamental to the nutrition, health and dignity of all. Lack of access to safe drinking water, sanitation facilities and hygiene practices undermines the nutritional status of people through water-borne diseases and chronic intestinal infections. Despite significant advances in access to drinking water and sanitation, in 2012, according to WHO and UNICEF, globally 4 percent of the urban population and 18 percent of the rural population (but 47 percent of the rural population in Sub Saharan Africa) still lacked access to an improved drinking water source[1] and 25 percent of the population lacked access to improved or shared sanitation.[2]
3. According to FAO, in 2009, 311 million hectares were equipped with irrigation, 84 percent of those actually being irrigated, corresponding to 16 percent of all cultivated land and contributing to 44 percent of total crop production. Reliable irrigation is also essential to increasing and stabilizing incomes and provides livelihood resilience for a vast number of smallholder farmers. Irrigated agriculture is by far the largest water user globally, totalling 252 billion cubic meters of surface and groundwater withdrawals[3] in 2013[†], equivalent to 6.5 percent of the global renewable freshwater resources flows, and 70 percent of anthropic withdrawals globally, with significant differences between countries: 90 percent in low income countries, 43 percent in high income countries.

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1 Sources protected from outside contamination, particularly faecal matter, by construction or through active intervention.

2 Facilities ensuring hygienic separation of human excreta from human contact.

3 A withdrawal of water (or "water use") does not necessarily translate in net water consumption, which is the portion of water withdrawn that is not returned to the original water source after being withdrawn (11 percent of the withdrawals by the energy sector are consumed, and 50% of the withdrawals for irrigated agriculture are consumed, i.e. evaporated into the atmosphere or transpired through plant leaves). Water withdrawn and returned to the original source is often accompanied by an alteration of its quality.

† World Development Indicators (World Bank database) estimates for 2013 as per available figures.

Water availability and stability for FSN

4. Availability of water is very different across geographical regions, both in terms of rainwater, and of surface and ground water. Therefore, water availability needs to be considered at regional, national and local levels.

5. Ground water is a particularly stable source of water. 40 percent of irrigation uses groundwater sources. It offers considerable opportunities especially for regions that have no other sources. However it is also a major challenge for the future as much groundwater is not renewable, and slowly replenishing reservoirs can get quickly depleted. Some "fossil" ground water reservoirs are replenished only on a geological timescale, thousands or even millions of years.

6. Ecosystems and landscapes sustain water resources. Forests play a major role in the watercycle, ensuring quantity, quality and stability of water for human use.

7. Climate change adds significant uncertainty to the availability of water in many regions. It affects precipitation, runoff, hydrological flows, water quality, water temperature and groundwater recharge. It will impact both rainfed systems, through precipitation patterns, and irrigated systems, through availability of water at basin level. Climate change will modify crop and livestock water requirements, and impact water flows and water temperatures in water bodies which will impact fisheries. Droughts may intensify in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration. Climate change will also significantly impact sea level, with impacts on freshwater resources in coastal areas.

Competing uses of water

8. In most parts of the world water resources are under increasing stress. Population growth, rising incomes, changing lifestyles and diets, and growing demands for different uses of water, are all increasing pressure on limited freshwater resources. Total water withdrawals for agriculture, energy, industry, and municipalities accounted in 2013[†] for globally 9 percent of internal renewable resources, a number ranging from 2.2 percent for Latin America and Caribbean, to 122 percent in the Middle East and North Africa.

9. Water and energy are closely linked: water use for energy generation represented 15 percent of world water withdrawals in 2010, and can compete with food production. At the same time energy is essential in making water available for irrigation, food processing and preparation and for water and wastewater treatment.

10. According to OECD's business as usual scenario global water demand is projected to increase by some 55 percent by 2050, with over 40 percent of the global population living in river basins experiencing severe water stress (where water withdrawals exceed 40 percent of recharge), especially in North and Southern Africa, and South and Central Asia. Manufacturing (+400 percent), thermal electricity (+140 percent) and domestic use (+130 percent) are responsible for the projected demand growth until 2050, with little scope to increase irrigation water use.

Water scarcity and access to water

11. Water scarcity is generally defined[4] by the difference between water availability - the level of renewable water resources (rain water, surface and ground water) available within a certain area - and a certain demand for water, including basic needs. There are however as many perspectives to "water scarcity" as there are perspectives to water availability and to water demand. Water scarcity can also be encountered in water rich regions, if there is an excess of water demand, with often increasing and badly managed competition for water use between sectors (agriculture, energy, industry, tourism, and household use).

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[4] Some authors have come to define "water scarcity" by pre-determined thresholds, such as 1 700 m^3 and 1 000 m^3 of available water per person per annum, which were determined to cover all uses including agriculture (irrigation) and other economic sectors. Other authors have defined "economic water scarcity" to define situations where water is physically available in the environment to, in theory, meet the demand, but not provided where it is needed and at the quality needed, due to economic factors, such as a lack of infrastructure, storage, distribution systems, etc. One could define "social water scarcity" for situations where part of the population does not have access to water in sufficient quantity and quality, for drinking and sanitation, as well as to sustain their livelihoods.

12. Access to, and use of, water for FSN is informed by social, political and economic power relations within countries, in water basins, and at the local level, as much as by infrastructure and rainfall. Securing access to water can be particularly challenging for small holders, vulnerable and marginalized populations and women.
13. Access to water, or the lack of it, is of particular importance for women as cultural norms in much of the developing world dictate that women and girls are responsible for water collection, and they may spend several hours per day collecting water, with impacts on their health and nutritional status as well as on time available for other activities, child-care, productive and educational activities. Moreover, women are often excluded from decision-making processes regarding water management or access to water technologies, and are often discriminated against by formal water allocation systems.

Water quality

14. The many potential uses of water, from drinking and sanitation, to growing food, energy, mining, manufacturing, etc. typically require different quantities and qualities of water, and therefore often specific treatment, which can be done at the source, or closer to the user, or even by the end-user itself (household or industry). Also, irrigation water quality needs vary by crop. This leads to trade-offs for the provision of water services, between their specialization versus a “multiple use approach” to serve different purposes or uses.
15. Poor water quality affects human health and ecosystems’ functioning. High water quality standards are needed for drinking water and important for other WASH components, and are important for food processing and preparation. Drinking water quality has improved in many developed countries over the last several decades and is supported by regulations and monitoring. In most parts of the global South, water quality and associated food safety risks still have adverse impacts on both human and ecosystem health.
16. Environmental impacts of uses and return flows vary between uses, as well as depollution needs, and all require specific attention. Pollution renders water unfit for use and undermines ecosystems’ health in many areas. Unsustainable water use and management reduce the ecosystems’ functions of land, fisheries, forests and water bodies, including their ability to provide food and nutrition.
17. Waste water is also a resource, and water-scarce countries often resort to wastewater reuse, which also provides for closing the nutrient cycle but poses risks to human health if not regulated effectively. Waste water, currently undervalued and underused, can be a resource for the future, with adequate safeguards. Desalination of sea water is a potential source of freshwater in coastal areas, particularly for drinking.

Managing water scarcities in agriculture and food systems

18. Improving water management in agriculture and food systems aims at improving the productivity of agriculture and food systems for FSN (availability, access, stability, nutrition), given water constraints. This can be achieved by improving water efficiency at all levels (how water is used, from ecosystems to plants) and by improving the agricultural water productivity (the ratio of output to the water input), in rainfed and irrigated systems.
19. Improving water management for FSN mobilises actions ranging from appropriate planning and optimization of resources, inputs and means of production, in both rainfed and irrigated systems, as well as along food chains, to sustainable management of ecosystems and landscapes which enhance, regulate and stabilize water provision. Water management will be key to the adaptation to climate change of agricultural systems both rainfed and irrigated.
20. For future food security, land and water management needs to preserve ecosystem functions and ensure the future of the resource. Sustainable management of ecosystems, and an ecosystem’s approach to water management from local to continental levels is key to ensuring quantity and quality of water for food security and nutrition in the future.

Management for improved water and agriculture productivity in both rainfed and irrigated systems

21. Broader agro-ecosystem approaches consider rainfed and irrigated agriculture as part of a whole, with upstream-downstream interactions, aiming to optimize water allocation and ensuring attention to ecosystem's health.

22. Globally, rainfed agriculture is the primary source of food production. In many regions, there is still an important yield gap, and potential to improve yields and water productivities without irrigation. Rainwater harvesting, as well as supplemental irrigation, can also substantially improve rainfed agriculture. Livestock water productivity can be improved, inter alia, through better management of grasslands and rangelands and through livestock systems resilient to water stresses. In pastoral systems, drinking water constraints for livestock often limit the use of pastures and rangelands, and making water available could increase the sustainable use of available biomass.

23. A range of means such as plant and livestock breeding, agro-ecology and conservation agriculture can also improve water productivity in both rainfed and irrigated systems. Better integration of plant and livestock production can improve nutrient management and water use efficiency. The water productivity of aquaculture, including in integrated systems, is high compared to other sources of protein and nutrients, which gives it an important role for FSN.

24. High variability of expected income, linked to dependence on variable rainfalls often constrain investment in rainfed agriculture, thus limiting potential improvements. Risk management strategies and tools can thus facilitate investments and productivity enhancements.

25. Groundwater is increasingly being used for irrigation and being overexploited in many regions In other areas it is still underutilized and can be further exploited for food production. A constraint to the sustainable use of ground water is the difficulty to monitor individual withdrawals and the impact on the resource.

Optimise uses and re-uses for FSN at all levels

26. In the irrigation sector, there are margins of improvement and revitalization of existing systems to improve productivity and sustainability. It requires appropriate maintenance, which necessitates institutions, technical competencies, and sustainable financing. In addition, cropping systems, patterns and practices can be adapted to reduce the need for irrigation water. Finally, there is scope for new systems and practices in some areas.

27. Currently, about 0.25 to 1.5 million hectares of irrigated land are estimated to be lost annually because of salinization due to bad irrigation practises.[5] Globally 34 million hectares are now impacted by salinity representing 11 percent of the total irrigation equipped area. Addressing secondary salinization and drainage issues is essential to keep the potential and valorize the investment of irrigation-equipped land.

28. Appropriate water pricing can be a tool to improve cost recovery in irrigation schemes. In addition, water and energy pricing can be used to increase efficiency. High levels of energy subsidies can also result in the overuse of water.

29. In some areas, more water can be made available through the development of new infrastructure. Marginal quality water including brackish, sewage and drainage water can also be used, although environmental, health and cost concerns must be managed.

30. In food processing, water management issues mainly regard the quality of the water needed, and the impact of activities on water quality through discharged water.

Trade can compensate water scarcities for FSN

31. The importation of food is a coping mechanism used by water scarce countries. Approximately 14% of world cereals are traded internationally, with a greater share of net imports by countries facing physical or economic water scarcity. Water scarce countries are thus particularly

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[5] Data on additional salinized areas per year are variable and challenging to compile at global level. The problem is mainly concentrated in irrigated land located in semi-arid and arid zones.

dependent on international trade and particularly affected by food price volatility as well as by export restrictions in times of crisis.

32. Trade has a key role to play for FSN, to cope with water scarcity and also to maximize FSN outcomes of water abundance. The food and nutrition security of water scarce countries depends on a reliable international trade. Measures to improve the reliability of international trade, such as the creation of AMIS can thus be also seen as measures to cope with water scarcity. Water used for agriculture in water rich countries contributes to ensure global availability of food.

Data and monitoring

33. Effective water management is grounded on appropriate tools to monitor and assess climate risks (floods and droughts), and can mobilize landscape approaches, such as land restoration, forest and watershed management, appropriate use of floodplains, as well as infrastructure for water storage.

34. Improvement in water management relies on appropriate data and tools, such as metrics of water use, water efficiency and water productivity. To improve water management, each stakeholder needs different tools, which to be mobilized will require appropriate data. In many countries, there is still a lack of basic data, particularly in relation to groundwater and water quality. There is also value to collect more data on informal uses as well as more gender disaggregated data. Another challenge is the rapidly changing situation of the resources, both in quality and quantity, as well as of the uses, and the need for up-to-date data systems at the appropriate level/scale.

35. Different water accounting schemes have been proposed (e.g. life cycle analysis, water footprinting etc.), with the aim to help orient production choices for producers to optimize water use, and to help raise awareness of consumers and contribute to orient their choices. It is however important to use such tools with caution as they often cannot capture all context specificities, particularity local scarcities and impacts on ecosystems.

Challenges of water governance for food security and nutrition

36. Water governance[6] has to deal with competing policies, interests and actors coming from numerous sectors, with different degrees of political or economic power. Access to water, control over water resources or water pollution can cause disputes and conflicts at various levels. Increasing scarcities and growing and competing demands on water by a multiplicity of users and sectors make water governance for food security and nutrition particularly challenging, from local to broader levels.

37. Water governance covers both water resources and water services. Depending on the situations, the governance of these two issues have been either linked or separated. The modernization of water provision, when it happened, often led to differentiated governance schemes for water services. Governance issues are different for resources and for services. For resources, the dominant challenges are competition between uses and users of different economic and political power, the rules of this competition and how FSN is taken into account, as well as the links with land. For services, the dominant challenge is the regulation, control and monitoring of the service provider, public or private, including how physical and economic access to water for different users, especially marginalized populations, is enabled, conditioned and performed.

The challenge of integration and priorization

38. Numerous policies have an impact on water resources: environment, energy, trade, food and agriculture, including fisheries and forests, industry, etc. Policy coordination is managed differently according to countries' institutional settings. At national level, when it exists, the coordination is assumed either by a lead ministry, or an interministerial coordination mechanism, or a dedicated body. In some cases, this leads to an integrated water policy.

[6] In this report, the following definition of water governance is used: "Water governance is the set of political, social, economic and administrative systems, rules and processes (i) which determine the way decisions regarding the management and use of water resources, and the delivery of water services, are taken and implemented by the various actors; and (ii) through which decision-makers are held accountable".

39. In many cases national water policies do not prioritise water for food security. While some do outline the order of priorities for water allocation with a focus on FSN, fully implementing it remains a challenge, not least due to the lack of integration in decision-making, with decisions on irrigation, industrial or power generation development being taken in different departments with little consideration for the cumulative impacts on water. Some countries however have put in place improved intersectoral decision making, a critical process in ensuring sufficient water for FSN.

40. Sustainable management of water resources for FSN often depends on the protection and conservation of specific ecosystems, particularly wetlands and forests, which themselves also contribute to the FSN of local populations. Similarly, quality water streams and bodies are important for inland fisheries and aquaculture. The ecosystem approach as defined by the Convention of Biological Diversity provides a good model. It requires specific integrated governance mechanisms.

41. The concept of Integrated water resources management (IWRM), following the Dublin principles (1992), was invented to bring together social, environmental and economic objectives, in a cross-sectoral approach of water management, combining users, planners, scientists and policy-makers. It has been widely used and promoted,[7] but also the object of numerous criticisms. Whilst the critics of IRWM recognize its value as a comprehensive framework, they argue that it is too abstract when addressing implementation challenges. This makes it less operational and practical especially in developing countries' contexts. Critics also point to IWRM's difficulty to recognize conflicts and to enable proper prioritisation of issues, especially those most important for people locally, including water for FSN.

Actors

42. Many different actors, public and private, operate in water use and management. There is often confusion, and a need for clear rules and common understanding, on their roles and functions, the way they interrelate, their different responsibilities and how they can be made accountable. In many cases, inclusiveness of governance schemes, accountability and control mechanisms do not function in such a way that the efficiency and fairness of the system can be fully guaranteed.

43. Corporate actors such as from energy and industrial sectors, cities, food transformation and beverage industry, or large-scale agriculture/plantations, have an increasing influence in water governance and management. First, some of them, like the big providers of services for large irrigation schemes or for drinking water, act as water managers. Second, large enterprises enter in competition for the allocation of the resource with agriculture and small users. Third, in some cases, the scale of the intervention or investment, or the economic and political influence, is such that the resource itself is controlled.

44. While there is also clearly a role for the private sector in the provision of water, in many countries there is insufficient regulatory oversight. Experiences with privatization of water services have not always been poor-friendly, affecting the ability of poor households to access sufficient water of an appropriate quality for food preparation, health and hygiene requirements.

45. In many countries, water users associations can play an important role in the management of water resources and water services, especially at local and community level, including in irrigation schemes. There is however often a divide between different categories of users, having different objectives: farmers, fisherfolks, urban users, environmentalists and recreational users, etc. Governance has to provide for mechanisms to arbitrate between diverging interests and to solve conflicts in a fair way.

Institutions

46. Institutions dealing with water resources are extremely diverse, depending on countries and situations. They can be formal or informal/customary, part of the local, sub-national or national administration, they can be specific water institutions, eventually linked to a water body (or not),

[7] IWRM has been defined, in 2000, by the Global Water Partnership as *"a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".*

they can be linked to an investment, they can be public or private, they can associate to various degrees the different users in the management of the resource.

47. Decentralized governance allows to take better into account the need of users and the state of the resource, and to better responsibilize users especially with secure rights and when they are associated to the resource management decisions. Decentralized governance often involves strengthening local organizations and/or the setting up of specific institutions, such as water user associations, or river basin organisations. However even at such levels, principles of good governance need to be put in place to ensure equitable access, and not exclude less powerful actors, including informal water users.

Mechanisms to manage competing demands

48. Many mechanisms and tools can be used to manage water scarcities and competing demands, such as: mechanisms to set maximum withdrawals; allocation tools, including access rights; permits and tradable permits; licensing systems; pricing schemes; other tools to protect the resource and its quality, such as to regulate water abstraction and discharge, protected areas, catchment protection, water quality and resource protection regulations. The choice of the tools and the way they are implemented can have diverse effects on FSN through the impacts on water available for agricultural uses, and on access to water for poor, vulnerable and marginalized populations. In particular, the impacts of tools on FSN and on populations depend on the social and legal systems in which they are implemented (formal and informal). Badly adapted tools can disrupt existing community-based systems. Market based tools often tend to give priority to the sectors which offer the highest economic value for water use, at the expense of food security.

49. Governance of water resources, especially in water scarcity contexts, goes with the establishment of an allocation scheme, including allocation tools and rules. In the context of FSN, the challenge is to ensure that allocation systems give adequate priority to water for food production as well as for the basic needs of poor and marginalized populations.

50. Allocation mechanisms, ideally, operate at a pertinent hydrological level where the resource is contained and shared. This can be particularly challenging because the institutional arrangements are not often aligned on hydrological bodies. A water resource can spread on different administrative entities including on different countries. Also, institutional arrangements do not always take into account interconnections between various water resources, such as between surface and ground water.

51. Allocation of, and access to water are determined not only by formal institutions (supported by laws) but also by informal arrangements such as customary law. In a context of increasing formalization of access rights, the rights of poor and marginalized women and men, often of a customary nature, are often overlooked and threatened, with impacts on FSN.

Land and water linkages

52. When land and water governance are not adequately linked, changes in land ownership and tenure at one location can have impacts on water access rights elsewhere, with impacts on agriculture and FSN. Conversely, loss of access to water can impede the proper use of land. In particular, large land acquisitions can lead to the re-allocation of water locally or downstream and can negatively affect the FSN of communities, local or remote.

53. The Voluntary Guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security (VGGT), and the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF) have not paid much attention to the topic of water resources, despite it having important linkages with land issues, and it being a determinant of fisheries resources.

Investments

54. Investments in various economic activities, and in particular in energy, industry and large scale plantations, by corporate actors, often have an important impact on water. Mobilizing the investment potential of businesses can benefit FSN by providing development opportunities. They can also, when directed to water supply and water services, increase the provision of water. However, in both cases they can often bear a very important negative impact on local population,

especially on the most vulnerable, marginalized, indigenous peoples and women. There is a need to ex-ante assess impacts on the FSN of all, including vulnerable populations, and to create mediation and dispute settlement mechanisms in case of negative impacts. Tools recently developed such as the CFS principles for responsible investments in agriculture and food systems can serve as a guide to maximize FSN outcomes of investments in the water sector and of investments in activities having an impact on water.

International agreements and initiatives

55. The 263 transboundary lakes and river basins account for an estimated 60 percent of freshwater flows. In addition approximately 300 groundwater aquifers are transboundary. Close to 700 bilateral, regional or multilateral water agreements in more than 110 basins cover different types of activities and objectives, from regulation and development of water resources to the setting of management frameworks.

56. The 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses is the only treaty governing shared freshwater resources that is of universal applicability. It introduced the principles of equitable and reasonable utilization and participation, in the use, development and protection of the international resource, the obligation not to cause significant harm to other states, principles of prior notification of planned measures, and provisions concerning management and settlement of disputes.

57. At the global level, several international initiatives have emerged, particularly in the aftermath of the Dublin conference in 1992. The Global Water Partnership aims at promoting integrated water resource management, and providing advice, helping with R&D and training. The World Water Council – a multistakeholder association, best known for its flagship conference, the World Water Forum, aims to promote awareness, build political commitment and trigger action on water issues. In addition, UN-Water has been created to strengthen coordination and coherence amongst the UN agencies, programmes and funds that have a significant role in tackling global water concerns.

The right to safe drinking water and sanitation, and the right to food

58. The human right to safe and clean drinking water and sanitation were recognized in 2010 by the United Nations General Assembly. It entitles everyone, without discrimination, to access to sufficient, safe, acceptable, physically accessible and affordable drinking water and to physical and affordable access to sanitation for personal and domestic use. It was incorporated in several constitutions and national legal orders.

59. The right to adequate food has been recognized in the International Covenant on Economic, Social and Cultural Rights (ICESCR), a multilateral treaty adopted by the United Nations General Assembly in 1966. The 2004 Voluntary Guidelines to support the progressive realization of the right to adequate food in the context of national food security (VGRtF) contain dispositions about access to and sustainable use of water.[8]

60. The human right to safe drinking water and sanitation and the human right to food have close ties because safe drinking water and sanitation are crucial for health and good nutrition, and because access to water is indispensable for food producers, and the right to food of producers. There are ongoing reflexions, warranting further exploration and research, on the consequences of these two rights for water governance, and how they can promote a human rights based approach to water governance for FSN. These reflexions also lead to considerations about the extra-territorial obligations of States to regulate the activities of third parties under their jurisdiction to ensure that they do not violate the human rights of people living in other countries.

[8] The VGRtF underline that the realization of the right to food necessitate State action to *"improve access to, and promote sustainable use of, water resources and their allocation among users giving due regard to efficiency and the satisfaction of basic human needs in an equitable manner and that balances the requirement of preserving or restoring the functioning of ecosystems with domestic, industrial and agricultural needs, including safeguarding drinking-water quality".*

Recommendations

The concept of "water for FSN" designates water's direct and indirect contributions to food security and nutrition in its four dimensions. It covers safe drinking water and sanitation, water used to produce, transform, and prepare food, as well as the contribution of water uses in all sectors to livelihoods and income and as such to food accessibility. It covers also the objective of sustainable management and conservation of water resources and of the ecosystems that sustain them, and that are necessary to ensure FSN for present and future generations.

1. Ensure sustainable management and conservation of ecosystems for the continued availability, quality and stability of water for FSN

States should:

a) Ensure continued availability, quality and stability of water for FSN through the conservation and sustainable management of landscapes and ecosystems, across biomes, including by using the ecosystem approach of the Convention on Biological Diversity.

b) Ensure that the quality of water resources is preserved, especially for the provision of drinking water, for food processing, for sanitation, as well as for irrigation water. This should be done through the introduction of regulatory systems as well as targeted incentives and disincentives, such as the polluter-pays principle and other measures commensurate with harm done. All actors should be held accountable for the impact of their activities on water quality.

States and other relevant stakeholders should:

c) Promote participatory mechanisms for sustainable management of ecosystems and landscapes that are key to ensure the availability, quality and stability of water for FSN. These include collective and coordinated action within and across watersheds and ecosystems, innovative capacity building and frameworks for accountability of governance and management, including of decentralized governance and local adaptive management.

d) Consider co-management of water resources whereby the design, implementation and monitoring of management measures are shared or developed with a range of different stakeholders closer to the resource such as local governments, basin organizational structures, associations of food producers and of other users.

2. Ensure an integrated approach to water and FSN related policies

States should:

a) Develop, through inclusive participation of all stakeholders, a national integrated water resource management strategy, and make sure that it incorporates FSN concerns related to water availability, quality and access to water for food production, food processing, drinking and sanitation. The strategy must be comprehensive across sectors. Such a strategy needs to ensure equitable access for all to safe drinking water and sanitation. It should also take into account the specific FSN needs and uses of water by urban and rural populations, and the contribution of food producers (subsistence, smallholders and large scale) and processors (small and large scale) to FSN.

b) Integrate water into comprehensive national FSN strategies, review national policies related to trade, rural development, and industrialization to ensure that they promote water for FSN and eliminate practices that disadvantage the vulnerable and marginalized.

c) Ensure coordinated policy development and implementation of water and FSN strategies across sectors and hold all sectors accountable for their impact on water for FSN.

d) Undertake evidence-based assessments of actual and future water demand in all sectors and plan investments, policies and allocation for the pro-active management of long-term water resources and uses accordingly, prioritizing water for FSN amongst uses.

e) Include sex-disaggregated indicators for water availability, access, quality and stability of supply of water for FSN in national food security information systems. This shall contribute to the implementation of the sustainable development goals, according to national priorities.

States and Civil Society Organizations and other relevant stakeholders should:

f) Strengthen the capacity of households and local organizations to adopt water-saving practices and technologies for innovative water storage and distribution, efficiency in multiple water uses and disposal of wastewater that is appropriate for the environmental, social and cultural contexts.

3. Prioritise the most vulnerable and marginalised, including mainstreaming gender and addressing the specific needs of women

States and, where relevant, other stakeholders should:

a) Ensure that policy and legislation give women and men equal access to water. Particular attention should be given to indigenous peoples, smallholders and marginalized communities.

b) Avoid negative effects on the FSN of the urban and rural poor and marginalized in any reform in water management.

c) Take proactive measures to ensure that women and men food producers are accorded equitable access to land, inputs, markets, finance, training, technologies, services, including climate information, that will allow them to use water effectively to meet their FSN requirements.

d) Design and implement appropriate infrastructure and technologies to improve water availability and access at household level that deliberately address the drudgery and burden of water collection and disposal and related health risks, and directly improve conditions for clean drinking water, hygiene and food safety to reduce the incidence of food-borne diseases.

e) Address the specific needs of women and girls in relation to water for FSN through their empowerment as well as through targeted interventions. These should take into account women’s productive and reproductive roles.

f) Strengthen rural women’s participation and representation at all levels of water governance (water users associations, ministries and other national institutions, regional platforms, etc.) to ensure that their perspectives and productive roles in all key sectors are taken into account in policy-making and reform processes.

Private, public, and public-private initiatives should:

g) Ensure that no action related to water have negative impacts on the availability and access to water for FSN of vulnerable and marginalized peoples.

4. Improve water management in agriculture and adapt agricultural systems to improve their overall water efficiency and water productivity, and their resilience to water stresses

States and, where relevant, other stakeholders should:

a) Develop and implement adaptive water and agricultural strategies and action plans based on a comprehensive approach to long-term availability and variability of all water sources (rain-water, surface water and ground water), considering also the impacts of climate change and the capacity of agro-ecological systems to retain moisture.

b) Reduce water scarcity risks through water management options such as water harvesting and supplementary irrigation, water storage infrastructure, including improving soil moisture retention capacity.

c) Design and implement agricultural practices (agronomic practices, agro-ecological innovations, seeds, livestock breeds, diversification) and landscape management which increase resilience of agricultural systems to water stress.

d) Make rain-fed agriculture systems a more reliable option for farmers and pastoralists, by reducing risk, and adapting formal and informal enabling mechanisms (e.g. credit, community solidarity) to enhance rain-fed systems' resilience to water stress.

e) Invest in an enabling environment, mobilizing the full set of tools (from meteorological predictions and credit provision, to social protection) in order to devise a risk management strategy that reduces water-related risks on agricultural production, communities and households.

f) Take into account the long-term availability of water in planning and investing in irrigation, to maximise long-term FSN objectives.

g) Investments in, and management of, irrigation systems should aim for water efficiency at catchment level and minimise adverse effects on land and water quality (e.g. salinisation and contamination of water tables), and on downstream water quantity (e.g. for the FSN of fishing and pastoralist communities).

h) Ensure, through appropriate governance mechanisms, sustainable management of groundwater taking into account renewal rates and future needs, and considering, when necessary, fixing maximum withdrawals levels and setting up systems to monitor and control individual water withdrawals.

5. Improve the contribution of trade to "water for FSN"

States should, when negotiating and implementing trade rules and agreements:

a) Take action to restore confidence in a rules-based, transparent and accountable multilateral trading system, taking into account the concerns and vulnerabilities of water-scarce countries that rely on international markets to meet their FSN needs through food imports.

b) Protect the interests of low-income, water stressed, net food-importing countries by strengthening trade rules on food exports, including rules that limit the use of export constraints.

States should:

c) Strengthen the capacity of AMIS (Agricultural Market Information System) to provide transparency about prices, production, stocks and trade in staple foods. This includes encouraging States to join AMIS and to ensure that all AMIS members provide up-to-date and comprehensive data.

d) Consider measures to ensure that commercial actors respect their contractual obligations to deliver food imports. For example, encourage contracted parties to use third party commercial conciliation for contract enforcement.

e) Incorporate trade and investment policies into their comprehensive national FSN plans, taking account of water-related risks and vulnerabilities for FSN, in particular at times of crisis. Policy instruments might include food reserves, risk insurance, social protection, and investment in the development of agri-food industries.

6. Devise and share enhanced knowledge, technologies and management tools related to water for FSN

States, research actors, and, where relevant, other stakeholders should:

a) Support the definition of global, national and local strategic research agendas through inclusive participatory processes by relevant actors including local communities and researchers engaged in water for FSN. They should also ensure that all research on water and FSN is gender-sensitive.

b) Enable methodological and institutional innovations for the participatory co-construction, co-validation and dissemination of knowledge appropriate for risk prone, diverse and complex environments, such as arid and semi-arid regions, wetlands, deltas, and mountains.

c) Increase investments in research and innovation for water and FSN, with due attention to neglected areas. Research is needed in the following key areas:

   - Impacts of climate change on run off, aquifer recharge, water quality and plant water use, and means to address them.
   - Incentive instruments and pricing structures for energy and water to reduce water waste or over-utilisation.
   - Monitoring and evaluation of the water-related impacts, at different geo-spatial and temporal scales, of large-scale land acquisitions and foreign direct investments impacting water availability, access, quality and stability of supply, as well as on policies, interventions and institutional innovation to regulate their negative effects on FSN.

d) Build the necessary capacities, professional re-training, and organizational change to develop systems approaches within the research and local communities, for the production of knowledge on water for FSN, including capacity building on community-established research protocols.

e) Intensify national and international efforts to collect sex-disaggregated data on water for FSN to monitor progress and improve gender-sensitive policies and practices.

f) Improve the local level relevance of climate models particularly for countries that are vulnerable to climate change impacts; and develop climate-resilience tools for decision making that combine information from improved localized climate and hydrological modelling.

g) Establish and manage open data systems to provide evidence for decision making and monitoring.

h) Facilitate knowledge exchange on best practices for the management and governance of water systems for FSN.

International research organisations (such as the CGIAR) should:

i) Take a lead role in research and development initiatives that seek to investigate the global issues related to water for FSN.

7. Foster an inclusive and effective governance of water for FSN

States should:

a) Establish effective governance mechanisms to strengthen policy coherence across sectors to ensure comprehensive water and FSN strategies.

b) Coordinate agriculture, land and water governance processes to ensure the full and effective participation and promote the interests of marginalized and poor disadvantaged users of common lands and pastures, water, and fisheries, particularly indigenous peoples and those whose rights are enshrined in customary arrangements.

c) Ensure the full and effective participation of all actors, including the vulnerable and marginalized, with special attention to gender inclusive processes, in the development of policies and practices for the conservation and sustainable use of water for FSN.

d) In the context of increasing uncertainty and rapid change, ensure the participation of all actors, including the vulnerable and marginalized, in the local adaptive management of landscapes and diverse ecosystems that sustain water for FSN.

e) Ensure that all investments respect the Right to safe drinking water and sanitation and the Right to adequate food, and are guided by the Voluntary Guidelines to support the progressive realization of the right to adequate food in the context of national food security (VGRtF), by the Voluntary Guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security (VGGT), and by the CFS principles for responsible investments in agriculture and food systems, in particular in relation to large-scale land acquisitions.

f) Ensure that all parties to contracts involving large-scale investments in land (with its associated water) are held accountable for the impacts on the sustainable use of natural resources and the consequences on the livelihood and FSN of the affected communities.

g) Protect the access, use and tenure rights of the vulnerable and marginalized to land, fisheries and water in particular, especially in the face of large-scale infrastructure development.

States, Intergovernmental Organizations, as well as Civil Society Organizations and other relevant stakeholders should:

h) Support communities to take ownership of water planning and management at relevant levels.

i) Comply with principles of good governance such as Free Prior and Informed Consent (FPIC) and build capacities about them.

States should

j) Recognize community-based actors and empower them with regard to water conservation and sustainable use of water for FSN in order to have a greater impact on outcomes.

k) Use the VGGT in the context of water for FSN, recognizing the particular relevance of article 8.3 on collective rights and common resources, and Section 9 on Indigenous Peoples, to develop, implement and assess policies and programmes, particularly those that affect access to water for FSN.

The CFS and relevant international water platforms should:

l) Jointly organize a special meeting inviting all food security, nutrition and water-related actors to discuss how to coordinate policies and programmes toward progress in the FSN outcomes of their activities.

8. Promote a rights-based approach to governance of water for FSN

States must:

a) Comply with their obligations under international human rights treaties and similar agreements, including but not limited to the International Covenant on Civil and Political Rights, and the International Covenant on Economic, Social and Cultural Rights.

States should:

b) Ensure the full and meaningful implementation of the existing Right to safe drinking water and sanitation.

c) Ensure the full and meaningful realization of the Right to adequate food, and the full and meaningful implementation of the VGRtF, fully taking into account the contribution of water to FSN.

d) Ensure the full and meaningful implementation of the VGGT in such a way that it takes into account the inextricable relationship between land (fisheries and forests) and water, and the associated tenure rights.

e) Fully take into account, in the governance of water, the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF) and the importance of quality water streams and bodies for inland fisheries and aquaculture.

f) Assess the direct and indirect effects, of the development and implementation of water and/or land related policies, interventions and investments, on the realization of Right to safe drinking water and sanitation, and of the Right to adequate food.

g) Implement the UN Declaration on the Rights of Indigenous Peoples, particularly in the context of laws and policies that affect water for FSN.

The CFS should:

h) Provide guidance on how to ensure access to water for FSN when implementing the VGGT and the VGRtF, based on experiences of members and participants of the CFS, as well as on technical work by FAO.

The United Nations Human Rights Council and its Special Procedures (especially the Special Rapporteurs on the Human Right to Safe Drinking Water and Sanitation, the Right to Food, the Right to Health, the Rights of Indigenous Peoples and the Independent Expert on Human Rights and the Environment) should:

i) Address in their work means to strengthen the realization of the Right to drinking water and sanitation and to explore the implications of the linkages between water and FSN on the realization of human rights.

j) Provide guidance on the relevance and possible use of the Maastricht Principles on Extraterritorial Obligations of States in the Area of Economic, Social and Cultural Rights, as related to water for FSN.

INTRODUCTION

Water is life, in symbolic and material dimensions. It is integral to human food security and nutrition (FSN) and it is the lifeblood of ecosystems upon which all humans depend, including forests, lakes and wetlands.[9] Water of sufficient quantity and quality is essential for agricultural production and for the preparation and processing of food (CA, 2007; FAO, 2012a; Rosegrant *et al.*, 2002). At global level, irrigated agriculture (including food and non-food crops) accounts for 70 percent of all water withdrawals, while 20 percent is for industrial uses, including energy production, and 10 percent for domestic uses (WWAP, 2014). Thus, water for food production and specifically irrigation is the sector that by far accounts for most freshwater withdrawals.

Safe drinking water and sanitation are fundamental to the nutrition, health and dignity of all (UNDP, 2006). Inadequate access to safe drinking water, sanitation facilities and hygiene practices can undermine the nutritional status of people through water-borne diseases and chronic intestinal infections (Humphrey, 2009). Women and girls often bear the drudgery of fetching water in difficult conditions.

In most parts of the world, however, water is a resource under increasing stress. Population growth, rising incomes, changing lifestyles and food consumption towards more livestock products, as well as demands from mining, and for energy generation and manufacturing (among others), are all increasing pressure on limited freshwater resources. Pollution from agriculture and industry is rendering water unfit for use and undermining ecosystem health. Unsustainable use and management are reducing terrestrial and aquatic ecosystem functions from land, fisheries, forests and wetlands, including their ability to provide food and nutrition.

Current trends in population growth and shifts towards increased use of animal-based food in affluent communities across the world are expected to require world food and feed production to increase by 60 percent between 2005 and 2050 (FAO, 2012a). The implied increase in pressure on water resources for agriculture, in an era of increasing competition among different water uses more generally, brings to the fore the issues of water scarcity, availability and access (see Camdessus, 2004; Fishman, 2012). How to address problems at the intersection of water and food security is a difficult challenge for society as a whole. Water availability is uneven and variable over time and space. It is conditioned by complex interactions of rainfall, temperature, wind, runoff, evapotranspiration, storage, distribution systems and water quality.

In this context, in its 40th session the Committee on World Food Security (CFS) requested the High Level Panel of Experts on Food Security and Nutrition (HLPE) to prepare a report on water and food security for its 42nd session in 2015, noting that water and its important role in and impacts on food security *“should be seen in the wider context of the nexus between water, soil, energy and food security which is recognized as a pillar of inclusive growth and sustainable development.”*.

This report explores the relations between water and food security and nutrition, from household levels to global levels. It investigates these multiple linkages, in a context of competing demands, rising scarcities, and climate change. It proposes ways for improved water management in agriculture and food systems, as well as ways for improved governance of water, for better food security and nutrition for all, now and in the future. The report is deliberately oriented towards action. It provides examples and options to be implemented by the many stakeholders and sectors involved, given regional and local specificities.

To prepare a short report on such a broad topic is particularly challenging. It requires adopting numerous perspectives and methodological approaches, at various scales, from global to households, covering very diverse situations.

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9 The World Food Summit in 1996 adopted the following as a definition of food security: *“Food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.”* (FAO, 1996a). This definition is based on four dimensions of food security. Food availability: the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports. Food access: access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Utilization: utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. Stability: to be food secure, a population, household or individual must have access to adequate food at all times.

Water availability, access and use depend on context-specific social-economic, cultural and political factors as well. Water shortages increase competition within and across sectors: water is often taken away from the agriculture sector, driven by greater economic return per unit of water in other sectors, while smaller, and poorer, agricultural water users tend to lose access. These problems tend to disproportionately affect poor and marginalized women, men and children, because of existing power imbalances, skewed access to resources, structural discrimination and gender inequalities. Inequality in access to water supply is due in part to prevailing cultural, gendered and socio-political norms. Some groups suffer from lack of water even when there is more than sufficient water available in a region.

Although water scarcity is often analysed on the basis of per capita water availability, this lens risks overlooking inequalities in access when applied to the population of the world as a whole (Sen, 1981). For this reason, water shortages can be best understood as entitlement failures requiring effective and democratic governance solutions that can be accepted as legitimate by all (Mehta, 2014). The ability of vulnerable communities to meet their basic nutritional food needs depends on effectively and efficiently allocating and utilizing available water resources, especially in regions marked by water scarcity. Climate change is likely to worsen water scarcities. As our water resources come under increasing pressure, with competing uses, conflicts are likely to grow between urban and rural, upstream and downstream, and in-stream (aquatic resources) and off-stream (mostly human) users (CA, 2007). The underlying questions are: how can water management in agriculture be improved for better FSN outcomes? And who should get what access to which water when, for how long and for what purposes? This question, and how to answer it within a single water basin, or at country level, given FSN concerns, is one of the main issues around water governance. It can be complicated when a water basin is shared between different administrative regions or even countries.

The report uses a variety of sources. The *Comprehensive Assessment of Water Management in Agriculture* (CA, 2007), published in 2007, deserves a specific mention. Co-sponsored by the CGIAR, the secretariat of the Convention on Biological Diversity (CBD), FAO and the Ramsar Convention on Wetlands, it involved a broad range of experts and organizations from both agricultural and environment communities. As such it provided particularly important data and analyses, many of which are used in this report.

The report is organized as follows. Chapter 1 highlights the multiple linkages between water and FSN and provides an overview of global and regional trends, as well as of the emerging challenges that are critically affecting water for FSN now and in the future. Chapter 2 considers how to manage water scarcities in agriculture and food systems and explores a range of approaches and alternative pathways to improve water management and conserve water in order to reduce risk and improve food security amidst growing uncertainties. Chapter 3 looks at water governance in its various dimensions and how it relates to food security and nutrition.

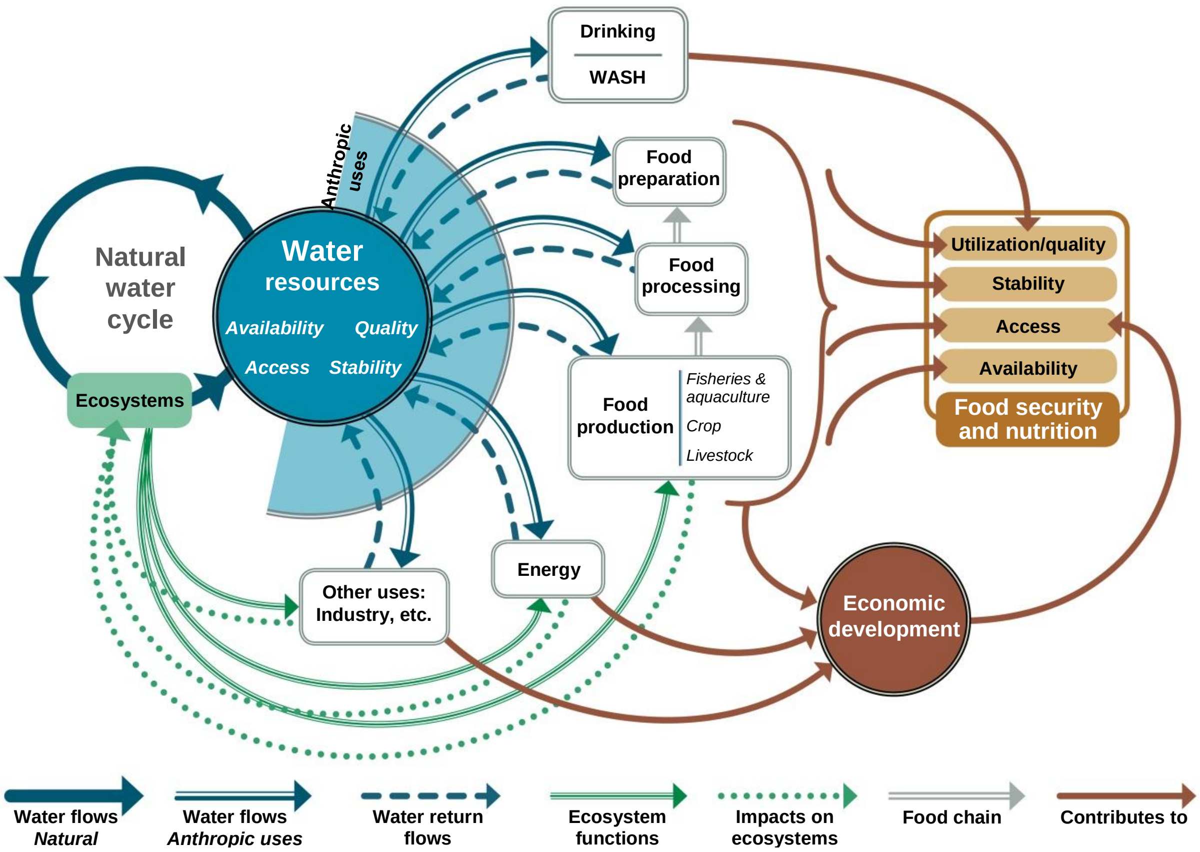
1 WATER FOR FOOD SECURITY AND NUTRITION: CHALLENGES FROM GLOBAL TO LOCAL

This section explores the relationships between water and food security and nutrition (FSN), from household level to global level. It investigates these multiple linkages by considering water along four dimensions: availability, stability, quality and access, in a context of competing demands, rising scarcities and climate change.

1.1 Charting the multiple linkages

Water determines food security and good nutrition in numerous ways (Figure 1). It is the lifeblood of ecosystems, including forests, lakes and wetlands, on which depend the food security and nutrition of present and future generations. Water of appropriate quality and quantity is essential for drinking and sanitation, for food production (fisheries, crops and livestock), food processing, transformation and preparation. The quality of drinking water conditions the effective absorption of nutrients by the human body. Water is also important for the energy, industry and other economic sectors. Water streams and bodies are often key ways for transport (including inputs, food and feed). All in all, water supports economic growth, and income generation, and thus economic access to food.

Figure 1 The multiple interfaces between water and food security and nutrition (FSN)



On the left-hand side of the figure, four dimensions of water, considered as a resource for anthropogenic uses, are highlighted:

1. Availability of water: in terms of its physical availability through rainfall, rivers and aquifers in a particular region.
2. Stability of water: availability, access and quality of water are variable through time. This results from natural cycles, but also from human interferences in the water cycle, through changes in return flows and ecosystem degradation. Different water resources may behave very differently in terms of stability.

3. Quality of water: water quality in terms of FSN has different implications according to its uses; water quality needs for irrigation vary by crop, are high for food processing, food preparation and drinking, and are important for health and hygiene. Food (and non-food) production and processing may, however, also have a negative impact on water quality (pollution).
4. Access to water: while there may be sufficient water in rivers, lakes and aquifers, issues pertaining to allocation and authorization to use water, and the infrastructure necessary to use the water where it is required (pumps, pipelines, taps, canals, etc.) may support access to water for food security and nutrition, or hinder it. This infrastructure also affects stability of supply. Access is also shaped by socio-cultural, economic and political factors.

These dimensions of water mirror those from the definition of food security (see also a similar approach by Webb and Iskandarani, 1998). Linkages between water, its four dimensions presented here, and FSN are multiple, and operate at various levels, including at individual and household level. Water is necessary for all the *"activities, processes and outcomes"* (cf. Ericksen *et al.*, 2010) related to the food system.[10] The framework in Figure 1 indicates multiple entry points for considering the effects of water and water use on FSN.

First, drinking water is a food (Codex Alimentarius[11]). Quality and availability of water are paramount for drinking water, and are also important for other domestic uses and hygiene or WASH,[12] which are key determinants for good nutrition and health.

Second, water is necessary for food production (fisheries, crops and livestock), food processing (industrial to household level) and food preparation (at household level as well as by formal and informal food vendors). The vast bulk of global freshwater withdrawals – about 70 percent – is used for agricultural purposes (including non-food crops), with relatively small amounts of water required for food processing and preparation.

Water is also essential for industries and for economic growth in general. As such water used in non-agricultural sectors can contribute to FSN by increasing incomes and facilitating access to food. However, competition for water can have negative impacts on food production and especially on access to water of smallholders and on their FSN.

Water streams and bodies are often key ways for transport (including inputs, food and feed). For instance, many areas of South Sudan have been cut off from road access because of fighting and the rainy season. Barge transport enables WFP to move food in bulk, and is less costly than air transport (UN, 2014).

1.2 Global and regional availability of water resources

Fresh water can be available from three different sources: rainwater (precipitation, including snow) – which is the parent of all continental water – surface waters (including melting snow and ice) and groundwater.

How much water is available for human use in a given period of time? The earth's land surface receives about 110 000 km^3 of rainfall annually. Of this amount, about 40 000 km^3 become available in dams, lakes, rivers, streams and aquifers (this is often called "blue water") for human and environmental use (WWAP, 2012; CA, 2007; Gleick, 1993). Groundwater aquifers receive

[10] The HLPE defines the food system as follows: "A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" (HLPE 2014a: 29). The complexity of food security requires a complex framework that encompasses social, political, economic, and ecological issues and must also include the "activities, processes and outcomes" related to food (Ericksen *et al.,* 2010: 27).

[11] For the purposes of the Codex Alimentarius: food means any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs (FAO/WHO, 2011).

[12] Water, sanitation and hygiene (WASH) are generally grouped together as research has shown that advances in all three areas are needed to reduce child mortality, improve health and education outcomes, and contribute to reduced poverty and sustainable development.

approximately 13 000 km^3 of this annual runoff (Döll, 2009). Discharge to the sea represents close to one third of the total annual land rainfall (CA, 2007).

The 70 000 km^3 of precipitation on land that does not run off or recharge groundwater is stored in soils, and ultimately evaporates or is transpired through plants. It is also known as “green water”.

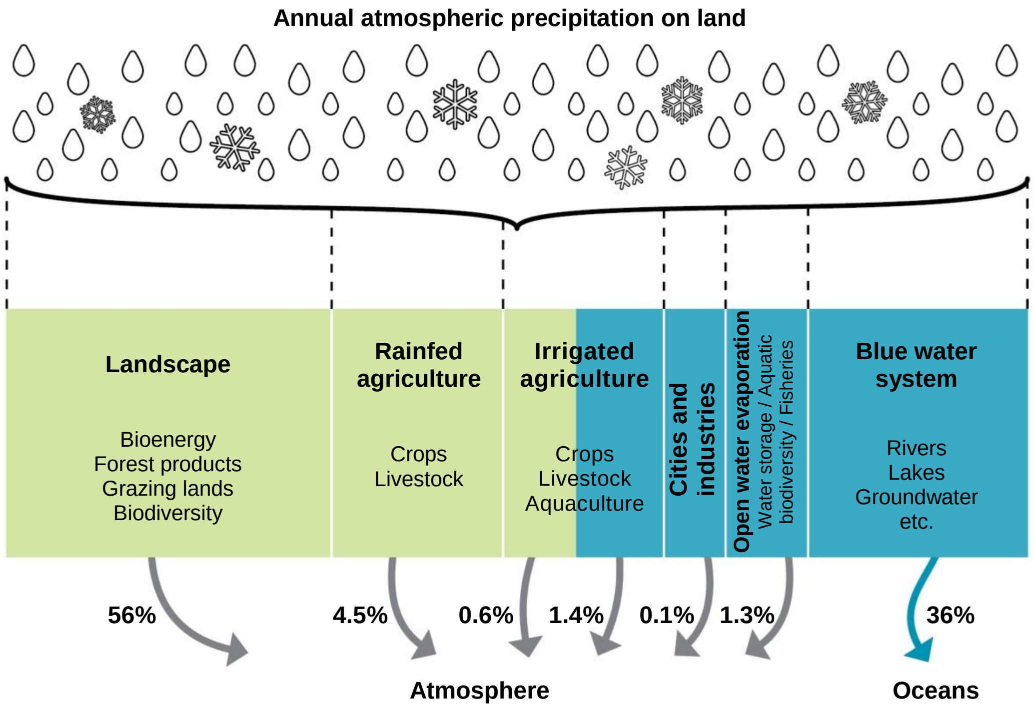
All forms of available water are important for agriculture and food security. Agriculture consumes or evapotranspires about 7 130 km^3 of water – 5 560 km^3 of which is directly from precipitation and 1 570 km^3 from irrigation, based on irrigation withdrawals of about 2 644 km^3 (CA, 2007).

When rainfall is insufficient or not reliable enough agriculture needs to rely on irrigation, which compensates for scarcity or irregularity of green water availability. Runoff can be re-used many times within a watershed or river basin, often degrading the quality of the water resource along the way. In some cases, when both green and blue water are insufficient, seawater is desalinized for FSN. However, due to the high cost of this process, this water is generally used for drinking and other domestic purposes.

While annual renewable freshwater resources are adequate at global levels to meet human water needs, these resources are very unevenly distributed across the globe. Per capita annual renewable water resources are particularly low in the Middle Eastern, North African and South Asian regions (see Table 1). There are also significant variations in water availability within regions and countries. Uneven water resource distribution can translate into uneven capacity to grow food and affect food availability and access.

Water may be abstracted or withdrawn from a reservoir at a rate that is greater than its replenishment rate, leading to the depletion of the reservoir (lake or aquifer). The term renewable water resources describes the long-term average annual flow of rivers (surface water) and groundwater. Deep groundwater aquifers often have a negligible rate of recharge on the human timescale and thus can be considered a non-renewable resource (FAO, 2006).

Figure 2 Global water use (consumption)



This figure is a schematic representation of the net use (consumption) of water through the terrestrial water cycle. Consumption of water means water that is evaporated to the atmosphere or that is embedded into produce. A withdrawal of water by a user (such as for irrigation) is never totally consumed, as part of it returns to land, to rivers etc. Blue water is the water in the surface and groundwater runoff system: rivers, lakes, aquifers, etc. Green water is the water that does not runoff and is kept as moisture in soils or on top of the vegetation.

Source: adapted from CA, 2007.

Table 1 Per capita internal renewable water resources (m^3/capita/year)

Regions	2010	2050
North America	13 287	10 171
Latin America and Caribbean	21 450	16 957
South Asia	1 325	910
East Asia and Pacific	4 279	4 129
Europe and Central Asia	7 756	7 572
Middle East and North Africa	778	506
Sub-Saharan Africa	5 492	2 645
Developed countries	7 510	6 099
Developing countries	5 353	3 956
World	5 675	4 250

Source: IFPRI IMPACT model simulations for IAASTD, 2009.

In many parts of the world water resources are under increasing stress. Population growth, rising incomes, changing lifestyles and diets, and growing demands for different uses of water, are all increasing pressure on limited freshwater resources. Water availability and its capacity to satisfy demand are very different by regions. This results in very contrasted degrees of withdrawals as compared with available renewable resources. Total water withdrawals for agriculture, energy, industry, accounted in 2013[13] to globally 9 percent of internal renewable resources, a number ranging from 2.2 percent for Latin America and Caribbean, to 122 percent in Middle East and North Africa.

Pressure on water resources varies greatly by country or region. Europe withdraws only 6 percent of its internal resources, and just 29 percent of this goes to agriculture. The intensive agricultural economies of Asia withdraw 20 percent of their internal renewable resources, of which more than 80 percent goes to irrigation. In many of the low rainfall regions of the Near East, Northern Africa and Central Asia, most of the exploitable water is already withdrawn, with 80–90 percent of that going to agriculture, and thus rivers and aquifers are depleted beyond sustainable levels (Frenken and Gillet, 2012). Western, Central and South Asia use half or more of their water resources for irrigation, and in Northern Africa, withdrawals for irrigation can exceed renewable resources as a result of groundwater use and of recycling. Among the 40 percent of land irrigated partially or totally with non-renewable groundwater figure key food production areas in China, India and the United States of America (Place *et al.*, 2013).

With population growth, by 2050 per capita internal renewable water resources are expected to diminish by 25 percent from 2010 levels, with important regional differences (see Table 1). Thus a key element of the issue of water for FSN is the concept of increasing water scarcity (FAO, 2012a; Falkenmark and Lannerstad, 2005).

According to OECD's business as usual scenario (OECD, 2012), in 2050, 2.3 billion more people than today (in total over 40 percent of the global population) will be living in river basins experiencing severe water stress.[14]

Water stress and water scarcity are generally defined by the difference between water availability – the level of renewable water resources (rainwater, surface water and groundwater) available, within a certain area – and a certain demand for water, including basic needs. There are, however, as many perspectives on "water scarcity" and water stress as there are perspectives on water availability and on water demand.

[13] World Development Indicators (World Bank database) estimates per 2013 as per available figures.

[14] For OECD, severe water stress is a situation when water withdrawals exceed 40 percent of recharge, therefore water stress refers to difficulties to meet human and ecological demand for water.

In situations of water stress the demand for water can exceed the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of freshwater resources in terms of quantity (aquifer overexploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.); it has short-term and long-term effects on water for FSN (drinking water, irrigation water, etc.).

Some authors (Falkenmark and Widstrand, 1992) have come to define "scarcity" levels by pre-determined thresholds, such as 1 700 m^3, 1 000 m^3, or 500 m^3 ("absolute scarcity") of available water per person per annum, which were determined to cover all uses including agriculture (irrigation) and other economic sectors. It is often referred as "physical water scarcity", which compares the amount of renewable water annually available per capita in a particular area (for example, Table 1) with these determined thresholds, to identify water-stressed and water-scarce areas.

Other authors have defined "economic water scarcity" to define situations where water is physically available in the environment to, in theory, meet the demand, but not provided where it is needed and at the quality needed, due to economic factors, such as a lack of infrastructure, storage, distribution systems, etc. (CA, 2007).

Similar situations in terms of water availability can mean very different situations in terms of water scarcity or stress, which are determined not only by availability but also by the different demands of water. In fact, water scarcity can also be encountered in water-rich regions, if there is an excess of water demand, with often increasing and badly managed competition for water use between sectors, agriculture, energy, industry, tourism, household use (CA, 2007).

One could define "social water scarcity" for situations where part of the population does not have access to water in sufficient quantity and quality, for drinking and sanitation, as well as to sustain their livelihoods. Availability of water, often expressed in order to present easily comparable figures, as an average volume per capita or per hectare, very often hides considerable inequalities in access to the resource (see Section 1.5). There are few reliable figures at a smaller scale. Moreover, average figures do not enable an adequate perception and description of the reality of water scarcity at farm and household level (Mehta, 2005; UNDP, 2006).

1.3 Stability of water for FSN

The stability of water resources is primarily affected by climate (Section 1.3.1), itself affected by climate change (Section 1.3.2). Stability is further determined by geophysical, demographic and socio-economic factors, and by different levels of storage (Section 1.3.3) and infrastructure providing access. Needs for stability of water provision vary by type of water use. For example, drinking and industrial water uses generally require stable, constant flows, whereas agricultural water needs are directly related to cropping seasons, crop types and associated climatic factors.

Availability and stability of surface water depend on precipitations and on the geography of the hydrological system, which can spread over very wide, up to continental scales, and include natural reservoirs, such as glaciers. Precipitations are often very variable over time (intra-annual variability and also inter-annual variability), as they result from complex climate cycles. From a water user perspective, surface water provides, especially in wide basins, a buffer to the irregular availability of rainwater. Groundwater is an even more stable source of water and 40 percent of irrigation uses groundwater sources. It is a considerable opportunity especially for regions that have no other sources. However, it is also a major challenge for the future as much groundwater is not renewable, and slowly replenishing reservoirs can get quickly depleted. Some "fossil" groundwater reservoirs are replenished only on a geological timescale, thousands or even millions of years.

1.3.1 Inherent, climate-induced variability of water resources over time

Availability of water, driven by climate, varies considerably over time, with significant intra- and inter-annual variations concentrated in poorer regions (Grey and Sadoff, 2007). Very high variability can translate into floods and droughts (periods of below average rainfall), which can have significant impacts on the production of food and on FSN in affected areas.

Droughts can result in crop failure and the death of livestock, particularly in areas of rainfed agriculture. Figure 3 describes the severity of droughts worldwide over the past century, highlighting those areas most susceptible to intense droughts, which can extend over several years. Box 1 describes some recent droughts.

Box 1 Recent droughts

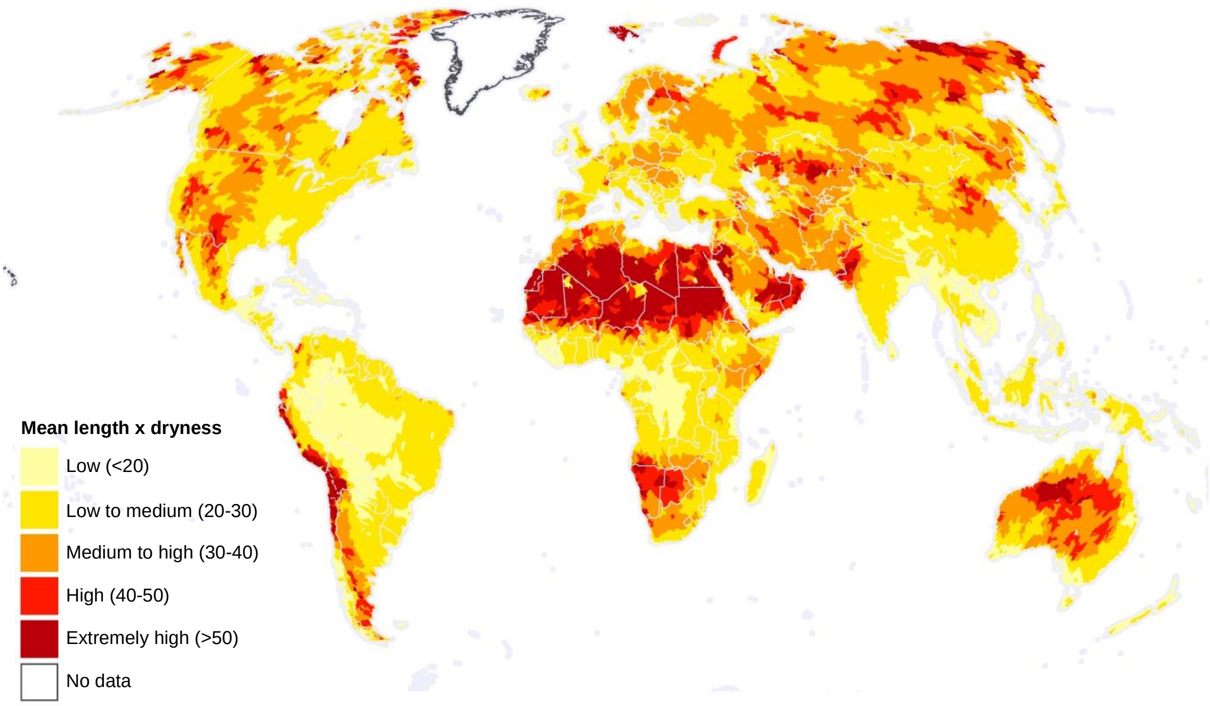
According to FAO, the Horn of Africa has been affected by droughts virtually every year for the past 12 years. Kenya experienced severe droughts in 2009 and 2011, with its agricultural production most severely impacted in 2009 where wheat yields were 45 percent below than in 2010. Australia suffered multiyear droughts between 2002 and 2010 with a drop in total Australian wheat yield by 46 percent in 2006 (below the 1960–2010 yield trend level). The 2010 drought in the Russian Federation, the worst in 38 years, was long, intense, spread over a sizeable area and resulted in serious environmental, social and economic impacts. The 2011 United States drought covered the southern states with Texas, Oklahoma and New Mexico most adversely affected while parts of Arizona, Kansas, Arkansas, Georgia, Florida, Mississippi, Alabama, South and North Carolina were also affected (source: FAO Land & Water, n.d.). In 2014, Brazil witnessed a massive drought situation due to erratic patterns of rainfall. This had significant impacts on the productive capacities of several sectors, which included fisheries, agriculture and industry, amidst a series of water conflicts (Watts, 2014).The impacts were so severe that water supply in cities had to be rationed, which affected the water access of the marginalized urban population (Davies, 2014).

Floods can sweep away villages, roads, crops, livestock and people, leaving affected communities without houses, services and food. Floods can result in the contamination of water supplies, resulting in outbreaks of disease and lowered nutritional security of affected populations (see also HLPE, 2012).

High climate variability can seriously affect food and nutrition security in the affected areas.

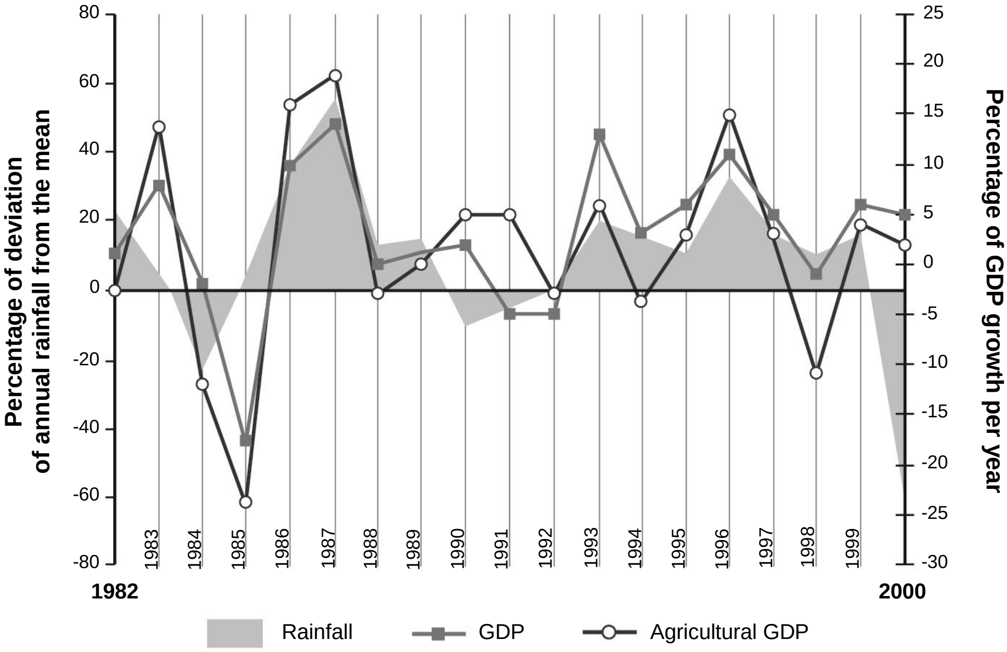
Grey and Sadoff (2007) show a correlation between rainfall and agricultural and economic growth in countries that are highly dependent on rainfed agriculture (see Figure 4 for Ethiopia). In these regions, crop failures during periods of drought not only increase the incidence of hunger among poor and rural people but also reduce the purchasing power (and FSN) of the general population and the state of the overall economy as failed crops have to be replaced with more expensive food. This also reduces the capacity of the state to intervene as scarce budgetary resources might need to be transferred from key public services, such as education and health, to disaster relief and food imports.

Figure 3 Drought severities, 1901–2008



Source: graphical elaboration from Gassert *et al.* (2013), data from Sheffield and Wood (2007).

Figure 4 Rainfall, GDP growth and agricultural GDP growth in Ethiopia



Source: adapted from Grey and Sadoff (2007).

Furthermore, high variability of resources and uncertain, changing patterns of rainfall can hinder farmers and other actors from investing in production, as *"the outcomes and returns seem so uncertain from year to year"* (Cooper *et al.*, 2008: 26).

1.3.2 Climate change and induced variability of water resources

In many parts of the globe, temperatures are increasing and historical rainfall patterns are changing as a result of climate change. Climate change is adding significant uncertainty to the availability of water in many regions in the future. According to the IPCC (2012), there is "medium confidence" that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration. This includes central and southern Europe and the Mediterranean region, central North America, Mexico and Central America, northeast Brazil and southern Africa. Climate change will affect precipitation, runoff, water quality, water temperature and groundwater recharge. In many regions changes in precipitations and snow/ice melt are changing hydrological systems. Climate change will also significantly impact sea level.

In regions with high food insecurity and inequality, these changes will particularly affect poorer households and may disproportionately affect women, given their vulnerability and restricted access to resources (IPCC, 2014). Climate change will particularly put at high risk indigenous peoples, who depend on the environment and its biodiversity for their FSN– specifically those living in areas where significant climate change impacts are expected such as mountain regions, the Pacific Islands, coastal and other low-lying areas, and in the Arctic (IPCC, 2014).

There are a number of challenges to estimate impacts of climate change on future water availability. First, there are a series of general circulation models and global climate models available, but they result in significantly different predictions of rainfall changes, especially at finer geographical scales. Second, changes in rainfall do not linearly correlate with changes in water availability: factors such as rainfall duration and intensity, surface temperature and vegetation all play a role in determining what percentage of rainfall is converted into surface water run-off into rivers, dams and wetlands, or into groundwater. Climate change will also reduce glaciers, which often play a key role to provide river flows in summer. Current models only imperfectly capture these mechanisms, and there is a need for more research to be able to more accurately assess national, regional and local impacts of climate change on water, particularly in areas of greatest vulnerability.

The impacts of changed rainfall patterns on water quality have not been sufficiently studied; heavy rainfall may well increase pollutant loadings, which would impact the quality of raw water for agriculture, industries and other uses as well as for drinking purposes, exacerbating existing access and quality problems (IPCC, 2014; ODI, 2011).

Finally, adaptation to climate change needs to carefully consider competing water uses and their various implications for FSN. Measures that can mitigate one type of adverse impact could also exacerbate another. For example, increased storage infrastructure to meet the water needs of irrigated agriculture arising from increased crop water demands, higher evapotranspiration and longer or more intense dry spells might negatively impact downstream fisheries.

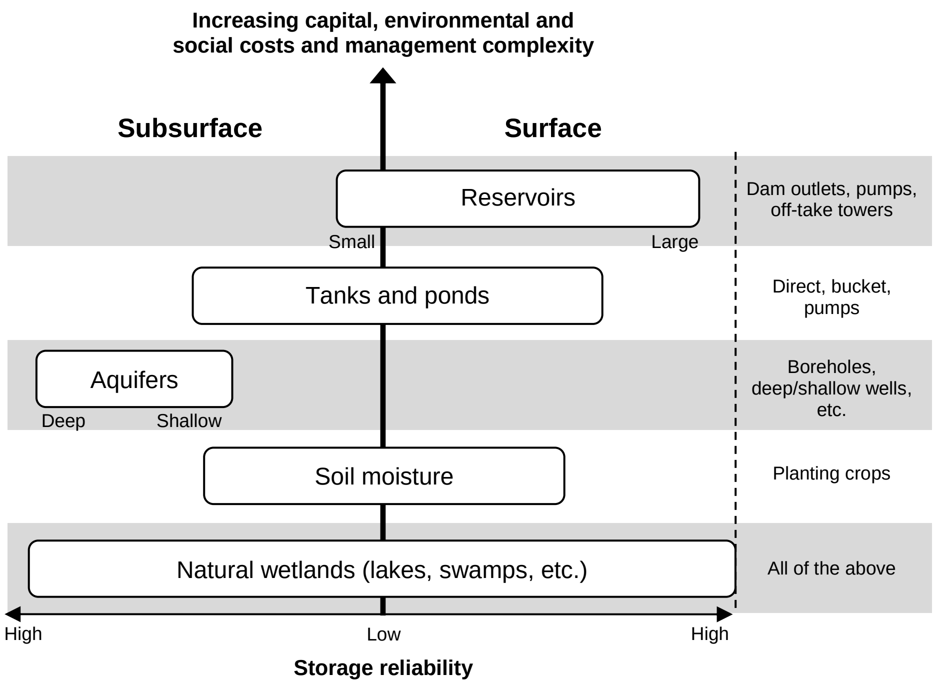
1.3.3 Increasing importance of storage and of groundwater resources

Water storage increases stability of water for FSN and other uses. The continuum of storage options includes natural storage mechanisms, such as aquifers, lakes, natural wetlands and soil moisture, and human-made storage, such as reservoirs, ponds and tanks (Figure 5). Storage options vary by reliability, environmental and social costs, management complexity and accessibility (see also Chapter 2, Section 2.2). Over the last 50 years, reservoir storage and use of aquifer resources through groundwater extraction have rapidly increased, improving the stability of water for FSN.

Adaptation to climate change will among others require additional investments in reservoir construction and irrigation, which have been estimated at a total of US$ 225 billion (or 11 billion per year) until 2030 for the IPCC A1B scenario (IPCC, 2014).

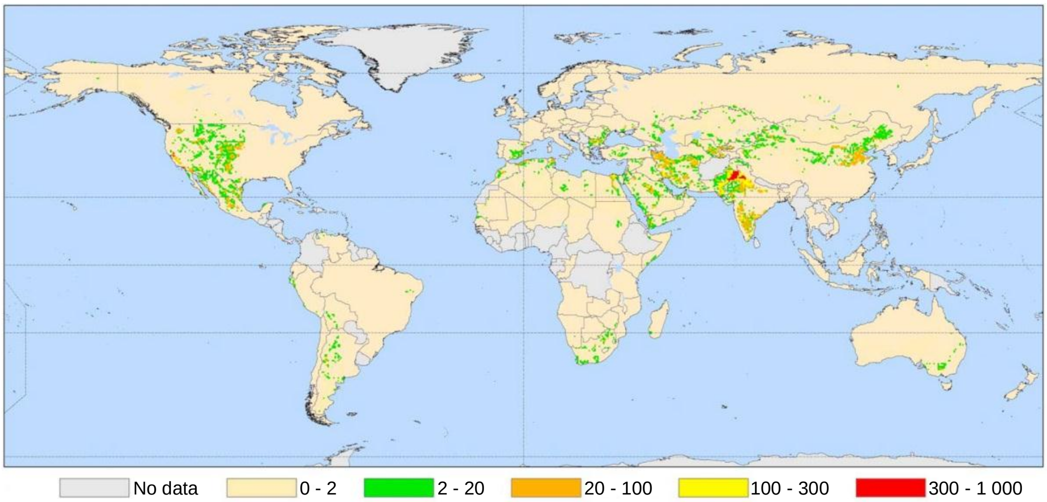
Many municipalities and industries have come to rely on groundwater as a more stable source of water compared with surface sources. But most groundwater withdrawals today are used in agricultural production to supplement scarce or substitute for lacking surface sources. However, information on groundwater, which is not visible and is more complex and costly to measure, is scarce. Even less information exists on access to and use of shared groundwater resources. According to Döll *et al.* (2012), 35 percent of all water withdrawals during 1998–2002 were from groundwater, and groundwater contributed 42 percent of all irrigated water use, 36 percent of domestic use and 27 percent of total manufacturing use.

Figure 5 Water storage continuum



Source: adapted from McCartney and Smakhtin (2010).

Figure 6 Ground water depletion for the year 2000



Source: Wada *et al.* (2010), data in mm/yr.

Groundwater abstraction is estimated to have increased from 312 to 734 km^3 annually between 1960 and 2000 (Wada *et al.*, 2010). Over the same period, groundwater depletion might have increased from 126 km^3 to 283 km^3 per year (Wada *et al.*, 2010). This has resulted in over abstraction in many areas (see Fig. 6), particularly in India, Pakistan, the United States of America and China, which are also the largest groundwater users.

Groundwater can also be subject to degradation and pollution, such as saline intrusion in coastal areas, or contamination with arsenic or other toxic chemicals.

1.4 Quality of water for FSN

The many potential uses of water, from drinking and sanitation, to growing food, energy, mining, manufacturing, etc. typically require different quantities and qualities of water, and therefore often specific treatment, which can be done at the source, or closer to the user, or even by the end-user itself (household or industry). Also, irrigation water quality needs vary by crop. This leads to trade-offs for the provision of water services, between their specialization versus a “multiple use approach” to serve different purposes or uses. Future water stresses will be compounded by issues of water quality.

Poor water quality affects human health and ecosystems’ functioning. High water quality standards are needed for drinking water and important for other WASH components, and are important for food processing and preparation. Lack of access to safe and clean water for drinking and hygiene was identified long ago as a key underlying cause of malnutrition, particularly in children (UNICEF, 1990). Drinking water quality has improved in many developed countries over the last several decades and is supported by regulations and monitoring. In most parts of the global South, water quality and associated food safety risks still have adverse impacts on both human and ecosystem health.

1.4.1 Safe drinking water and sanitation and hygiene practices

Safe and reliable water supply, sanitation and hygiene practices (WASH) are basic necessities, required to ensure human development and to allow human activity to flourish (Mehta, 2014). Drinking water can also provide important micronutrients, particularly fluoride, calcium and magnesium, although risks of undesirable or excess elements, such as fluoride or arsenic, exist in certain regions (Olivares and Uauy, 2005; Wenhold and Faber, 2009). Poor quality water is a major cause of diarrhoea (Box 2). Several water-related diseases directly lead to food and nutrition insecurity: water-borne diseases such as cholera, water-washed (or faecal-oral) diseases such as environmental enteropathy; water-based diseases such as schistosomiasis and other parasitic worms; and water-related and vector-borne diseases such as malaria. Easy access to safe and convenient water supplies is also crucial to enhance women’s and girls’ well-being.

Drinking water

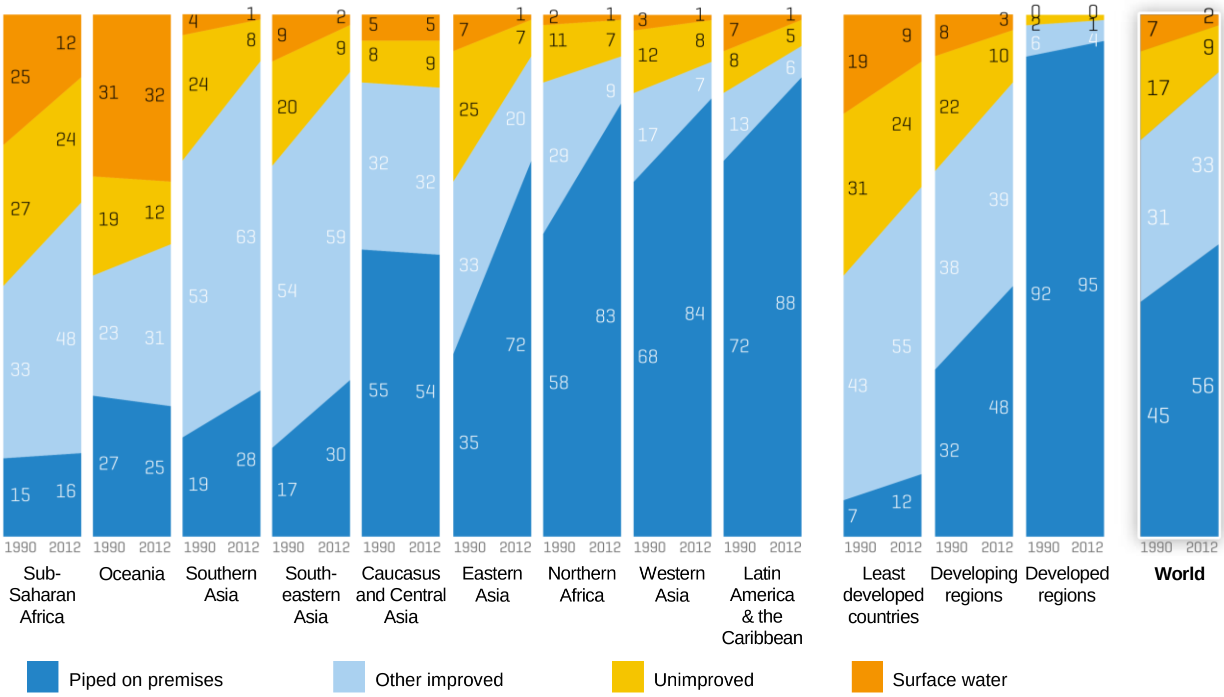
In March 2012, well in advance of the MDG 2015 deadline, it was announced that the world had, in 2010, met the Millennium Development Goal (MDG) of halving the proportion of people without sustainable access to safe drinking water. Between 1990 and 2012, 2.3 billion people gained access to improved drinking water sources, (sources that, by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter) such as piped supplies and protected wells. Global coverage now stands at 89 percent (WHO/UNICEF Joint Monitoring Programme, 2014) (see Figures 7 and 8).

However, 768 million people still use unimproved sources of drinking water; and safe drinking water coverage is only 56 percent in Oceania and 63 percent in sub-Saharan Africa. Other regions have coverage rates of 86 percent or higher (WHO/UNICEF Joint Monitoring Programme, 2014). Figure 7 shows the trends in safe drinking water coverage in nine regions across the world.

Access to an improved water source is often assessed through available infrastructure without enough information on whether the improved source is (still) functioning, whether the quality of the water provided meets WHO standards, or whether the structures are actually used. For instance, the figures provided by the South African Government on the delivery of safe drinking water and sanitation are based on a national collation of figures provided by municipalities in terms of infrastructure provided, and do not always reflect the functionality of the infrastructure or the reliability of the service provided (see Box 31, Chapter 3). Moreover, existing data are often not sufficiently disaggregated to allow for monitoring of intrahousehold inequalities in access based on gender, age or disability (WHO/UNICEF Joint Monitoring Programme, 2014).

Urbanization increases both water demand and pollution, putting pressure on water supplies (WWAP, 2009). Denser populations and inadequate infrastructure can lead to poor wastewater management, and changing urban landscapes can cause higher run-off of pollutants into local water supplies. Data from the Joint Monitoring Programme indicate that, although urban areas have better access to improved water sources than rural areas, the number of people without access to improved water sources in urban areas continues to increase (WHO/UNICEF Joint Monitoring Programme, 2014) as urban populations grow faster than supporting water infrastructure and services.

Figure 7 Trends in drinking water coverage (percentage) 1990-2012



Source: WHO/UNICEF Joint Monitoring Programme (2014).

This demographic shift also results in large informal settlements where people do not have access to safe drinking water or adequate sanitation. Public water provision services often do not reach informal settlements, leaving small-scale independent providers to fill the gap. These small-scale providers sometimes provide water at competitive prices (Schaub-Jones, 2008). However, there is also evidence that poorer households in informal settlements pay more for their water supplies through these small-scale providers than wealthier households pay in the city centre and, since provision is not monitored, the poorer households have little power to ensure quality water or service provision (Kacker and Joshi, 2012).

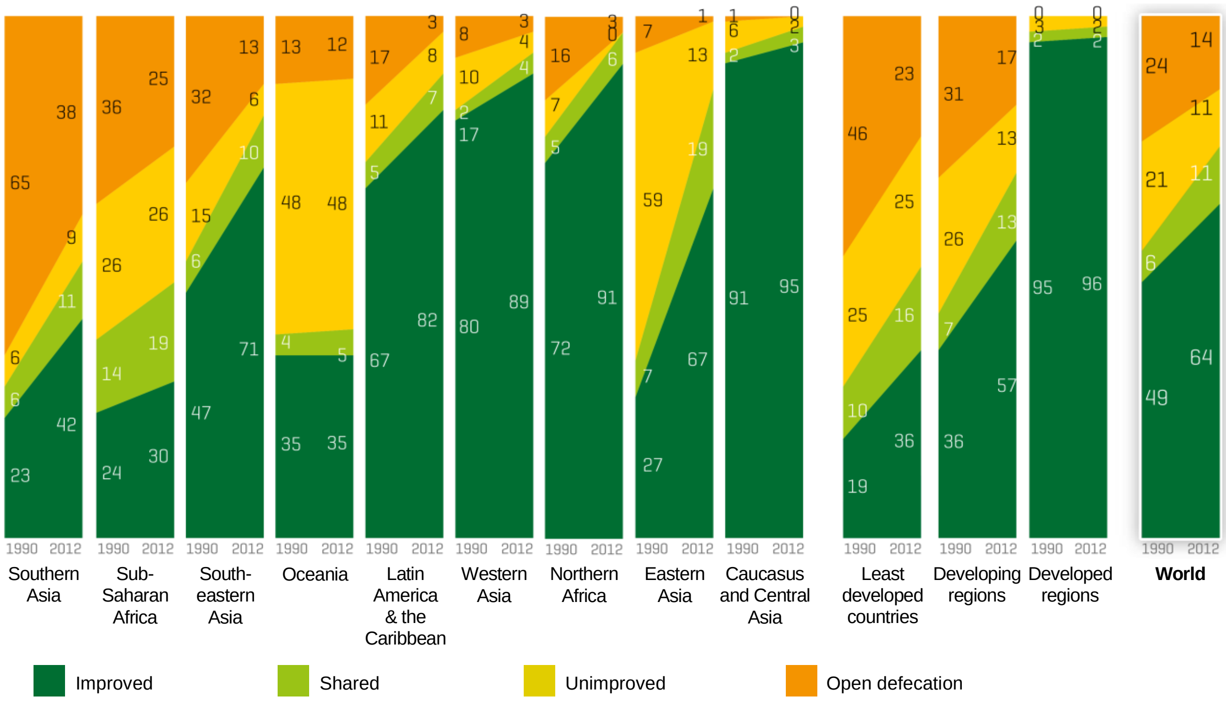
Sanitation

In 2012, 2.5 billion people still lacked access to an improved sanitation facility (i.e. facilities that ensure hygienic separation of human excreta from human contact) and, of those, 1 billion people, or 14 percent of the world population, practice open defaecation, including 600 000 people in India alone (WHO/UNICEF Joint Monitoring Programme, 2014). There are also major disparities in sanitation provision between regions, as can be seen in Figure 8, and between rural, urban and peri-urban areas. Lack of access to sanitation is a particular challenge for women who, as a result, in many societies have to defaecate at night. There are few studies assessing the impacts of lack of adequate sanitation facilities on women. A study focusing on the slums of Kampala, Uganda, found *“a firm link between a lack of access to adequate sanitation and women’s experiences of humiliation and violence”* (Massey, 2011: 3). There is also evidence that lack of safe, private toilets can impede girls’ education (WHO/UNICEF Joint Monitoring Programme, 2014).

The vast majority of those without sanitation are poorer people living in rural areas. Yet, progress on sanitation is first benefitting wealthier people before benefitting the poor, and progress in rural areas lags behind progress in urban areas, even if rural-urban inequalities tend to diminish at global level (WHO/UNICEF Joint Monitoring Programme, 2014; Mehta, 2013).

The WHO/UNICEF Joint Monitoring Programme (2014) report recognizes that, despite the fact that progress towards the MDG targets of water and sanitation represents important gains in access for billions of people around the world, there are still significant inequalities, with marginal and vulnerable groups experiencing much lower levels of delivery than other groups.

Figure 8 Sanitation coverage trends (percentage) 1990-2012



Source: WHO/UNICEF Joint Monitoring Programme (2014).

Box 2 Diarrhoea: a major cause of malnutrition?

Diarrhoea, the second leading cause of child death around the world and the leading cause in sub-Saharan Africa, is both a cause and a result of inadequate nutrition. According to WHO (2010) food- and water-borne diarrhoeal diseases kill an estimated 2.2 million people annually, most of whom are children in the global South. Repeated bouts of diarrhoea prevent children from achieving normal physical and cognitive development, while poor nutrition weakens the immune system, leading to more frequent bouts of diarrhoea. The result is a negatively reinforcing cycle. In addition, infection impacts negatively on nutritional status by reducing appetite and intestinal absorption of nutrients. It is estimated that the provision of safe drinking water, adequate sanitation and hygiene education could prevent at least 860 000 child deaths per annum (Prüss-Üstün *et al.*, 2008), suggesting that interventions on the water supply/sanitation side are important nutrition interventions. Integrating WASH, nutrition and behaviour change, based on UNICEF's nutrition framework, has been recognized as an effective means to address childhood malnutrition and has been incorporated into several public health promotion strategies (see for instance the work by Oxfam Intermón: oxfamintermon.org/es).

1.4.2 Water quality for food production and transformation

Water quality is of crucial importance for food production and transformation. Many, if not most, food-borne illnesses can be related back to poor water quality used in food production and/or post-harvest processing and/or food preparation. Water can in fact be the vehicle for both pathogens and chemical contaminants to be transferred from the environment into the food chain, thus impacting on food safety and public health. It is a complex challenge, especially in the informal food production sector and for street vendors. According to a 2007 estimate, 2.5 billion people depended on at least one meal provided by street food vendors every day (FAO, 2007), and for which meeting the challenge of a clean environment and of the provision of clean water is important for food safety.

Irrigation is also sensitive to water quality. Some crops, such as barley and sugar beet, are relatively tolerant to high salt levels, while most fruit and nut trees and several vegetables, such as beans and carrots, are highly sensitive to salinity levels (FAO, 1985). The use of treated wastewater for crop production is common in both countries of the North and South, but generally regulated in the former regarding the quality of the wastewater and the type of crops that can be watered, to address health concerns (FAO, 1985). Regulation of irrigation with wastewater is, however, weak in most countries of the global South with potential negative impacts on human health.

The growing demand for quality water accompanied by the increasing water scarcity and pollution calls for a more systematic and at the same time safe approach to water re-use. Jawahar and Ringler (2009) caution that while dietary diversification has improved the nutritional and health status in the global South, it has also added a new range of food safety risks along the value chain, principally caused by poor water management and quality, which affects particularly the consumption of fresh fruits, vegetables, dairy and other animal products.

1.4.3 Water pollution

Water quality in surface and groundwater sources is deteriorating globally as a result of the discharge of poorly or untreated sewage, effluents from mining, industry and agriculture into water bodies (including permeation through the soil into groundwater), and increased abstraction of water leading to lower dilution capacity.

Impacts include: increased contamination of water by pathogenic organisms; unacceptably high levels of trace metals and toxic chemicals; eutrophication from high nutrient levels in the water; and changes to the acidity, temperature and salinity of water. In addition, many water bodies around the world have been impacted by the presence of alien invasive species, both fauna and flora (Palaniappan *et al.*, 2010).

In most industrialized countries, the focus on water pollution control has traditionally been on point source management but it is recognized that further point source control cannot achieve major additional benefits in water quality without significant control over non-point sources (US-EPA, n.d). The link between non-point source pollution and long-term pollution of surface and groundwater has been well-established (see for instance Dubrovsky *et al.* 2010; Preston *et al.*, 2011; Pucket *et al*., 2011).

Agriculture is very often regarded as the main cause of diffused pollution. Nitrogen and phosphorus, as well as pesticides applied to crops, are key water pollutants stemming from agricultural production. Both livestock and aquaculture production, when done on industrial scale, are associated with significant wastewater discharge along their value chains with potential adverse impacts on human and animal health and the environment (Delgado *et al.*, 1999; Naylor *et al.*, 2000). Several solutions exist to reduce these adverse impacts from agricultural inputs. They include: enhanced nutrient use efficiency, either as a trait in plants or through improved fertilizer management; the phasing out of subsidies for fertilizers; conservation agriculture measures that reduce erosion and crop rotations with nitrogen-fixing cover crops; and closing the nutrient cycle through recovery from effluents and sewage, followed by reuse in agriculture. Appropriate reuse of wastewater also can reduce the cost of fertilizer applications, particularly phosphorus and nitrogen (Drechsel *et al.*, 2010).

1.5 Access to water: increasing and changing competition for the resource and its consequences for FSN

Access to water for FSN can be limited, and unevenly limited, in both water-stressed and abundant areas. It depends on three factors: (i) availability/scarcity (how much water there is on average); (ii) the strength of the competition between concurrent actors and uses; and (iii) the way the competition is organized, with impacts on the access of populations to water.

Many sectors compete for water resources: agriculture, energy, industry, residential, etc. This influences food security and nutrition in three main ways:

- how much water and of what quality, is allocated for safe drinking and sanitation;
- how much water (and of which quality) is allocated to agriculture and food production, including inland fisheries;
- how equally these allocations are distributed between people, and particularly how are taken into account the marginalized and vulnerable populations as well as women.

Availability or scarcity of water is generally measured in average water per capita. This can however hide real inequalities in water access, which ultimately depends on how distribution of and control over water are exerted.

Distribution of water and control over water are determined by the way water is managed, priced and regulated (Mehta, 2014; UNDP, 2006), by property rights, social and political institutions, and cultural and gender norms. Therefore access to water is often socially differentiated by gender, caste, race, occupation and other categories.

Gender and other markers of identities continue to mould water allocation and access among users. For example, deeply rooted traditional or historical inequalities can limit women's and other vulnerable groups' access to land and thereby to water for agricultural uses, which hampers livelihood strategies and negatively impacts food security (FAO, 2012b; FAO, 2001; see also Box 3 for an example of the reality of access).

Cultural norms in much of the global South dictate that women and girls are responsible for water collection, and they may spend several hours per day collecting water. Unequal power relationships within the household, and women's minimal control over household finances or spending, can force women into a daily trudge (taking precious time) for fetching cheaper or free untreated water, which may result in health problems and increased poverty and destitution. This time could instead be used to focus on livelihood and agricultural activities, to attend school and to improve maternal and infant health (Mehta, 2014; WHO/UNICEF Joint Monitoring Programme, 2012). This situation is worsened by the fact that women are often excluded from decision-making processes regarding water management projects or natural resources allocation (FAO, 2012a).

Box 3 Competition for groundwater resources in water-abundant Bangladesh

"Jobeda Khatun, a widow about 40 years old, lives with three of her children, a son aged 20, and two daughters aged 17 and 13. Ten years ago when her husband was still alive […] they installed a hand tubewell on their homeplot. This privately owned well serves about six households in a cluster. Like many other hand tubewells in the village, their pump becomes inoperative during the dry months of February – April. Jobeda and her daughters […] must go 500 meters away to collect water from the nearest pump. As they are adult women, local customs do not allow her or her daughters to venture out and collect water from the deep tubewell far away in the fields. […] and as a landless non-agricultural household they are least favoured in receiving deep tubewell water. […] Their hand tubewell does not yield water during the dry season due to the operation of mechanized deep tubewells [for irrigation]. Despite seemingly abundant water, increasing use of deep water table extracting technologies for irrigation takes water away from shallow hand pumps used for domestic water supply […] Because groundwater rights are not clearly defined, no one is sure how to deal with the growing problem."

Source: Sadeque (2000: 269–270).

1.5.1 Water for food production

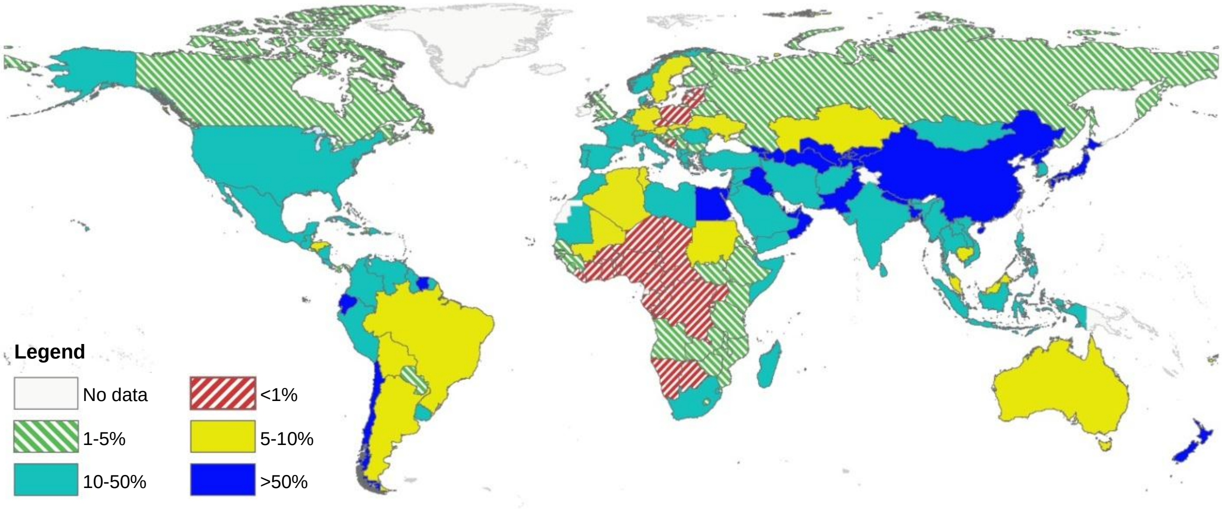
Irrigated agriculture (including food and non-food crops) is by far the largest water user globally, and roughly accounted for, in 2013, 252 billion cubic metres, or 6.5 percent of the global renewable freshwater resources flows, representing 70 percent of surface and groundwater water withdrawals globally, with significant differences between countries: 90 percent in low-income countries, 43 percent in high-income countries. According to FAO, in 2009, 311 million hectares were equipped with irrigation (Figure 9), 84 percent actually being irrigated, corresponding to 16 percent of all cultivated land and contributing to 44 percent of total crop production. Reliable irrigation is also key to increase and stabilize income and to provide livelihood resilience for a vast number of smallholder farmers. The largest irrigated areas can be found in India, China and the United States of America, which are also major contributors to the world's food supplies.

Income growth and urbanization are linked to changing consumption patterns toward more livestock, sugar, fruit and vegetable products, all of which are more water-intensive commodities (Ringler and Zhu, 2015). Poultry, pork and beef require much larger quantities of water per unit of nutritional energy compared with foods of plant origin (Gerbens-Leenes *et al.,* 2013). As a result, animal-sourced food is currently associated with one-third of freshwater withdrawals (Mekonnen and Hoekstra, 2012), with, however, great variations between animal types and production systems.

There is also insufficient understanding of future demands for water for food production. According to the IPCC, climatic changes (including changes in precipitation, temperature and radiation) are likely to result in an increase in agricultural water demand in irrigated and rainfed systems (Jiménez Cisneros *et al.*, 2014, see also Chapter 2). This is over and above the increasing water demand for the expansion of agriculture in order to meet the FSN needs of a growing population. Irrigation demand is projected to increase in many regions, for instance by more than 40 percent in Europe, the United States of America and parts of Asia (Jiménez Cisneros *et al.*, 2014). However, there are experts who suggest that agricultural water demand will decline substantially over the next several decades (OECD, 2012; Konzmann *et al.,* 2013) due to the beneficial CO_2 effects on plants, shorter growing periods, regional precipitation increases under climate change and stable irrigated areas. As a result, estimates of current and future water demands vary widely.

Generally, few economic instruments are used to manage demand for water for food production while many complementary policies, such as agricultural input and output price policies, lead to injudicious or wasteful use of agricultural water for food production. For example, subsidized electricity has led to increased pumping for irrigation in India and overexploitation of water resources (Narula and Lall, 2009); it has also led to overuse of groundwater in Mexico (Scott, 2011). In western India, there is overextraction of groundwater and water-intensive crops, such as sugar cane, are grown in drought-prone areas by large irrigators while dryland farmers struggle during droughts to meet their basic food requirements (Mehta, 2005). Finally, decisions outside the water domain, such as those concerning energy, trade, mining and extractive industries and agricultural input subsidies, often impact on water supply and demand, and hence on relative water scarcity for other economic or social sectors (see also FAO, 2012a; Ringler *et al.,* 2010).

Figure 9 Area equipped for irrigation as percentage of cultivated area (2012)



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Source: AQUASTAT and FAOSTAT databases.

1.5.2 Water for energy and energy for water: impacts on FSN

Energy is estimated to account for 15 percent of total water withdrawals globally (IEA). Many energy generation systems require water as part of the generation process, including thermal energy generation (including solar thermal generation), hydropower and nuclear plants (see Box 4). One of the major challenges for water for energy is that it must be provided at a high assurance of stability of supply. As a result, in times of low water availability, irrigation may be reduced in priority in order to continue to ensure water for energy production.

There is growing pressure around the world to increase renewable energy generation to reduce carbon dioxide emissions. While some kinds of renewable energy, such as wind and solar photovoltaic (PV) power, do not consume much water, other renewable energy processes, such as biofuels, use significant quantities of water (HLPE, 2013a).

Hydropower is presented as a climate-friendly option (Allouche *et al.,* 2014) and also as a way to increase water storage infrastructure (see Chapter 2). However, hydropower can also create conflicts between water for energy and water for agriculture (for dams in Central Asia, see WWAP, 2014). Hydropower dam releases tend to meet the needs of hydropower rather than downstream farmers or ecosystems. This can have adverse impacts on irrigation and on inland fisheries and their contribution to FSN (HLPE, 2014b).

Box 4 Increase in global energy demand and impact on water withdrawals from thermal electric plants

At global level, energy demand is projected to increase by one third by 2035, with demand for electricity expected to grow by 70 percent over the same period (IEA, 2013), with global power generation still dominated by thermal electricity production from coal, natural gas and nuclear − with coal remaining the largest source. The share of renewables, including hydropower (the largest source), is expected to double, accounting for 30 percent of all electricity production by 2035 (IEA, 2013). Because 90 percent of thermal power is water intensive, the estimated 70 percent increase in electricity production by 2035 would translate into a 20 percent increase in freshwater withdrawals. Water consumption would increase by 85 percent, driven by a shift towards higher efficiency power plants with more advanced cooling systems (that reduce withdrawals but increase consumption), and increased production of biofuel (IEA, 2012).

Source: WWAP (2014).

Biofuels can add pressure to *"water supply and water quality problems"* (HLPE, 2013a) especially if irrigated (Lundqvist *et al.,* 2008). Although regional variation is large, de Fraiture *et al.* (2008) estimate that on average it takes around 2 500 litres of crop evapotranspiration (green water) and 820 litres of water withdrawals (blue water) to provide one litre of biofuel. It is at the country or local level that the trade-offs between water for food and water for biofuels are felt. For example, in India water for biofuels competes directly with water for food such as cereals and vegetables (Lundqvist *et al*., 2008).

The increasing use of the practice of hydraulic fracturing, or "fracking"[15] as it is more commonly known, has raised concerns about the risks of contamination of water resources, in particular groundwater, by the mix of chemicals used in the process (Myers, 2012; Ridlington and Rumpler, 2013). There has been little quantification of the actual water use in fracking because requirements are dependent on the nature of the shale, well depth, number of fracking stages and the length of the lateral pipes underground (Nicot and Scanlon, 2012). Frack sand mining – an offshoot of the hydrofracking industry – is a related sector, the impact of which on water is yet to be assessed as well.

Energy is needed in the anthropogenic part of the water cycle to abstract, distribute and treat water and wastewater, as well as for heating water, for food production processes, for domestic hygiene and for food preparation.

The energy requirements of the water distribution sector are increasing. Higher pollution levels require more energy for treating water and the increasing need to transport water over longer distances also uses significant energy. Groundwater extraction has increased dramatically as a source of irrigation water with the result that energy use for groundwater pumping is now often the largest source of direct energy use in semi-arid and arid countries of the global South, such as Pakistan (for example, Siddiqui and Westcoat, 2013). Thus water use practices are contributing to the growth in energy demand.

Food processing requires reliable supplies of water and energy. Closed loop systems for both energy and water are feasible for some processing industries, but require higher initial capital investments. Several companies have started to develop plans to become carbon and water-neutral.

While there are important trade-offs between water, energy and food resources and uses, there are also large opportunities for synergies. For example, small run-of-the-river hydropower stations have been built on large irrigation canals in southern Viet Nam to harness the energy created by canal flows,[16] and Ethekwinin municipality in South Africa is looking at hydropower generation on distribution pipelines on steep hillsides in its area of jurisdiction. Nutrients contained in point source wastewater, such as phosphorous, can also be reused as fertilizer on agricultural fields.

1.5.3 Corporate actors are increasingly competing for water resources

Corporate actors have an increasing influence in water management and governance. First, as water managers, as providers of services for drinking water. Second, as big water users entering in competition for the allocation of the resource with agriculture and small users. Third, in some cases, the scale of the intervention of corporate actors is such that they tend to control the resource itself, by the size of investment, their economic power, which often gives them a considerable political influence. Such big users belong to energy and industrial sectors, to cities, but also to the food transformation and beverage industry, or to large-scale agriculture/plantations.

Investments in various economic activities, and in particular in energy, industry and large-scale plantations, by corporate actors, often have an important impact on water. Mobilizing the investment potential of businesses can benefit FSN by providing development opportunities. They can also, when directed to water supply and water services, increase the provision of water. However, in both cases they can often bear a very important negative impact on local population, especially on the most vulnerable, marginalized, indigenous peoples, women.

Over the last decade, there has been increasing corporate interest in water resources arising largely from the perceived business risks as a result of increasing competition for water and decreasing water quality. Since 2011, global corporations have spent more than USD 84 billion on how they manage, conserve or obtain water (Clark, 2014). The reasons include physical water shortages, the need for reliable supplies of water for industrial and production processes, and concerns about water quality.

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15 Fracking "is the process of injecting a mixture of water, sand and chemicals into wells at high pressure to crack dense rock formations and release oil or gas" (Food and Water Watch, 2012).

16 Nguyen Vu Huy, personal communication, 2014.

Some argue that the growing corporate involvement in water management is to be welcomed because it will lead to technological innovation (Clark, 2014) and improved water management in areas of weak governance. Others argue that it poses risks for current and future water and food security (Sojamo and Larson, 2012) if decision-making around water (re)allocation is guided solely by its "highest economic value" with detrimental impacts on local livelihoods and water and FSN (Franco *et al*., 2013). In recent years, attention has focused on the rapid growth of large-scale land deals around the world (von Braun and Meinzen-Dick, 2009; Borras and Franco, 2010; World Bank, 2010a; Deininger, 2011; De Schutter, 2011; HLPE, 2011). In addition, some studies have underlined that water is often the driving factor behind many international land deals (HLPE, 2013a; Mehta *et al.,* 2012) and such deals often exert a great impact on water uses and customary water rights (HLPE, 2011, 2013a). A special issue of the *Water Alternatives* journal discusses the water implications of land deals on local food production and agriculture (Mehta *et al*., 2012).[17] The papers show how land acquisitions have led to a significant re-appropriation of water resources and to water tenure relationships with negative implications for basic human rights and local water and food security. In Ghana, Williams *et al.* (2012) observe how *"companies initially leased large-scale lands to grow a crop, Jatropha, which is less water demanding but have ended up diversifying into other crops that require full or supplemental irrigation to give optimal yields"* (Williams *et al.*, 2012: 256).

Houdret (2012) describes how, in Morocco, deep drilling by agricultural investors may intensify water conflicts and increase the marginalization of small farmers as shallower wells used by local communities may dry up. Bues and Theesfeld (2012) describe how water rights have changed both directly and indirectly as a consequence of foreign horticulture farms in Ethiopia. While direct changes include new associations reshaping formal agreements, the indirect ones include changes in water access and withdrawal rights, which are directly tied to land rights. The re-appropriation of resources described is only possible due to sharp power inequalities between resource poor smallholders (often holders of customary or collective water use rights) and large investors and companies (see Chapter 3). For example in the Indian state of Maharashtra, planned canals are being abandoned and the irrigation potential drastically reduced as water is diverted to petro-chemical industries and thermal plants owned by major corporate houses (Wagle *et al.,* 2012). A particular challenge is posed by the imbalance of power between large transnational corporations and under-resourced government departments in the global South, with the possible outcome that water is de facto regulated and managed by the private sector and not by the state. The water competition between large, powerful private sector water users and smaller private or domestic water users has been documented in several of the afore-mentioned studies.

At the same time, in a strong regulatory environment, the water-related concerns of the private sector can be harnessed to support improved water management within an equitable and sustainable paradigm. In addition, within the right regulatory environment, there is considerable potential in harnessing the capital and capacity present in the private sector for developing and operating infrastructure, and to improve water use productivity (for a further discussion of the role of private sector and corporations, see Chapter 3). More work is needed on understanding under what conditions country governments in the global South can make use of these opportunities effectively.

There is also a need for *ex-ante* assessments of impacts of investments on the FSN of all, including vulnerable populations, and to create mediation mechanisms in case of negative impacts. Tools recently developed such as the CFS principles for responsible investments in agriculture and food systems can serve as a guide to maximize FSN outcomes of investments in the water sector and of investments in activities having an impact on water.

1.5.4 Impact of growing competition on FSN

According to OECD's business as usual scenario, in 2050, 2.3 billion more people than today (in total over 40 percent of the global population) will be living in river basins experiencing severe water stress (where water withdrawals exceeds 40 percent of recharge), especially in North and South Africa, and South and Central Asia. While there have been various scenarios and projections in terms of water requirements by different sectors over various timescales, there is uncertainty with regard to the development of real demand due to poor baseline data in many countries on current national and subnational sectoral withdrawals, rapid changes in use patterns informed by different drivers, and high uncertainty regarding technological change (WWAP, 2012).

[17] See: www.water-alternatives.org/index.php/tp1-2/1881-vol5/213-issue5-2

Water use for food production increased steadily over the last 100 years but has been outpaced over the last few decades by more rapid increases in water demand for domestic and industrial uses (Rosegrant *et al.*, 2002). As competition for water increases, it is expected that the share of agriculture will decrease (CA, 2007).

There is an expected increase of agricultural, energy, industry, and of domestic uses of water, but with differences between sectors. FAO projects a 6 percent increase of agriculture volumetric withdrawals between 2005/7 and 2050, together with a 12 percent expansion of harvested irrigated areas (40 million ha) (FAO, 2012c), mainly concerning the more land-scarce regions hard-pressed to raise crop production through more intensive cultivation practices, such as East Asia, South Asia and the Near East/North Africa, although in the latter region further expansion will become increasingly difficult as water scarcity increases and competition for water from households and industry will continue to reduce the share available to agriculture. Under the comprehensive assessment scenario (CA, 2007), and with assumptions on crop water productivity qualified as optimistic, withdrawals by agriculture are expected to increase by 13 percent. OECD's business as usual scenario, in turn, confronting all the uses, projects a 14 percent decrease of water used for irrigation between 2000 and 2050, within an overall total increase of water demand of +55 percent, due to growing demand from manufacturing (+400 percent), thermal electricity generation (+140 percent) and domestic use (+130 percent).

1.5.5 The question of water storage and hydropower

A contentious issue is that of large dams and the role they play for enhancing water and food security. Until a few decades ago, the large dam[18] was universally considered to be vital for water and food security. Historically, many proponents of large dams focused on the benefits of hydropower and irrigation and downplayed the social and environmental costs.[19] These views have been contested by affected communities living adjacent to the dam sites, academics, scientists and NGOs, all of whom have highlighted the problems of involuntary resettlement and environmental damage due to large dams and questioned the benefits claimed in relation to irrigation and food security (see McCully, 1996). As a response to this controversy and in response to social movements fighting for the rights of displaced groups, the World Bank, social movements representing displaced people and several international NGOs created a multistakeholder process, the World Commission on Dams (WCD) in 1997. The WCD mandate was to investigate issues related to dams including economic growth, equity, food security, environmental conservation and participation. The Commission's report concluded that while dams have made a considerable contribution to human development, in too many cases the social and environmental costs were unacceptable. The Commission also argued that water and energy needs could often be met through alternative solutions that would fare better than large dams on equity and environmental grounds (WCD, 2000).

In recent years, dams have made a comeback (Molle *et al.*, 2009). The World Bank has argued again that investment in dams is necessary for economic growth (Calderon and Servén, 2004). In addition, in the context of climate change, hydropower is seen to be a clean and renewable source of energy because it does not emit significant levels of greenhouse gases (World Bank, 2009). In sub-Saharan Africa there is a strong position that there is immense hydropower potential that has not been realized as well as storage potential for productive use, which is needed not least due to high seasonal and inter-annual rainfall variability, climatic shocks as well as recurring droughts.

The controversies around large dams, however, continue. A recent study by Ansar *et al.* (2014) draws upon cost statistics for 245 large hydropower dams built between 1934 and 2007. Without even taking into account social and environmental impacts, the study finds that *"the actual construction costs of large dams are too high to yield a positive return*" (Ansar *et al.*, 2014: 44). This study also found that hydropower dam construction costs were on average more than 90 percent higher than initial budgets and eight out of ten suffered a schedule over-run, thus seriously questioning their economic/financial viability (*ibid*). This may be true for all infrastructure projects but the time and cost overruns are significantly higher for large dams (WCD, 2000).

The costs and benefits of large dams are complex, particularly as they relate to fisheries, an aspect that is often neglected in the large dams debate. There are now many studies on the proliferation of dams on the Mekong River. They highlight how their damaging impact on artisanal fishing

[18] According to the World Commission on Dams, there are currently over 800 000 dams in the world of which 45 000 are large; a large dam has a wall height of more than 15 metres (WCD, 2000).

[19] See the Web site of the International Commission on Large Dams http://www.icold-cigb.org/ accessed 26/2/2015.

communities poses a serious threat to the region's food security. If all of the 88 dams planned for the Mekong river basin are built, fish stocks are expected to drop by 40 percent by 2030 (China Dialogue, 2012). This loss of fish stocks would necessitate a switch to industrial livestock rearing, counteracting claims that these hydropower projects would reduce carbon emissions (Eyler, 2013).

More broadly, beyond the negative impact on fish stocks, dams also impact the people who depend on fisheries for their livelihoods. In a survey among fishers and fisher groups in the Gangetic Basin, there was a widespread understanding that dams and their impact on river flows were a main cause for declines in fisheries and fish resources, which negatively impacted the livelihoods of these communities (Kelkar, 2014). Although large dams have particularly large impacts, for instance in terms of sediment fluxes (Gupta *et al.*, 2012), small dams also adversely affect communities, particularly if they interfere with those communities' only water source (Erlewein, 2013). Traditional fishing communities' generally marginalized status and the lack of any post-dam construction compensation for them indicate that the concerns of these communities may not have been given adequate attention when considering the trade-offs related to dams (Kelkar, 2014).

Large dams have displaced around 40–80 million people globally (WCD, 2000). In India, a large proportion of these have been from tribal communities. Displaced people not only lose their lands, but also lose access to common property resources such as rivers, forests and grasslands, all of which are vital sources of nutrition. Studies have shown that people displaced by the Tehri Dam in North India had to shift from subsistence-oriented farming that included hunting and fishing to dependence on cash crops and buying food from markets. This led to a shift from a protein-rich diversified diet to a lower-nutrient diet high in carbohydrates, leading to poor nutritional outcomes (Bisht, 2009). Furthermore, resettlement land is not always of good quality, yields may be poor and water quality is also often inferior. The resettlement literature acknowledges that health problems and food insecurity can increase after displacement. In Gujarat, resettled villagers felt that the poor quality of ground and surface water had led to chronic diarrhoea, dysentery, colds, nausea and even an increase in mortality (Mehta, 2009). At the other end of the scale, however, large numbers of people, often in urban areas, have benefited from the food produced through water from dams, and from the energy produced in hydropower systems.

The challenge, as highlighted in the WCD report, is thus to ensure that the environmental and social impacts of dams are minimized and that local communities do not carry disproportionate costs, and are left, as a minimum, no worse off than they were before the dam was built (WCD, 2000). There is now a growing understanding of the continuum of water storage options that include natural wetlands, enhanced soil moisture, groundwater aquifers and artificial recharge, ponds[20] and tanks, and large or small dams/reservoirs (McCartney and Smakhtin, 2010). Each has a role to play in contributing to food and water security. Of particular importance in addressing water for food security is ensuring that the full range of options are considered in consultation with women and men of the communities concerned, and that by taking into account social and environmental costs and benefits, appropriate water storage schemes are developed to support the production of food and the provision of water.

1.6 Water for FSN: from the four dimensions of water to the four dimensions of food security

We have detailed in this chapter several links between water (availability, access, stability and quality) and food and nutrition security (availability, access, utilization and stability).

The contribution of water to food security, in all its dimensions, takes several pathways, which in turns depend on the various dimensions of water that we have distinguished above. We propose to identify four main pathways:

1. Water for utilization of nutrients and foods: safe drinking water and food preparation (including urban, issues of quality, etc.), key to food absorption, etc.
2. Water determining availability of food: water for food production and transformation (taking into account the impacts of climate change, from global to local, the role of markets, etc).

[20] See, for example, the Cambodian Farmers Association Federation of Agricultural Producers' (CFAP Cambodia, n.d.) recommendations regarding upgrading multipurpose ponds for improved production (available at www.fao.org/fsnforum/cfs-hlpe/sites/cfs-hlpe/files/resources/Folder%20CFAP%20(1).pdf).

3. Water for access to food: as a key factor for livelihood, especially smallholder farmers, for the poorest, vulnerable, hungry.
4. Stability of water as contributing to stability of food security, including issues of stability of water supply, access, rights, etc. conditioning the three roles above.

We propose to use the concept of "water for FSN" to designate water's direct and indirect contributions to food security and nutrition in its four dimensions. It covers safe drinking water and sanitation, water used to produce, transform and prepare food, as well as the contribution of water uses in all economic sectors to livelihoods and income and as such to food accessibility. It covers also the objective of sustainable management and conservation of water resources and of the ecosystems that sustain them, and that are necessary to ensure FSN for present and future generations.

Can we measure water for FSN? Water for FSN is necessarily multidimensional. A multiplicity of pathways to assess the role of water for food security and nutrition implies potentially a multiplicity of metrics to measure effects in the various dimensions, as well as trying to attribute them to different causes. It also implies to "go down the scales", from biophysical data on water and food, to people-centred, gender-sensitive approaches. It is not enough to know the average water availability: there is a need to know about water distribution and how people "live" their water reality (Mehta and Movik, 2014).

To perceive the complexity of "water for FSN", a single indicator is not enough. First, indicators are not correlated among themselves (access to safe drinking water for all is not necessarily correlated to water abundance, for instance). Therefore it is necessary to have comprehensive and sufficiently disaggregated data on all these pathways, at the degree of disaggregation necessary. Policy debates can wrongly focus on the "available" indicators (that are often the indicators of availability). Accessibility to water is more difficult to measure both from a methodological point of view and often from a political one (especially in informal systems).

For instance, access to drinking water is much more difficult to measure in peri-urban and slum areas (WHO/UNICEF Joint Monitoring Programme, 2012). There has also been little comparable international data on gender indicators and most agencies lack sex-disaggregated data, making it impossible to monitor progress or devise gender sensitive policies.[21] For instance, most official indicators do not question the time taken by women and girls to collect water. There is also not enough data or understanding regarding how much food is produced by women or resource users that lack formal land and water rights.

Finally, painting the global, regional or even national pictures can still fail to be enough context-specific. Figures on country-level water availability, for example, mask in-country differences, discrimination between social groups as well as gendered differences. Similarly, inter-annual averages can smooth out the extremes of climate variability. Areas with high climate variability may experience several consecutive years of below average rainfall, with significant impacts on food production – particularly, but not only, in areas dependent on rainfed agriculture.

These issues need to be borne in mind while trying to understand the extremely different water contexts across the world and what they mean for FSN. Assessing water for FSN implies giving all its importance to local perspectives and contexts, as well as to diverse ways by which local women and men can develop resilient systems to deal with increasing uncertainties. How water for FSN can be managed amidst growing uncertainties alongside governance challenges will be considered in the next chapters. Considering water availability, at regional and local levels, increasing demand for water, and the imperative of reaching safe drinking water and sanitation as well as to ensure other uses of water for food security and nutrition, there is a need to improve water management in agriculture and food systems at all levels. Access to and use of water for FSN is informed by social, political and economic power relationships within countries, in water basins, and at the local level, as much as by infrastructure and rainfall – therefore there is a need to improve water governance for FSN.

[21] There have recently been some improvements, however. The WHO/UNICEF Joint Monitoring Programme post-2015 consultation has emphasized issues of equity, equality and non-discrimination (END), which can overcome some of the issues outlined above. For instance, it has been proposed that intrahousehold inequality should be addressed through disaggregating data by age, gender, health, disability and so on. How these issues will be taken up in the post-2015 agenda remains to be seen but these do constitute progress in the desired direction. See WHO/UNICEF Joint Monitoring Programme, 2012 and Mehta, 2013.

2 MANAGING WATER SCARCITIES IN AGRICULTURE AND FOOD SYSTEMS TO IMPROVE FSN

As shown in Chapter 1, water availability/scarcity at local level, as determined by physical and economic availability and competing demands, imposes making better use of available water, to improve water productivity. It reflects the objectives of producing more food, income, livelihoods and ecological benefits at less social and environmental cost per unit of water used, either delivered to or depleted by the use. Improved productivity is a critical element of agricultural water management in order to meet the FSN needs of a growing population (Molden *et al.*, 2007).

High priorities for water productivity improvement include areas of high poverty and low water productivity such as sub-Saharan Africa and parts of South Asia and Latin America – areas where there is intense competition for water such as the Indus Basin and Yellow River and areas where ecosystem functions are negatively affected by water withdrawals for agriculture (Molden *et al.*, 2007).

This chapter considers potential ways to improve water management in agriculture and along food chains to improve food security and nutrition.

Improving water productivity in food and agriculture goes by two ways: first, better water management and, second, increased productivity by improved management, in the agricultural and food system, of all other inputs and parameters. These could lead to various degrees of system change. Both water management and also food and agricultural systems management need to be considered across scales.

This chapter investigates those management challenges for FSN across a range of scales and from agriculture (rainfed and irrigated systems) to water use in food processing and preparation, as well as the role of trade. Finally, it considers water accounting tools and methodologies as a way to measure water productivity and efficiency, and to orient progress and management decisions, including consumption choices.

2.1 Managing water and managing systems for water, from ecosystems to agricultural food systems

2.1.1 The role of ecosystems and landscapes to sustain water resources

Availability of water at local level is determined by availability of water at broader levels, in ecosystems.

Box 5 Amazon sky rivers

In a recent and comprehensive review of scientific papers on the Amazon and its relationship to climate and rainfall in Brazil, Nobre (2014) concluded that deforestation in this region influences the water shortage felt in the most populous regions of the country. The removal of vegetation cover interrupts the soil moisture flux to the atmosphere. The decrease in the number of trees in the biome prevents the flow of moisture between the north and the south. The lack of precipitation mainly felt in the southeast would be an indirect consequence of the Amazonian deforestation. Since the early 1970s to 2013, the logging and the gradual deforestation removed from the biome 762 979 km² of forest, an area equivalent to two Germanys. A "flying river" greater than the Amazon River and responsible for freshwater supply throughout Southeast Latin America, is seriously threatened. The term "flying rivers" (Marengo *et al.*, 2004) refers to low-level jets of water (water vapour flux) driven by the winds that move from the Amazon region towards the east of the Andes and, barred by the mountain range, reach the southeast and southern regions of Brazil and the north of Argentina. This river flies around the country daily, pouring 20 billion tonnes of freshwater in a region that accounts for 70 percent of the gross domestic product (GDP) of South America. The Amazon River, the world's largest source of water, turns out daily 17 billion tonnes of fresh water into the Atlantic Ocean. Among the lessons learned from these studies, the authors point out that if the current course of "development" in the Amazon region continues, the lack of water will occur in a more permanent way, not only a variation from one year to another. The second lesson is that the "natural" climate variability is increasing due to global warming. This leads to more severe extreme events and more frequent droughts and floods, compared with historical standards. The increase of drought and flood extremes in the Amazon is already clear.

Sources: Nobre (2014) and Marengo *et al.* (2004).

Water basins can be of huge dimensions and in some cases continental. Furthermore, the interaction between ecosystems and the water cycle can operate at continental scales, meaning that ecosystem management can have sometimes very remote effects on water availability, as the example of land-use change in Amazon shows (see Box 5).

2.1.2 An ecosystems approach to water management

The approach taken towards water management, and the technological and institutional choices made, will depend, at least partly, on the scale of the area to be managed. As is discussed in more detail in Chapter 3, current global discourse favours a decentralized approach, based on the principle of subsidiarity as espoused in Agenda 21 of the UN Conference on Environment and Development of 1992. One such approach to water management is the ecosystem approach (ES), which aims at the integrated management of land, water and living resources. Importantly, the ecosystem approach recognizes that humans are an integral component of ecosystems (CBD, 1992), and calls for strong stakeholder participation – involving those who have an interest in, or could be affected by, decision-making. It also recognizes that management of natural resources should be decentralized to the lowest appropriate level. Whether within more traditional water management approaches, or newer approaches such as the ecosystem approach, it is at the local level that there is the greatest potential for collective action around water management. Despite the adoption of the ES by the Conference of the Parties of the Convention on Biodiversity (CBD), implementation is still in its early stages in most basins, as evidenced by a 2011 study (Roy *et al.*, 2011). The same study concluded, that *"a stronger focus on ES would produce new benefit opportunities, such as biodiversity benefits and increased resilience to extreme climate events such as floods and droughts, which would complement more traditional benefits such as hydropower and navigation".*

A multiscalar and ecosystems approach allows for embracing both hydrological and social complexities while taking into account local users' needs and perspectives. This is ultimately what will make water management practices sustainable over time. Here local co-management alongside local ownership is critical. As demonstrated by the Moroccan and Ethiopian cases (see Box 30, in Chapter 3), technological innovation alone is not enough to improve water and food security. Instead, there needs to be a combination of improving water and land productivity alongside institutional change, increased local ownership, and improved regulatory and policy environments. Water management practices inevitably interact with social, power and gender relationships and with wider issues concerning policy and decision-making across a range of scales, which shape on-the-ground outcomes, issues that are the focus of Chapter 3.

2.2 Improving rainfed agro-ecosystems

Agro-ecosystems range from fully rainfed to fully irrigated, with several combinations in between, such as using supplementary irrigation to improve rainfed production systems. In rainfed agro-ecosystems, rainfall captured in the soil (or green water) is used directly to support crop production while irrigation systems make use of ground or surface water sources (or blue water) to supplement rainfall. The main rainfed challenge, especially in dry areas (and more so with climate change), is to manage the risk of rainfall variability.

Globally small-scale farmers produce over 70 percent of the world's food needs (Wolfenson, 2013). Small farms produce about 80 percent of the food consumed in Asia and sub-Saharan Africa (HLPE 2013b) and play a major role in providing employment in many countries. Given growing natural resource constraints, the challenge today is not only to increase productivity of both land and water through programmes that simultaneously generate employment to increase incomes, but also to preserve and restore biodiversity and natural resources, and help address climate change challenges (Parmentier, 2014). In India, the Mahatma Gandhi Rural Employment Guarantee Act has contributed – at least partially – to meeting the challenges of water for FSN. It guarantees assured income (100 days a year per household) through employment on land and water conservation initiatives. The recent Food Security Act also offers opportunities to forge links with this programme to provide FSN (see Swaminathan, 2009).

As discussed in Chapter 1, climate change is causing changes to temperature and rainfall patterns with the potential to cause agricultural losses estimated at 10–20 percent of production area (Fischer *et al.*, 2002). Hilhost and Muchena (2000) estimate that cultivation potential in sub-Saharan Africa could decline by 12 percent, particularly in the Sudano-Sahelian zone. Moreover, by increasing the volatility of crop yields, climate risk provides a disincentive for investments in soil fertility and agricultural technologies, including improved crop varieties and other yield enhancing inputs (Boucher *et al.*, 2009; Barrett *et al.*, 2007; Vargas Hill and Viceisza, 2011; Binswanger-Mkhize, 2010; Barnett *et al.*, 2008). The potential impacts of climate change have to be understood as interacting within a system, and their effects are likely to be not simply additive (adding one more problem on the list) but multiplicative, with changes in one area likely to either mute or amplify changes in another.

Rainfed agro-ecosystems will be directly affected by climate change in three ways (Wreford *et al.*, 2010):

1. Increased temperature and CO_2 levels will increase evapotranspiration and reduce soil water putting stress on plants in dry ecosystems, shortening crop growing periods and reducing yields. In wet and cool agro-ecosystems the same changes may prolong crop-growing periods and increase yields in the short term.
2. Rainfall patterns are likely to change in many dry and wet regions though predictions of changes lack precision. Expected increased rainfall intensity will, especially on degraded sloping lands, result in more runoff with higher soil erosion and lower soil infiltration causing more moisture stress on plants and reduced recharge of groundwater. Increased rainfall may increase the availability of surface water and the potential for rainwater harvesting but it may also result in increased floods. More intense and/or longer droughts will expose crops to moisture stress, and reduce rainfed yields and quality.
3. Climate change will also affect agriculture through impacts on biotic factors such as diseases and pests. While it is likely that these impacts will be substantial there is insufficient information as to what will precisely happen in different environments and more research is needed in this area.

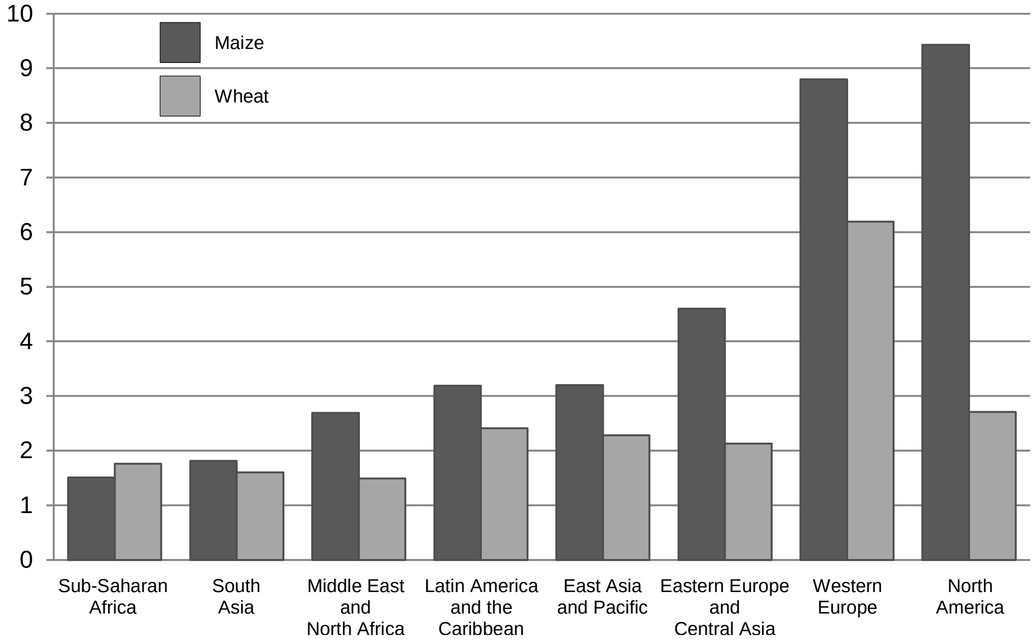
Irrigated agro-ecosystems will also be affected by climate change in three ways (Wreford *et al.*, 2010; IPCC, 2014):

1. Increased temperature will increase evapotranspiration so that more water will be needed for irrigation. However, increased CO_2 levels will act as a fertilizer for crops and improve transpiration efficiency causing water productivity to increase. Again, further research is needed to understand the overall impacts of climate change in terms of crop water use.
2. Blue surface water supply may be higher in some regions as more runoff will be generated as a result of increased rainfall intensity, but less groundwater may be available due to reduced opportunities for water infiltration. The overall impact on blue water resources is difficult to predict especially taking into consideration the variations between regions and the upstream–downstream consequences of changing agricultural demands and investments in improving green water use. More downscaled modelling work is needed in this area.
3. Faster melting of glacial bodies may require new storage facilities for the increased surface water. In the long term, however, the melting of glacial bodies will reduce the volume of water in some major water streams.

2.2.1 Rainfed agro-ecosystems

Rainfed agriculture is the primary source of food production globally. Almost all land in sub-Saharan Africa (93 percent), three-quarters of cropland in Latin America, two-thirds of crop land in the Middle East and North Africa region, and more than half of cropland in Asia is rainfed (FAO, 2002a). While the yields from rainfed agriculture vary widely across regions (see Figure 10), on average rainfed agriculture productivity (tonnes/ha) is globally less than half of that of irrigated agriculture (Rockström *et al.*, 2010). The highest yields from rainfed agriculture are found in the predominantly temperate regions, with relatively reliable rainfall and inherently productive soils, particularly in Europe and North America. However, even in tropical regions, agricultural yields in commercial rainfed agriculture can exceed 5–6 tonnes per hectare (CA, 2007). The dry subhumid and semi-arid regions experience the lowest yields and weakest yield improvements per unit of land.

Figure 10 Rainfed maize and wheat yields per region (2004–2006 average) (tonnes/ha)



Source: IFPRI impact simulations used in Sadoff *et al.* (2015)[22]

Constraints to improving rainfed system productivity differ greatly from one region to another. In the arid regions, the absolute amount of water available constitutes the major limiting factor. In the semi-arid and dry subhumid tropical regions, seasonal rainfall is generally adequate, and managing extreme rainfall variability over time and space is the largest challenge. In the wetter part of the semi-arid zone and into the dry subhumid zone, rainfall generally exceeds crop water needs and the key challenge is the extreme variability in rainfall, characterized by few rainfall events, high-intensity storms, and the high frequency of dry spells and droughts. However, the large differences observed between farmers' yields and attainable yields cannot be explained by differences in rainfall but are the result of differences in water, soil, and crop management (Wani *et al.*, 2007). Soil fertility is a limiting factor in many areas especially in dryland systems and sub-Saharan Africa. Poor soils are often also associated with poor capacity for water retention. Soil-moisture retention and micro-climate management are crucial strategies that can help farmers under all of these varying conditions. In rainfed farming systems, agro-ecological approaches are particularly suitable for building healthy soils with higher water retention capacity, which improves crop productivity in all types of farming systems (Kremen and Miles, 2012; Hepperly *et al.*, 2007; Pimentel *et al.*, 2005).

The high risk of water-related yield loss can adversely influence farmers' investment decisions, including investments in labour, improved seed and fertilizers. Combined with the fluctuations in yields, this makes it hard for resource-poor men and women in semi-arid areas to respond effectively to opportunities made possible by emerging markets, trade and globalization. Management options should therefore start by supporting farmers to adopt practices for reducing rainfall-induced risks. This is where agro-ecological practices can be extremely relevant, as they help build climate-resilient farms, and help farmers make investment decisions that are less risky as they have control over more factors of production (Holt-Giménez, 2002; Fraser *et al.*, 2011).

Rural women are important producers (FAO, 2011) of the world's staple crops but they operate under conditions of significant discrimination in many parts of the world. For example, less than 10 percent of women farmers in India, Nepal and Thailand own land and, in five African countries examined, women received less than 10 percent of the credit that male smallholders received.[23] These figures are not universally accepted and Doss (2011) argues that is impossible to measure precisely women's contribution to food production since the labour data (between men and women) may be difficult to disaggregate. Lack of gendered data, but also lack of proper conceptualization for statistics to embark

[22] Wheat yields in Western Europe are higher due to longer cooler growing seasons and highly intensive use of inputs.

[23] See http://www.fao.org/gender

on gender aspects is a challenge, with gender inequalities often poorly quantitatively documented (Doss et al, 2013). The problems with sex-disaggregated data and their implication in terms of evidence-based policy making notwithstanding, it is important to recognize women's key role in agriculture and how unequal access to technology, credit, land and other resources can severely impede this contribution.

2.2.2 Upgrading rainfed agriculture

According to Rockstrom *et al.* (2010), attention should be focused on enhancing rainfed outputs through better water management. Despite successes in upgrading rainfed agriculture through soil, water and crop management practices, supplemental irrigation and water harvesting, these tend to be isolated successes in practice. Adoption rates have been low for four main reasons: low profitability, often a result of volatile prices and market failures originating both in domestic and international markets; dumping of agricultural commodities; lack of local processing facilities; and poor access to storage or markets. Relatively high labour costs and high risks may also contribute (CA, 2007).

Better management of rainwater, soil moisture and supplemental irrigation is the key to helping the greatest number of poor people through reducing yield losses during dry spells, and to giving farmers the security to risk investing in other inputs, such as fertilizers and high-yielding varieties, and allowing them to grow higher value market crops, such as vegetables or fruits.

Supplemental irrigation (SI) is a key strategy, still underused, for unlocking rainfed yield potential and water productivity in rainfed agriculture. Supplemental irrigation can substantially increase rainfed production by using limited amounts of water, applied during dry spells, to alleviate soil moisture stress and thereby reduce the risk of crop failure. SI of 50–200 mm a season is sufficient to double or more than double the rainfed yields. Such small amounts can be collected using water in local springs, shallow groundwater, water harvesting or conventional water resource schemes. SI allows modifying crop calendars to escape climatic extremes and adapt to climate change. By reducing risk, supplemental irrigation may provide the necessary incentive for investments in other production factors such as improved crop varieties, fertilizer, labour and tillage techniques, and for diversification (Oweis, 2014).

SI can, in addition to improving rainfed crop yields and water productivity, help stabilize farmers' production and income. For the greatest benefit, SI should be accompanied by a package of soil and crop management practices. In areas where groundwater is used, policies should encourage deficit SI to reduce pumping and sustain the functionality of aquifers (World Bank, 2006a). SI also supports adaptation to climate change (IPCC, 2014; Sommer *et al.*, 2011). This is not to say that there are no external consequences to SI. Using blue water upstream in traditionally rainfed areas may reduce flow amounts and quality in downstream irrigated areas (Hessari *et al.*, 2012). Trade-offs between using blue water upstream jointly with green water and downstream for fully irrigated areas should be considered.

Rainwater harvesting (WH) designates the recovery of otherwise lost water in rainfed systems and provides opportunities for decentralized community-based management of water resources. In dry environments, hundreds of billions of cubic metres of rainwater are lost every year through runoff to salt sinks and evaporation from bare soil surfaces as a result of a lack of proper management and sustainable ecosystems management. Through water harvesting, runoff water is collected and stored for beneficial use, either in surface storage areas, in the soil profile or by recharge of aquifers. Stored water can be used later if retained in surface or groundwater storage, for human, animal or SI use, or used immediately by crops from the soil profile. Often rainwater harvesting actions halt soil erosion and improve soil fertility, especially when microcatchment types are used. Water stored in surface ponds or aquifers is often used as a source of supplemental irrigation.

Water harvesting plays a crucial role in adapting to climate change and increasing agricultural resilience. By slowing down or halting the increased runoff from increased rainfall intensity, rainwater harvesting allows more infiltration, increased soil water storage and better groundwater recharge. As water harvesting efficiency is dependent on runoff, climate change, by increasing rainfall intensities, may in fact provide an opportunity instead of a disadvantage (Oweis *et al.*, 2012).

Managing risks and reducing vulnerability

The objective of increasing investment in rainfed agriculture is to reduce vulnerability to risks and improve productivity to ensure equity and sustainable development. Implementing already developed technologies in rainfed areas is usually cheaper and easier than in irrigated areas, with fast returns that help farmers to increase income. Some practices, however, such as water harvesting and supplemental irrigation, need infrastructure and equipment that can be an obstacle for small and poor farmers, particularly women who struggle to access financial resources (CA, 2007).

Actions to mitigate risks for individual farmers and enhance water management in rainfed agriculture to increase food production and reduce poverty while maintaining ecosystem benefits include (Rockström *et al.*, 2010):

- make rainwater available to crops when it is most needed, for example, through storage of precipitation;
- build the capacity of water planners, policy-makers, extensionists and community institutions in rainfed systems;
- use an integrated approach that considers rainwater management in upper catchments in addition to on-farm management;
- use Learning and Practice Alliances to scale up technologies and practices (see Box 8).

Box 6 Supplemental irrigation may triple rainfed productivity

Research has shown that wheat yields can be increased from 2 tonnes per hectare to more than 5 tonnes per hectare by the conjunctive use and timely application of only 100 to 200 mm of irrigation water. While the limited amount of water available would not support a fully irrigated crop it can substantially increase productivity when used as a supplement to rainfall. Water productivity under supplemental irrigation is far higher than in full irrigation (Oweis and Hachum, 2003).

The area of wheat under supplemental irrigation in northern and western parts of the Syrian Arab Republic increased from 74 000 hectares (1980) to 418 000 hectares (2000). The estimated mean increase in net profit between rainfed and supplemental irrigation for wheat is USD 300 per hectare. Deficit supplemental irrigation (managing plant water stress optimally when water availability is insufficient) led productivity in northwest areas to increase from 0.84 to 2.14 kilograms of grain per cubic metre of water (Oweis and Hachum, 2003).

"Research in Burkina Faso and Kenya has shown that supplemental irrigation of 60 to 80 mm can double and even triple grain yields from the traditional 0.5–1 ton per hectare (sorghum and maize) to 1.5–2.5 tons per hectare. However, the most beneficial effects of supplemental irrigation were obtained in combination with soil-fertility management. The major constraint to supplemental irrigation development in Africa is farmers' capacity, both technical and financial, to develop storage systems for runoff water" (Rockström *et al.*, 2003 cited in World Bank, 2006a: 210).

Box 7 Rainwater harvesting in subsurface tanks for rainfed systems in China and Africa

In Gansu Province in China, small subsurface storage tanks are promoted on a large scale to collect surface runoff from small catchments. Research on the use of these tanks to alleviate the drought spells that stressed rainfed wheat in several counties in Gansu Province (Li *et al.*, 2000) indicates a 20 percent increase in water productivity, from 8.7 kg/mm/ha for rainfed wheat to 10.3 kg/mm/ha for wheat receiving supplemental irrigation. Incremental water productivity ranged from 17 to 30 kg/mm/ha, indicating the large relative added value of supplemental irrigation. Similar results were observed in maize, with yield increases of 20 to 88 percent, and incremental water use efficiencies ranging from 15 to 62 kg/mm/ha of supplemental irrigation (Li *et al.*, 2000).

Benefiting from the Chinese experience with subsurface tanks, similar systems are being developed and promoted in Kenya and Ethiopia. In Kenya (Machakos district) these tanks are used to irrigate kitchen gardens, and enable farmers to diversify their sources of income from the land. Micro-irrigation schemes are promoted together with commercially available low-pressure drip irrigation systems. Cheap drip kits (e.g. the Chapin bucket kit) save water and labour, and are increasingly adopted by farmers, e.g. in Kenya. Combining WH with drip irrigation can result in very significant water productivity improvements (Rockström *et al.*, 2001).

Box 8 Building solutions with farmers through Learning and Practice Alliances

In East Africa, rainfed farming can be high risk (Rockström *et al.*, 2003; Wani *et al.*, 2009). Long or short rains fail and crops die or provide consistently low yields. Rain, when it comes, can also be in highly destructive bursts, causing soil compaction and massive run-off. Smallholder farmers face a real challenge, therefore, in capturing, storing and using the resource effectively to help support crop production for their own food security or the wider market for food and cash crops.

Through Learning and Practice Alliances, CARE has been working with smallholders and local extension staff and researchers in Ethiopia, the United Republic of Tanzania and Uganda to establish and scale up technologies and practices that can enhance the effective management and use of water for smallholder agriculture. This "water smart agriculture" (CGIAR, 2014) entails helping farmers make informed choices about ways of improving the capture and storage of surface runoff, accessing and using sustainably available groundwater and, crucially, maximizing the efficient use of rainfall, or "green water", with a focus on enhancing soil water retention around crop root systems.

The specific focus of this work under the Global Water Initiative East Africa (CARE, 2013) is to seek increased farmer productivity and resilience through empowering women farmers. Though comprising the bulk of farmers in many communities, women often have fewer opportunities to access investments and inputs into their farming (UNEP, 2013) and can struggle to "graduate" to farming that produces a surplus each year. Many of the technologies and practices that are available are simple and low-cost, including rainwater harvesting tanks for dry season cropping in northern Uganda, hillside terracing and "double digging" to break hard pan soil compaction in the Kilimanjaro Region of the United Republic of Tanzania and the establishment of small-scale irrigation to supplement rainfed cropping in the Amhara region of Ethiopia. CARE's emphasis is on joint learning and peer-to-peer demonstration to help scale up successful techniques and practices and to monitor impacts across seasons and years, encouraging farmers to become investors in innovation.

For further information see CARE, 2013 and Rockström *et al.* (2003).

Box 9 Landscape restoration and small-scale irrigation development in Tigray, Northern Ethiopia

With an estimated population of about 4.5 million and a total land size of 80 000 km2, the Tigray region is one of the most food insecure and drought-prone regions in Ethiopia. According to the Tigray Bureau of Agriculture and Rural Development (TBoARD) (2013), in 2006 1 453 707 people were under the Productive Safety Net Program (PSNP). To reverse environmental degradation and ensure food security at household level, several interventions (natural resources management and water harvesting) have been implemented by different organizations and communities in the last two decades. About 960 000 ha of land are under soil and water conservation (TBoARD, 2014). As indicated by Woldearegay *et al.* (2014), the interventions include construction of: thousands of deep trenches, percolation ponds and check-dams; hundreds of river diversion weirs; about 130 small-scale dams and other moisture conservation/water harvesting methods; afforestation programmes and area closures; and water harvesting and management. Due to this landscape approach of the interventions, new water (groundwater, springs, stream flows, reservoir water, etc.) has been created in Tigray. As a result, out of the 1.2 million ha of cultivable land in the region, irrigation has increased from less than about 50 ha in the year 1994 (Woldearegay *et al.*, 2006) to over 240 000 ha in 2014 (TBoARD, 2014).

In 2013, the number of people under the PSNP decreased to 1 238 677 at least partly thanks to two programmes that are enhancing food security at household level: the intense watershed programme and more recently the promotion of small-scale irrigation. Though this was a region with few modern irrigation practices, there have been remarkable achievements in enhancing productivity of rainfed and irrigated agriculture in recent years: rainfed agriculture has improved its yield from 4 quintal/ha in 1994/1995 to 24 quintal/ha in 2013/2014. Moreover, to arrest the negative impacts of runoff from roads (gully formation, flooding, water logging, etc.), the Tigray region is implementing road water harvesting using various techniques in all *woredas* (local level administration) of the region. This is enhancing productivity through improving soil moisture and recharging shallow groundwater systems. Despite the high rainfall variability in the region, over the years, through landscape restorations and introduction of appropriate water harvesting and moisture conservation technologies, it has been possible to enhance the productivity of both rainfed and irrigated agriculture and avoid climate-related disasters.

2.2.3 The role of livestock and fisheries

Livestock and/or aquaculture are an important part of agricultural production systems and agroecological approaches, providing milk, meat, eggs, fish, cash income, farm power and manure that can enhance soil fertility, while being often nurtured by hay and other crop residues. Being high in nutrition value, livestock products are important for food and nutrition security. Livestock also has important cultural values, and is a means for poor people to accumulate wealth and provide some resilience to drought and other harsh environments. It is particularly important in arid and semi-arid areas.

Livestock consumes about 20 percent of the water allocated to agriculture (de Fraiture *et al.*, 2007) and with the rapid increase of consumption of animal products this portion is likely to increase in the near future. Livestock vary in their efficiency in converting feed to animal products, which significantly affects the amount of water used. Generally, though, the water productivity of livestock products is much lower than that of crops. The production of a kilogram of meat requires on average about 15 400 litres of water (excluding water needs for processing), with averages of 10 400, 5 500 and 4 300 litres respectively for lamb, goat and chicken meat. Animals use about 2 422 Gm^3 of water per year, one-third to produce beef and one-fifth for milk. About 98 percent of this water is used to produce feed for the animals while the rest is for drinking and food processing (Mekonnen and Hoekstra, 2010).

In many areas concentrated animal feeding operations (CAFOs) have significant localized negative impacts on water quality (Halden and Schwabb, 2014). CAFOs can result in excessive nutrient loading leading to eutrophication of surface waters, for instance, creating “dead zones” in both inland and marine waters due to algal blooms and resulting in massive fish kills and declines in biodiversity (Halden and Schwabb, 2014).

There is considerable scope for increasing both physical and economic livestock water productivity through, for example, improving feed sourcing, enhancing animal production, improving animal health, and adopting proper grazing practices to reduce rangelands degradation (Peden *et al.*, 2007). Better integration of plant and livestock production, from farm to catchment level, can improve nutrient management and water use efficiency. Using agricultural crop residues in animal feed and open grazing may provide a several-fold increase in livestock water productivity, and better integration of livestock in irrigated and rainfed systems and using irrigation water for household and small industries can all increase water productivity.

In many arid and semi-arid regions livestock represents a key component of livelihoods, often the only one. Rangelands account for more of 85 percent of land use in these regions (MA, 2005). Pastoral systems are a particularly efficient way to exploit sustainably scarce biomass resources. They are extremely dependent on access to water, during the “hard” season, along the road to pastures and in the pastures. Lack of access to water at one of these points/stages can threaten the whole system. All of this requires carefully managed investments, practices and institutions. In Kenya, sedentarization around water has often totally modified access rules to water (Huggins, 2000). Sedentarized populations tend to refuse access rights to pastors, endangering some routes and thus reducing the possibility to exploit some pastures. At the same time, overgrazing around water sources often leads to land degradation. In many regions, cultivation is extending on land that was used for grazing during the dry season, threatening capacity to exploit other pastures (Steinfeld *et al.*, 2010). Lack of access rights to water at a certain point or moment can have as a consequence the loss of exploitation of biomass far away, with consequences on food production and livelihoods. An analysis of the opportunity costs of irrigation in the Awash valley of Ethiopia (Behnke and Kerven, 2013) has shown that pastoralism is consistently more profitable than big cotton or sugar cane irrigated farming, precisely because access to water and pastures during the dry season enables pastoralists to exploit land that otherwise would be improductive. Using natural rangelands and enhancing the production of water-efficient livestock can help to reduce the pressure on water for feed production. Poultry, for example, has a high water productivity level and is increasingly replacing beef and lamb meat in many countries of the global south. Further research is needed to assess livestock water productivity and how to improve it. Research may include better evaluation of water productivity along the value chain of livestock products, improving/changing feed resources to reduce water consumption, modifying low water use-efficient animal diets especially of beef (this will eventually contribute to climate change mitigation) and improving the genetics of low water productive animals. For example, the Brazilian Corporation for Agricultural Research (Embrapa) works on products, processes and services related to the agriculture sector and has done extensive research on augmenting both the agricultural and livestock production in the country.[24]

Women tend to be low-income livestock keepers in rural livestock-based economies, particularly for small livestock production (poultry, sheep, goats), and milking and processing of milk (FAO, 2011). Despite this, women are often invisible in livestock support programmes, and face greater constraints than men in obtaining access to land and water resources, extension and financial services, and markets. This limits their ability to achieve optimal livestock production (FAO, 2012c). Despite that, small livestock often function as an asset base for poorer women (and sometimes men), an insurance in informal economies.

The role of fish and fisheries in food security and nutrition has been extensively dealt with in the HLPE Report on Sustainable Fisheries and Aquaculture for Food Security and Nutrition (HLPE, 2014b). The water productivity of fish and aquaculture is high compared with other sources of protein and nutrients: cage fisheries can produce up to 100 kg of fish for each cubic metre of water (Dugan *et al.*, 2006), although such production methods have downstream impacts due to pollution from the solid organic wastes, antibiotics, pesticides and other chemical treatments, which has implications for small-scale capture fishery operations and other small-scale productive activities in the area. The two major components of water use in aquaculture are the water required to produce feed and the water required for the aquaculture itself. Water needs range from 0.5 to 45 m^3 per kilogram of produce depending on the intensity/extensity of the system used (Verdegem *et al.*, 2006). Better integration of fisheries and aquaculture with water management systems can also improve water productivity. Fish can often be integrated into water management systems with the addition of little or no water (Prein, 2002). Aquatic ecosystems provide many other services and benefits beyond fisheries such as biodiversity. Considering only the value of fish produced per unit of water is an underestimation of water productivity in these systems (Dugan *et al.*, 2006).

Aquaculture operations, often run by small-scale farmers, and inland fisheries, are often critical to local food security and nutrition and have important social and gender dimensions through induced jobs and livelihood opportunities (HLPE, 2014b). Lack of understanding of this importance by people outside the sector often causes non-inclusion or non-consideration of fisheries in basin water management and investment plans (HLPE, 2014b). It is critical that the role of capture fisheries and aquaculture in meeting the nutritional needs of poor rural communities in many areas, but also of the world at large, is considered in water policy and practice.

As competition for water resources increases, fish, inland capture fisheries and aquaculture often suffer most as water allocation priorities are focused on other sectors. For instance, the recent drought in California saw the salmon competing for water with farmers (Bland, 2014). Several freshwater fish species are seriously threatened, mainly due to environmental pressures such as poor water quality and habitat destruction.

More efficient water use and higher water productivity are critical elements of ensuring optimal water use for FSN. Without water conservation in agriculture the world will need to substantially increase water withdrawals to produce more food. However, this is not inevitable, and world food demands can be satisfied with available water and land resources by: increasing water and land productivities through upgrading rainfed and irrigated systems; optimizing virtual water flows (trade) between countries based on comparative advantages that take into account environmental costs and sustainable use of natural resources; and reducing food demand by adjusting diets and improving the efficiency of food processing and distribution (CA, 2007). There are many additional options to conserve water for FSN, some of which are presented below.

2.2.4 Plant and livestock breeding

Plant breeding approaches have helped to reduce crop water use and will be an important tool to address future water and other biotic and abiotic stresses. Passioura (1977) and Passioura and Angus (2010) identified four avenues to improve the relationship between crop yield and water use: increase the water supply; increase the fraction of water supply that is transpired; more effectively exchange transpired water for CO_2 in producing biomass (transpiration efficiency); and raise the harvest index, i.e. convert more of the plant biomass into grains.

[24] https://www.embrapa.br/en/quem-somos (accessed 28 February 2015).

The last three items are interrelated, but advances through breeding can be made separately in all three. To increase the fraction of water supply that is transpired, more optimal breeding of cultivars has allowed sowing at early, mid or late starts in the season, reducing non-beneficial evaporation, and through breeding for optimal canopy and root development. Transpiration efficiency is increased in C3 crops[25], such as wheat, with rising atmospheric CO_2 levels, with yield improvements when water is limiting normal growth (Wall *et al.*, 2006). Such a growth response is not found in C4 crops, such as maize and sorghum (Long *et al.*, 2006). Breeding focuses here on cultivars with larger transpiration efficiency (Passioura and Angus, 2010). A number of advances have been made to increase the harvest index, particularly through the breeding of semi-dwarf varieties of several cultivated crops (Richards *et al.*, 2002). Further breeding efforts focus on continued protection of floral fertility from major environmental problems (heat, frost, water deficits as described in the stress breeding), and transferring assimilates stored in the stems to the grain.

Specific stress tolerance breeding is a further avenue to improve plant–water relationships, particularly under more adverse growing conditions, such as drought (rainfed conditions), salinity (irrigated conditions) and cold and heat stress (rainfed and irrigated conditions), as well as under changing biotic stresses, such as fungi and insects. Moreover, breeding for more nutrient-use-efficient crops is of high importance for improving water quality. Breeding for stress tolerance is complex, but new genomic technologies promise to make progress for breeding tolerance through a more fundamental understanding of underlying processes and identification of the genes responsible (Witcombe *et al.*, 2010).

Barnabas *et al.* (2008) suggest three possible drought resistance strategies for maize. These include escape, which is successful reproduction before the onset of severe stress, which could be achieved through short crop duration and rapid growth; avoidance, which relates to the maintenance of high tissue water status during drought or through enhanced water uptake by modifying root growth or crop architecture; and direct tolerance, through internal osmotic adjustments or other structural changes that allow the plant to function under water stress and to recover function after the stress is relieved.

Given that the nutrient quality of grains may be compromised under water stress and global warming, breeding for enhanced nutritional quality of crops is of increasing importance. Enhanced breeding efforts into so-called orphan crops and underutilized plant species, such as quinoa or amaranth, are also important as many of these varieties are more resilient to water stress or have high nutritional qualities.

Low levels of precipitation are one of the major factors limiting crop production worldwide. It is unanimously recognized that breeding for water-limited environments is difficult and, in fact, has improved yield at about half the rate achieved for crops grown in higher rainfall regions (Turner, 2004). Dry areas offer a much less homogeneous population of target environments than areas with high and reliable rainfall. An important aspect of the relationship between the type of germplasm and drought resistance is the buffering capacity of heterogeneity. This might explain why it has been difficult traditionally to out-yield landraces consistently with genetically uniform modern germplasm in areas where rainfed crops are commonly grown under water-limited conditions. The much larger complexity in low rainfall areas suggests the need for a wider diversity of varieties (Bellon, 2006). The value of landraces, which are genetically heterogenous, as sources of drought tolerance is well documented in the case of barley in the Syrian Arab Republic (Ceccarelli and Grando, 1996) and in others crops elsewhere (Brush, 1999). In tapping such underexplored areas, investments are increasingly being made in participatory plant breeding approaches, where farmers and scientists work together to complement the strengths of each (Ceccarelli *et al.*, 2007).

Genetic resources play a key role in FSN in the face of a changing environment. Importantly, genetic diversity allows for greater sustainability, resilience and adaptability in production systems as they encounter the effects of climate change (HLPE, 2012; WWAP, 2015a). Preservation and use of genetic diversity in plant breeding can usefully be accomplished through participatory breeding efforts. Evolutionary plant breeding is one avenue for increasing genetic diversity and adaptation to dynamic change over time and space. In evolutionary plant breeding, crop populations with a high level of genetic diversity are subjected to the forces of natural selection. In a cycle of sowing and re-sowing seed from the plant population year after year, those plants favoured under prevailing growing conditions are expected to contribute more seed to the next generation than plants with lower fitness. Thus, evolving crop populations have the capability of adapting to the conditions under which they are

[25] C3 and C4 crops are classified based on the way they assimilate carbon dioxide in the leaves.

grown. This resilience is seen as a major advantage under the predicted threats of global climate change (Döring *et al.*, 2011).

Heat tolerance is a major constraint to increase livestock productivity in hotter, more water-scarce environments. Heat stress reduces productivity and fertility and increases mortality. The breeding focus is therefore on maintaining productivity while increasing heat tolerance or maintaining heat and water stress tolerance while increasing productivity. Other breeding avenues focus on improved forage breeds, following the strategies laid out in the plant breeding section, as well as breeding for reduced environmental impact and increased disease resistance (Thornton, 2010), all of which directly relate to too much or too little water.

2.2.5 Investing in agro-ecology

Agro-ecology is an approach to agriculture that considers agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices. As such, it focuses on the entire agro-ecosystem (rather than individual plants, animals or humans) in specific socio-economic contexts (IAASTD, 2009; Altieri *et al*., 2012a). Agro-ecological approaches can also stress the right of people to define their own food and agriculture systems, allow producers to play a lead role in innovation, and place those who produce, distribute and consume food at the centre of decisions on food systems and policies. Benefits of this approach can include: dietary diversity and nutrition security through preserving macro- and micronutrients in the soil; protecting natural resources through using fewer artificial inputs; promoting agricultural resilience through use of diverse farming systems; and providing a sustainable and scalable path to food security through allowing smallholder farmers to lead. In more drought-prone and marginal environments, water and land management practices that make use of indigenous technology and involve techniques such as water harvesting, micro-irrigation, mulching and the construction of hillside terraces lined with shrubs and trees, which enhance the ability of the soil to catch and store water, can prove highly effective.

Agro-ecological practices can be important for water for FSN through conservation agriculture, no-till and integrated soil fertility management that support water infiltration, reduced evaporation through soil coverage, the build-up of soil organic matter and enlarged root growth and thus increased soil moisture holding capacity. Farming techniques with fewer inputs protect water from degradation due to chemical pesticides and fertilizers (Altieri *et al.,* 2012a), and agro-ecological methods maximize the productivity of available resources through context-specific soil, water and biodiversity management regimes informed by local knowledge (Altieri *et al*., 2012b). Agro-ecology's focus on maintaining crop diversity also allows farmers to appropriately utilize available water resources (Altieri *et al.,* 2012b). A study in Argentina comparing traditional agricultural techniques with newer techniques showed that traditional ecological approaches could better preserve available water resources (Abbona *et al.*, 2007), while farmer experiences with conservation agriculture in the United Republic of Tanzania have indicated that agro-ecological approaches to water management can increase crop productivity (Altieri *et al*., 2012b).

Many of these traditional and modern water conserving and management practices, including supplemental irrigation and SRI (system of rice/root intensification), are part of agro-ecological approaches. While agro-ecology is rooted in the rationale of traditional peasant farming systems, agro-ecological transition processes include innovative forms of collaboration between farmers and researchers, building primarily on functionalities given by ecosystems and on traditional knowledge while combining these with the best use of modern agro-ecological science (see also Parmentier, 2014). One example of such collaboration is in Swaziland where the government and the International Fund for Agricultural Development (IFAD) run the Lower Usuthu Smallholder Irrigation Project, which combines water harvesting techniques with sound land practices such as minimal tillage, conservation agriculture, rangeland management and afforestation to alleviate current and future stresses on scarce water resources. This initiative has also contributed to the health, livelihoods and food security of participating smallholder farmers (IFAD, 2013). Moreover, by selecting crops that are native and agro-climatically suited (such as drought-resistant millets in India), agro-ecological approaches also build climate resilience in an effective and cost efficient manner that is affordable for poor communities (Holt-Giménez, 2002; Varghese, 2011).

However, there are other experts and studies that suggest that zero external input farming would put global food supplies at risk, exhaust soils and lead to the deforestation of the world's remaining tropical forests. Two recent meta-studies showed that yields from organic farming average 20–25 percent less than those from conventional agriculture, but with large variations (de Ponti *et al*., 2012; Seufert *et al*., 2012).

Can also be mentioned, as part of the range of agro-ecological approaches, those "ecological sanitation" or eco-san approaches aiming at closing the nutrient cycle by making use of human excreta to improve soil nutrients and increase food production (Esrey *et al.*, 2001), seeking to do so without using water to carry the excreta to reduce discharge into water bodies. Although hygiene guidelines (see WHO, 2006) should be followed when handling human excreta for agriculture, both urine and faeces are high-quality, complete fertilizers that have been shown to improve crop production when appropriately applied (Jönsson *et al.*, 2004). Such closing of the nutrient cycle along with other soil management activities can contribute to improved water productivity, including improved nutrient content of crops. Estimates based on available phosphorus from human excreta in 2009 indicate that this source could provide up to 22 percent of total global phosphorous demand and could be a particularly important source of soil nutrients in regions with severe soil degradation (Mihelcic *et al.*, 2011).

2.3 Improving water management in irrigated agro-ecosystems

Irrigation has been essential to achieve the productivity gains and food price reductions seen all over the world, if not enjoyed equally by all, over the last three decades. Irrigation is also associated with significant positive multiplier effects, such as employment in the lean season, widening of livelihood opportunities through household gardens, livestock rearing, aquaculture and handicrafts, and benefits for health and nutrition (Meinzen-Dick, 1997; Lipton *et al.*, 2003; Domenech and Ringler, 2013; Rosegrant *et al.*, 2009a).

Box 10 The gendered nature of irrigation and water management

Globally, women own considerably less land than men. One claim is that women own only 2 percent of land (Urban Institute). However, due to lack of sex-disaggregated data it is hard to establish an accurate figure substantiated by empirical evidence, as current knowledge do not reflect variations in landownership across or within countries, do not acknowledge differences in landownership regimes, nor address comparative ownership by men in the same contexts (Doss et al, 2013) – for example, it is unclear to what extent some of the matrilineal practices in Africa are recognized in assessing land ownership.

In addition, the issue of ownership does not sufficiently take into account water-related activities of women and men who are not landowners. Even where women own land either independently or jointly with family, their common exclusion from decision-making structures reinforces the male bias in irrigation. Men and male engineers dominate the irrigation sector and the implementation of water and sanitation projects (Zwarteveen, 2008). Even where the involvement of women is a requirement of the implementing agency, it is often either tokenistic or women and girls are expected to devote their voluntary labour rather than have any clear influence on decision-making or develop particular skills.

For example, as a rule, men are trained to manage wells, pumps and sanitation facilities and women are required to maintain and clean them, drawing on the traditional imagery of women as the keepers of cleanliness and purity in their families and local communities. Women's participation in decision-making is hampered by cultural barriers and traditional gender roles. Nationally and internationally very few women are represented in relevant ministries and international agencies or bodies (Zwarteveen, 2008).

Studies have shown that when women are included in irrigation project design and implementation, the projects are more effective and sustainable (FAO, 2012b). There are examples of female empowerment through community and institutional leadership in various countries, including Australia, Bangladesh, India, Nepal, the United States of America Southwest, and Viet Nam (see Lahiri-Dutt, 2011). One such leader, Stella Mendoza, became the first woman elected to the Board of Directors of the Imperial Irrigation District in Southern California, and ultimately served as Board President during complicated litigation with the US government over the Colorado River water supply for irrigated agriculture in California).

Box 11 Salinization

Salts may exist in agricultural lands due to natural geological causes, but large irrigated areas in the arid and semi-arid regions face problems of reduced soil productivity as a result of secondary soil salinization. As an example, 50 percent of the fertile land in Iraq has been salinized over the last two decades due to mismanagement or lack of drainage facilities (Wu *et al.*, 2014), and in Central Asia, the lack of proper maintenance of drainage systems is causing substantial salinization of irrigated lands.

Salts accumulate in the irrigated soils as a consequence of continuous addition of salts with irrigation water or due to a rising water table (waterlogging) bringing salts to the surface through capillary rise. Tens of thousands of hectares of productive irrigated land are salinized every year to various degrees, affecting the livelihoods of communities dependent on this land.

Two strategies are available to deal with secondary salinization: (a) “living with salinity” by allowing the land to salinize and then cultivating salt-tolerant crops and halophytes with special management; or (b) “controlling salinity” through leaching and maintaining highly productive land. It is estimated that 40–60 percent of irrigated areas require drainage to avoid soil salinization (FAO, 2002b). Controlling salinity is the recommended strategy in irrigated areas, which requires investment in drainage facilities and irrigation management with appropriate institutions and policies.

Yet public investments in large-scale irrigation have declined substantially over the last two decades in much of the world; only sub-Saharan Africa has seen strong increases in investment, albeit from a small base (Rosegrant *et al.*, 2009b). As aptly put by CA (2007: 30) *“The era of rapid expansion of large-scale public irrigated agriculture is over: for most regions a major new task is adapting yesterday’s irrigation systems to tomorrow’s needs”*. The reasons for the decline in large-scale irrigation systems include underperformance, which reduced donor interest, concerns over negative social and environmental impacts, more competition for water from other sectors and declining cereal prices, which reduced the urgency of and the returns on irrigation investment (Ofoso, 2011).

Moreover, the development of private irrigation systems, particularly groundwater-irrigated systems, has also reduced the pressure to develop large systems, even though many groundwater irrigation systems depend on underperforming surface systems with substantial leakage (see Section 2.3.2). Other systems include: farmer-financed and managed irrigation, chiefly supported by motor pumps, smarter surface systems; judicious investment in selected, large-scale systems linked with reservoirs that are often built for multiple purposes; and reforming water management institutions towards maintaining the ecological integrity of systems while improving productivity and profitability (FAO, 2006; Rosegrant *et al.*, 2009a; Wichelns, 2014; Faurès *et al.*, 2007). An important issue is salinization, which degrades land already equipped for irrigation (see Box 11). FAO estimates that globally 34 million ha are now impacted by salinity, representing 11 percent of the total irrigation equipped area (FAO, 2011a). The challenge for irrigated agriculture in this century is to improve equity, reduce environmental damage, strengthen ecosystem functions and enhance water and land productivity in existing and new irrigated systems.

2.3.1 Groundwater for irrigation

Thanks to access to new drilling technologies and cheaper pumps, a quiet groundwater revolution has taken place since the 1970s (see Custodio, 2010; Margat and van der Gun, 2013) and this has helped millions of farmers and pastoralists in Asia improve their livelihoods and food security. Groundwater development has been particularly rapid in the Indo-Gangetic plains of South Asia and the North China plains, both areas with high concentrations of poor farmers. The Gulf Countries rely almost entirely on groundwater, although with increasing production of freshwater through desalination. In sub-Saharan Africa no such revolution has taken place and efforts “to unlock the groundwater potential” in this continent should take place in a way that avoids the mistakes committed in South Asia and elsewhere.[26]

[26] See www.upgro.org for details of a UK cross-council research programme on unlocking the potential of groundwater in Africa for the poor.

Table 2 Global survey of groundwater irrigation

REGION	GROUNDWATER IRRIGATION		GROUNDWATER VOLUME USED	
	Mha	propn total	Km^3/a	propn total
GLOBAL TOTAL	***112.9***	***38%***	***545***	***43%***
South Asia	48.3	57%	262	57%
East Asia	19.3	29%	57	34%
South-East Asia	1.0	5%	3	6%
Middle East and North Africa	12.9	43%	87	44%
Latin America	2.5	18%	8	19%
Sub-Saharan Africa	0.4	6%	2	7%

Source: GWP (2012), derived from Siebert *et al.* (2010).

There are estimates that groundwater accounts for 38 percent of the total irrigated area and 43 percent of total irrigation volumes (Siebert *et al.*, 2010). While in parts of South Asia groundwater expansion was directly associated with higher water tables arising from leaky public surface irrigation systems (Indo-Gangetic Plains), in other places groundwater use developed due to the lack of available surface systems (e.g. in the Vietnamese Central Highlands for coffee production). In yet other places, easily accessible aquifers have resulted in overexploitation of groundwater (for example the Ogallala in the United States of America; or much of the groundwater pumping in Bangladesh).

While it has been argued that groundwater irrigation *"promotes greater interpersonal, intergender, interclass, and spatial equity than does large surface irrigation"* (CA, 2007: 32), researchers looking at informal groundwater markets in South Asia have demonstrated that access to groundwater is often tied to access to credit and subsidized electricity, thus benefiting large farmers with resource-poor farmers bearing the cost of the depleting resource (Dubash, 2007; Sarkar, 2011).

The energy-groundwater nexus has created a curious political economy paradox: soaring energy prices may help save aquifers by reducing the degree of pumping, thus reducing overabstraction of groundwater in places where energy is not (highly) subsidized and where groundwater-based livelihood systems are currently under threat from overabstraction. However, recent developments of affordable solar pumps may significantly change the energy–groundwater relationship. Relying on high energy costs to limit water extraction rates is unlikely to prove sufficient to ensure the sustainable use of groundwater.

Box 12 Changes in irrigation in Spain

Recent shifts in Spain's water management, particularly as it seeks to comply with the EU Water Framework Directive, have led to conflicting developments adversely affecting irrigation. The Shock Plan of Irrigation initiated in 2006 was intended to save water and align with European water policy regulations (Ministry of Agriculture, Fishing and Food and Ministry of the Environment, n.d.). Spain's modernization of irrigation systems, which refurbished and modernized about 1.3 million ha of irrigation schemes, coupled with farmers' move from gravity irrigation to drip irrigation, has been shown to conserve water resources. But moving from canals to pressurized conveyance networks and drip irrigation requires substantially more energy (Hardy *et al.*, 2012). From 1970 to 2007, on-farm irrigation water use decreased by 21 percent while the cost of energy consumption increased by 657 percent (Corominas, 2010, cited in Stambouli *et al.*, 2014). These changes have meant that 40 percent of electricity used in Spain on water-related activities is used for irrigated agriculture (Hardy *et al.*, 2012). At the same time, Spain moved towards a changing energy mix adding more renewable energy sources, subsidized by increases in energy tariffs (using the feed-in regulation) and increasing the electricity tariffs to all Spanish users. For farmers the results of these dual developments are ambiguous: while their capital and infrastructure improved significantly, with all the benefits this creates, the cost of electricity has grown significantly. This, and the financial costs of the investments that were only partially funded by the government, are the main drawbacks of this major policy reform. Less water consumption, greater water and land productivity, more water control and monitoring and better farmers' lives are, however, unquestionable benefits (Garrido, personal communication).

In areas with good aquifers and recharge and a high prevalence of poverty, such as the Eastern Gangetic plains, the groundwater potential could be further exploited (see Mukherji *et al.*, 2012). Groundwater irrigation remains an important development strategy especially in countries where it is still underutilized such as in parts of Central Asia (Rakhmatullaev *et al.*, 2010, Karimov *et al.*, 2013) and much of sub-Saharan Africa (MacDonald *et al.*, 2012).

Groundwater is much more challenging to manage than surface water because it is not visible; underground connections and flows are seldom well understood, and the interaction between surface and groundwater is also poorly understood. Moreover, individual well-owners are often dispersed, might have several wells, and often consider groundwater as private property. It is also generally not directly or easily known how extraction by one party affects others. Groundwater use management is also relatively recent, compared with surface water management, and the norms and regulations for its management have yet to mature. This can lead to a "race to the bottom" where those with the strongest and deepest wells persevere until the resources are exhausted (Bruns, 2014). Attempts at top-down formal regulation of groundwater use, based on well licensing and regulation of water withdrawals, have usually been ineffective (Shah, 2009), in part as the numbers were too large to administer. However, there are some cases of successful, formalized groundwater management, such as in parts of southern California (Blomquist, 1992), but management does not necessarily prevent depletion.

The Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS) is one of very few successful, voluntary groundwater governance systems that have resulted in both higher farmer incomes and water savings (World Bank, 2010b; Das and Burke, 2013). The project was implemented through direct community leadership of hydrological monitoring and measuring of local rainfall and groundwater levels. The information was then displayed publicly. Moreover, communities co-developed crop-water budgets and received information on alternative crops and cultivation practices (Garduño *et al.*, 2009). Why did increased profitability not lead to irrigation expansion and further depletion? Bruns (2014) suggests that the creation of common knowledge and shared strategies helped to limit water use and balance water demand and supply.

Sustainable groundwater management requires balancing supply (which is dependent on recharge) and demand, and needs effective interventions on both the supply and demand side. Supply-side measures may include artificial recharge, aquifer recovery or the development of alternative surface water sources, while demand-side measures generally focus on water use rights and permits, collective management, water pricing, legal and regulatory control and water-saving crops and appropriate technologies (CA, 2007) (see also Box 12). However, supply-side measures may be easier to implement than demand-side measures due to local socioeconomic and political factors (see Dubash (2007) for an example from India). The only way to maintain aquifer systems to an acceptable degree may be to control the expansion of irrigated areas, improve practices and adopt water-use efficient crops (Shah, 2007; Rakhmatullaev *et al.*, 2010).

2.3.2 Enhancing irrigation management

Although still necessary, government supported or public investment in irrigation must become more strategic so that irrigation development takes into account the full social, economic and environmental costs and benefits of development. The model of irrigation adopted can be selected from a range of options, from small-scale, individual-farmer managed systems to large-scale, reservoir-based systems (Wichelns, 2014; CA, 2007; Faurès *et al.*, 2007). At the same time, rehabilitation of existing systems, chiefly through irrigation management reform, has started to show promise. Conjunctive or joint use of surface and groundwater systems, such as those in parts of South Asia, have superseded surface-only systems to achieve higher productivity and efficiency. In yet other systems, multiple uses of irrigation water (such as for fisheries) provide greater benefits than irrigation alone (CA, 2007; Meinzen-Dick, 1997).

It is well documented that women have less access to technology, extension and advisory services, which are key to ensuring the success of modernizing efforts (FAO, 2011). As irrigation systems are developed and rehabilitated, consideration must be given to women's differentiated needs, capacities and priorities in the agriculture sector. Technology is not sufficient to improve irrigation efficiency if it is not made accessible to all the stakeholders involved in the sector.

Under climate change, irrigation systems will be called upon to provide even greater water control to compensate for more erratic precipitation, which will come at a cost, given that much of the infrastructure is aging (CA, 2007). Calls for expanding irrigation systems are confronted by increased water scarcity and competing uses. Unless water savings are made in existing irrigation systems, it will be difficult to achieve substantial expansion in most parts of the world. Some measures towards saving water are discussed below.

Revitalizing large-scale surface irrigation systems

Most of the large-scale irrigation systems, generally referred to as canal irrigation, were constructed in the second part of the last century when they played a pivotal role in increasing food production. However, the efficiency and effectiveness of those systems have deteriorated over the years and they need revitalization. This deterioration is mainly due to lack of investment in maintenance and operation and to poor management practices. Governments that invested in building the systems were generally unable to establish a water pricing scheme that users accepted, and maintenance and operations fees were not enough to keep the systems operating at high efficiency (Malik *et al.*, 2014). A further factor is the lack of sufficient water measurements, especially at the farm level. Revitalization of irrigation systems requires investment in automation and measurement, as well as increasing the reliability of the water supply and upgrading the technologies used. More attention and investment is needed in maintaining existing drainage systems and building new systems. The participation of water user associations in setting the rules for water allocation and managing the irrigation system – administering appropriate user charges and limiting allocations to actual needs – is thus critical.

Increasing irrigation efficiency

The issue of irrigation efficiency is often subject to controversy and misinterpretation. Because only 30–50 percent of the water withdrawn from a resource is actually evapotranspired by crops in a typical irrigation system, many conclude that substantial gains in water volumes can be obtained by increasing application efficiency in irrigation. However, as Seckler *et al.* (2003) state, irrigation efficiency improvements at the irrigation system level might yield little real water savings at the basin scale where water is reused many times, and the concept of water efficiency is therefore site-, scale- and purpose-specific (Lankford, 2006). It is, therefore, important to understand the hydrology of the entire catchment or basin before suggesting investments in water-use efficiency.

Reducing field losses by converting to modern systems will increase yields and save some water but will not create substantial additional water resources. In Egypt, farmers along the Nile and around the delta lose on average about 55 percent of the water they apply through surface irrigation systems in runoff and deep percolation (an application efficiency of 45 percent). However, the lost water is continuously recycled through the drainage system and groundwater pumping. Only about 10–15 percent of the Nile water in Egypt enters the sea, which brings the system's overall efficiency to about 85 percent. So understanding surface irrigation system losses needs to be put in the context of scale to evaluate the real vs paper losses across the system (Molden *et al.*, 1998; Oweis, 2014; Seckler, 1996). On some occasions these losses are not recovered as they may join salt sinks or be stored in unreachable locations. While farm level losses are important to the farmer as water and pumping bring costs to bear, these are usually not total losses at the larger scale (Oweis, 2014).

Other issues to consider when devising irrigation efficiency improvements include the irrigation design, operation and management, equity in access, energy savings and levels of waterlogging and salinization (Bos *et al.*, 2005; Faurès *et al.*, 2007).

Modernizing irrigation systems

It is well established that modern irrigation systems can achieve higher crop productivity, but this is achieved not by reducing system losses in deep percolation and runoff, but rather through better control, higher irrigation uniformity, more frequent irrigation (to link water supply with crop water needs), better fertilization (fertigation), and other factors. In some modern systems, such as drip systems, real water saving can be achieved by reduction of evaporation losses, where the wetted soil surface is limited and mulches can be used to further reduce evaporation. The increased land productivity, however, comes at a cost – higher capital, higher energy consumption and more maintenance requirements. Successful conversion requires a developed industry, skilled engineers, technicians and farmers, and regular maintenance (Oweis, 2012).

Modern systems are meant to be efficient. However, they can be efficient only if they are managed properly and often they are no more efficient than traditional surface irrigation systems because of poor management. The vast majority of irrigation systems worldwide are surface irrigation; this is unlikely to change in the near future (FAO, 1997). Selection of the appropriate irrigation system may not depend solely on its application efficiency, but on other physical and socio-economic conditions at the site (Keller and Keller, 2003).

Modern systems are most successful in areas where water is scarce and expensive so that farmers can recover the system cost by reducing irrigation losses and increasing productivity. When water is cheap and abundant, farmers, especially in the global south, have little incentive to convert to modern systems. In fact, improving surface irrigation systems through land levelling and better control may be more appropriate for most farmers in the global south than modernizing the irrigation systems.

Managing demand

In most countries, large water users, such as energy producers, extractive industries and beverage companies, pay very little for the water they abstract for their operations. In the context of agriculture, in many countries water for irrigation is highly subsidized. Farmers have little incentive to restrict their use of water or to invest in new technologies to improve the use of available water. Although it is widely accepted that appropriate water pricing would improve efficiency and increase cost recovery of irrigation projects, the concept of pricing presents enormous practical, social and political challenges, including the difficulties in measuring water and monitoring its use by farmers and the pressures for subsidized inputs. There is also a fear that once water is established as a market commodity, prices will be determined by the market, leaving the poor unable to buy water even for household needs. Downstream riparian countries fear that upstream countries may use international waters as a market commodity in the negotiations on water rights (Altinbilek, 2014). While water pricing may reduce the demand for water in agriculture or divert it to higher-value or luxury crops, it may not improve agricultural production for food and nutrition security and/or poor farmers' livelihoods, thus making little direct contribution to increasing FSN (Perry *et al.*, 1997). On the other hand, without water use rights and without paying for the water service for irrigation, farmers have little recourse when water is re-allocated to more valuable urban or industrial uses or becomes non-available in times of drought.

One cannot ignore these very real concerns. Innovative solutions are therefore needed to put a real value on water in order to improve efficiency, while at the same time recognizing cultural norms and ensuring that people have sufficient water for basic needs. Subsidies for poor farmers may be more purposely provided for inputs other than water, to avoid wastage of water. Countries must also improve cost recovery of irrigation supply systems.

2.3.3 Use and management of marginal quality water

In recent years, marginal quality water has emerged as an important source especially in water scarce arid and semi-arid regions and in peri-urban agricultural developments (see Box 13). Potential sources include brackish water, agricultural drainage water and treated sewage effluents. While in many areas poorer people have little option but to use marginal water in agriculture, there are management concerns regarding negative impacts on people and the environment. The UN has identified four strategies to cope with these concerns: pollution prevention measures; treatment to higher quality; safe use of wastewater; and restoration and protection of ecosystems. Close monitoring of marginal quality water use and development of the appropriate institutional and policy environments are necessary to ensure productive use of this important source without degrading ecosystems or affecting people's health.

Brackish water is available in notable amounts, mainly in groundwater aquifers, in many regions, with varying levels of salinity. While a number of fresh water aquifers have become brackish as a result of groundwater mining and seawater intrusion others are naturally brackish. They are either used directly in agriculture when salinity is not too high for salt-tolerant crops or after desalination for human, industrial or general agricultural use. The desalination cost of brackish water is not as high as that for seawater, and farmers in many countries, such as in the Middle East, are desalinating on-farm for agricultural purposes. Using brackish water in agriculture can contribute to food production and the environment, but it requires special management to prevent land salinization and degradation of ecosystems, as well as the development or selection of crops that tolerate some level of salinity. Currently saline water is being used innovatively to produce products with a special taste and texture with higher market value (Byczynski, 2010). Overexploitation of brackish water, however, will increase salinity.

In the last few decades there has been considerable research on the reuse of drainage water in agriculture and its impacts on the environment. Due to overirrigation, drainage water quality is suitable for most crops and is used by farmers at the tail of the canals when freshwater is scarce. In Egypt, the drainage water from agricultural lands is collected by an extensive drainage network and recycled after being mixed with freshwater downstream, until it becomes too saline for productive use. Currently about 5.5 billion m^3 of drainage water are reused in Egypt annually and this is expected to increase to about 10 billion m^3 by the year 2017 (Abdel-Shafy and Mansour, 2013).

Treated sewage effluent is increasingly becoming an alternative source of irrigation water. Generally, about 70 percent of water used for domestic purposes can be treated and recycled for agriculture or environmental purposes. In Jordan, where the per capita annual share of water is about 130 m^3, over one-third of agricultural water comes from treated sewage. Millions of small-scale farmers in urban and peri-urban areas of the global south irrigate with wastewater from residential, commercial and industrial sources, often with no treatment before use (see Box 13). In some areas there is scope for expanding irrigation on this basis, while in others the challenge is to get more productivity from existing infrastructure. Many factors prevent the expansion of wastewater reuse, however, including cost, social barriers, technical obstacles and institutional and political constraints. Utilizing treated sewage water is essential especially in water-scarce areas but requires developing policies and practices to properly control quality and handling in the field (UNDP, 2013). Given the significant potential health risks associated with wastewater reuse, CA (2007) suggests three approaches to addressing marginal water: reduce the volume of wastewater generation; address risks in agricultural use of wastewater; and improve handling of food irrigated with wastewater. It is essential that sewage effluent is treated to the standards and guidelines set by WHO and other UN organizations for various uses. In addition, countries should develop their own guidelines regarding the types of crops that could be grown with treated sewage water. In general, it is best used for irrigation of ornamental gardens, non-edible crops or those not consumed fresh.

Box 13 Urban and peri-urban agriculture

Urban agriculture has the potential to contribute to food security both directly through producing nutritionally rich food for consumption and indirectly by providing livelihoods to urban poor through producing food for the market (Zezza and Tasciotti, 2010). Participation in urban agriculture is correlated with wealth and landholdings since it requires access to land and inputs (Frayne *et al.*, 2014), limiting its potential as a solution to food security issues for the truly poor. However, in the Kibera slums in Nairobi, Kenya, sack gardening has become increasingly common since it can be practised with limited space (Gallaher *et al.*, 2013). It has been demonstrated to have a positive impact on household food security and sense of food security, but its impacts are limited by access to inputs, including water. Limited access to water for irrigation in urban areas can also have negative health consequences if polluted water resources are used – a common problem for urban and peri-urban agriculture (Cofie and Drechsel, 2007).

A recent report on urban agriculture in London encourages agriculture in the city in order to improve food security and meet the demand for locally grown food (London Assembly, 2010). The report suggests using city wastewater for irrigating agricultural spaces in order to counter the impact of increased demands on the city's water supply.

In many peri-urban areas, particularly in South and Southeast Asia (Holm *et al.*, 2010), wastewater is used for growing food that is sold in the urban fringe and in urban centres. Use of wastewater for irrigation provides water in areas of scarcity, disposes of waste and decreases the need for other inputs such as fertilizer because of the higher availability of plant nutrients in wastewater (Ghosh *et al.*, 2012). However, wastewater use for irrigation can also lead to higher concentrations of metals in agricultural products, especially vegetables, and in the soil. Consuming food with heavy metal-contamination can deplete nutrients in the body, leading to health problems associated with malnutrition. Studies of levels of food contamination through use of wastewater in production in Viet Nam, Cambodia and India have found limited health risks but noted that some foods, such as spinach, have higher concentrations of toxicity (Holm *et al.*, 2010; Ghosh *et al.*, 2012).

2.3.4 Desalination

Desalination of seawater is a potential source of freshwater especially in coastal areas. Increased water demand coupled with lower production costs due to technological advances has helped in the rapid growth of this sector. Over 40 percent of the world's desalinated water is in the six Gulf Cooperation Council (GCC) countries. Currently they produce about 30 million m^3 a day and this is expected to increase to over 50 million m^3 a day by 2025 (Fath *et al.*, 2013). This is due to the region's extreme freshwater scarcity and the abundance of energy resources for desalination. According to Ghaffour *et al.* (2013), desalination capacity is growing rapidly in water-short countries where demands on water resources have risen beyond reliable supplies and as desalination costs have declined to less than USD 0.50 per cubic metre in some places. These lower costs are, however, generally associated with energy subsidies and ignore environmental costs. As new technologies develop, costs might eventually drop sufficiently to enable the profitable use of desalinated water for agriculture, possibly using natural gas or solar energy as a source of energy. Nonetheless, its production is still generally too costly for agricultural use. Adding to that the high energy demands and the potential environmental impacts on coastal areas (the concentrate and chemical discharges to the marine environment and the emissions of air pollutants), it may not emerge as a major water source for food production in the near future.

2.4 Improving water management in food processing

Data on water used in food processing are not always directly available. It is often part of industrial manufacturing data, itself part of industry use, of which energy is by far the biggest part. For instance for the US Geological Survey (USGS) *"industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility"* (USGS, 2014). This includes the water used in food processing. The USGS reports that the "industries" that use the largest amount of water are those that produce food, paper, chemicals, refined petroleum or primary metals (Kenny *et al.*, 2009). In the United States of America, in 2005 the amount of water for industrial use, including processing, was estimated at 70 million cubic metres of water per day. Eighty-two percent of this total was supplied through surface water and the rest from groundwater.

Food processing uses much less water than primary production. In Europe, manufacture of food products consumes on average 4.9 m^3/inhabitant, ranging from 1.7 m^3/inhabitant in Malta to 15.8 m^3/inhabitant in the Netherlands (Förster, 2014). The volumes needed for some products are, however, significant. According to UNIDO (n.d.), water use for the processing of peaches and pears ranges from 14 000 to 18 000 litres per tonne of product but is much higher for green beans, at 45 000 to 64 000 litres per tonne of product. Water use for 1 tonne of bread is estimated at 1 800 to 3 600 litres, and for milk products at 9 000 to 18 000 litres.

Importantly, use of water at the food processing stage includes adding water to food, and the use of water for cleaning (Table 3). As mentioned in Chapter 1, water is one of the main causes of food-borne illnesses. Quality of water is thus particularly important to ensure the quality and food safety of the final product. Availability of appropriate water sources in quantity and quality can be a constraint to local food transformation in some areas. This is why some large users of water for food transformation tend increasingly to secure their supply through control of the resource (see Chapter 1).

There are opportunities to reduce water use intensity (litres of water used per kilogram of product), as shown by the recent reduction in some sectors. Kirby *et al.* (2003) estimated that general changes in culture, such as educational and monitoring programmes, and changes in operations (e.g. installation of taps with automatic shut-off systems) could reduce consumption by up to 30 percent. Further improvements could be achieved through water reuse and recycling, but would require higher capital investments as well as strong food safety safeguards.

Table 3 Water quantity and quality requirements for selected processes in food processing

Process	Relative water quantity	Water quality
Direct preparation of product	Low	High; Potable
Bottled water	High	High; Potable
Cooling water	High	Medium-High
Product washing	Medium–High	Medium–High
Fluming water (conveying and washing raw products)[27]	High	Medium–High
Production of ice, hot water and steam	?	Medium–High
Air conditioning and humidity control	?	Medium–High
Starting-up, rinsing and cleaning of processing equipment	High	High
Cleaning and disinfection of processing facilities	High	Medium
Sanitization water	?	?
Boiler feed water and fire extinguishing	High	Medium

Source: adapted from Kirby *et al.* (2003); data from Codex Alimentarius Commission (2000).

The food processing sector has potentially adverse environmental impacts through the discharge of wastewater from processing facilities, as well as through the production of solid waste. While relatively low in volume, wastewater discharged from food processing tends to be highly polluting if untreated, and as such warrants analysis. It is generally rich in nutrients with potential risks of eutrophication. Wastewater from fruit and vegetable processing may be rich in pesticides and suspended solids. Rinds, seeds and other raw material require storage or composting. Meat, poultry and seafood processing produce wastes that are more difficult to treat and control. Blood and other by-products create a waste stream high in biochemical oxygen demand (BOD) and that may carry pathogens.

The best method for environmental protection and reducing water pollution has been to develop systems to reduce, reuse, recycle and treat wastewater from food processing. Reduction consists of limiting the amount of waste before it is washed away from processing facilities. Reuse of waste products as animal feed, for energy production, or through composting as soil additives, are approaches that help reduce waste and reuse important nutrients. Wastewater can then undergo an advanced treatment process, which may include ozone or chlorine disinfection when needed (e.g. meat by-products) (UNIDO, n.d.) (see for example Box 14).

Box 14 Case study Vissan Slaughterhouse, Ho Chi Minh City, Viet Nam

In 1999, Vietnam Meat Industries Limited Company (VISSAN) was the only large, integrated modern slaughterhouse and meat processing unit in Ho Chi Minh City, processing cows and pigs. But almost all by-products and waste streams generated by the slaughtering process were directly discarded into local water bodies. These included blood, hides, offal, stomach contents and manure, wastewater and hair, leading to a high organic pollution load. A cleaner production team funded by the Swedish International Development Cooperation Agency (SIDA) and the United Nations Industrial Development Organization (UNIDO) identified a series of causes of waste generation as well as a series of solutions. Solutions, such as collecting blood for sale as fishmeal, and solid waste from offal cleaning for resale as manure, brought immediate benefits in terms of hygiene, water use reduction and reduced choking of sewers as well as potential income from sales. Changes in the water pipes used and installation of closed loop cooling systems brought further large benefits in terms of water savings and hygiene. As the polluter-pays principle is not in force in many countries, the identification of incentive aligning win–win approaches such as those that improve the balance sheet of the company while also reducing adverse impacts on natural resources from either overextraction or pollution will continue to play a major role in managing the rapidly growing number of processing industries in the world.

Source: SIDA/UNIDO/DOSTE (1999).

[27] Flumes for conveying and washing unprepared raw products (e.g., beets, tomatoes, other unprepared fruits and vegetables).

The above *gives a partial and very incomplete picture* of how much water is used in the food processing, distribution and retail end of the food chain/value chain. In the case of more industrialized food systems where food supply chains have become extremely complicated and geographically dispersed, there is a high probability that the figures provided above for water use are considerably underestimated. A better measure would be based on a systemic life cycle analysis. All stages involved when moving the food product through the processing, distribution and retailing (and subsequent waste management stages) need to be assessed — so that the analysis covers the water use of all processes involved in the production and delivery of a food product, including water used in manufacturing machines and tools used in food processing and distribution, water used in the energy required for food processing, and the water used in the production of additives and other chemicals. Such a comprehensive approach can lead to a more accurate value for the water footprint, embodied water, or other indicator of water use (see Section 2.5).

2.5 The role of trade as an option to manage/cope with water scarcity/abundance

As is the case in most of the issues that the HLPE has examined, trade in relation to water for food security and nutrition plays an essential but complicated role. Viewed through the perspective of water, trade is an important strategy to support a stable food supply in countries that are confronted to with water scarcity. Trade also offers countries with water-abundant regions the livelihood opportunities and income benefits that come from agricultural export revenues (trade in virtual water), which, so long as they are managed sustainably, need not jeopardize the underlying natural resource assets essential for their FSN.

As discussed in the 2011 HLPE report on food price volatility, however, distortions in agricultural markets can create FSN vulnerabilities for water-scarce countries that have come to rely on imports. Export restrictions and bans were a significant factor in the 2007–2008 food price crisis, particularly in the extreme price volatility seen in the rice market but also in wheat and soybean (HLPE, 2011). The export bans and restrictions exacerbated price increases and added to the uncertainty food-importing countries faced as to the availability of supply (Sharma, 2011). The use of export restrictions by exporters such as the Russian Federation, Argentina and India sent a strong signal to importing countries that exporters' domestic interests remained paramount and that water-scarce food importers were vulnerable to FSN risks at times of crisis. In addition, some low-income importers were priced out of the market when private grain traders broke contracts, choosing to buy out their obligations and sell grain for higher prices elsewhere.

Countries adversely affected by trade disruption to imported food supplies reacted by looking at measures that would reduce their exposure to price volatility, revisiting the policy of holding food stocks, investing in risk management strategies such as weather insurance for producers, and renewing their investments in both domestic agricultural production and food processing industries. Some richer water-scarce countries looked abroad for places where they could grow their food. For example, in the first big wave of large-scale land investments following the food price crisis of 2007–2008, Middle Eastern oil states were prominent among those who looked abroad for arable land with reliable water that they could lease to grow food for their domestic use (Cotula, 2009). More generally, the dramatic increase in land investments from 2008 reflected a new interest among investors for land with good potential for agricultural production, for which water was of course essential.

Donors and national governments have supported a number of initiatives to improve market transparency and strengthen domestic food production in low-income net-food-importing countries. In 2011, the G20, supported by CFS, also agreed to establish AMIS – the Agricultural Marketing Information System – to improve transparency in international markets by publishing information on stocks. But WTO member states have failed to agree as yet on binding rules to limit the use of export restrictions. The situation is especially acute for net-importing low-income countries that face water scarcity and/or periodic flooding that have come to rely on international markets to bring some stability to domestic markets. A review of the causes of price volatility shows that 30 years ago much of the volatility in developing countries' food import bills was linked to fluctuations in domestic production; only 25 percent of the change was due to international price shifts. By 2012, however, most of the total increase in developing countries' food import bills was due to changes in international prices, and for some countries all of it was (Valdés and Foster, 2012: 13).

This observation is counter to the predicted outcome of globalization, which held that increasing integration into international markets would limit volatility everywhere by increasing the number of consumers and producers participating in the quantitative adjustment between supply and demand. In part, this could be because economic integration remains far from complete, particularly in agriculture and food markets. The degree of market integration, and domestic price system connections (and related stabilization polices) to global markets and international prices depends on countries. (OECD, 2009; Yang *et al.*, 2008; HLPE, 2011).

Rapid growth in demand, including for water-intensive animal-sourced foods, which in turn is linked to rising incomes in emerging economies, is also putting pressure on low-income consumers who are at risk of being priced out of local markets. National policies are urgently needed to protect poorer and relatively marginalized communities' access to affordable nutritious food. One avenue is through social protection policies such as cash transfers (HLPE, 2012b). Other approaches include supporting continued access of lower income producers to arable land with good water availability in the face of the price effects of powerful demand growth, whether domestic or foreign, for food, feed or biofuel crops. Water may be largely invisible in these situations, at least to policy-makers, but is nevertheless an important contributing factor that needs to be given careful attention in national food security strategies.

2.6 Metrics for water management

There is a range of metrics used to characterize and assess water use, some of which are particularly pertinent in the water for FSN arena. There are many challenges to water accounting methodologies, to the comparability of the results and to the way they can be used for decision-making. It is first important to distinguish accounting of water "consumed", that is evapotranspired, from water withdrawn, as part of it returns immediately to the ecosystems, even if generally modified in quality (see Figure 2). Some methodologies do include green water, which is of particular importance for agriculture. Another key issue is how to account for quality issues, which some call "grey water". Local dimensions are particularly important, because of local scarcities, both physical and economic/social, and in relation to demand; also to account for what happens with the water withdrawn but not "consumed" (evapotranspired or embedded in produce). To reflect adequately all these parameters would require very precise methodologies, grounded on a considerable amount of data and lead to results often difficult to compare and communicate easily. The section that follows describes, briefly, some of the key metrics used, what they aim to measure, and some caveats as to their use.

2.6.1 Water efficiency

The concept of water efficiency has its origin in biology, engineering and ecology, and reflects how a process - be it biological, engineering like irrigation, or ecological – uses water to deliver a service, i.e. how much water enters a system and how much gets out and how, (plant growth, irrigation water delivered, ecosystem services). Water efficiency is mainly a process-centred concept and often (but not always) a dimension-less variable (such as "water out/water in").

Crop physiologists defined water-use efficiency as carbon assimilated and crop yield per unit of transpiration (Viets, 1962) and then as the amount of produce per unit of evapotranspiration. In that sense it is also used to assess water-use efficiency of terrestrial ecosystems (see for instance Beer *et al.*, 2009; Tang *et al.*, 2014).

Irrigation specialists use the term "water-use efficiency" to assess how effectively water is delivered to plants and to indicate the amount of water that is wasted along the delivery process. However, it can be misleading, as water "lost" in the irrigation system often still returns to useful water flows and can be reused further downstream (see Section 2.3.2). Water lost by irrigation is often gained by other uses (Seckler *et al.*, 2003).

2.6.2 Water productivity

The concept of water productivity has its origin in agronomic and economic sciences, and reflects how much output (out of an agronomic or economic process) is generated by water inputs. Therefore water productivity is rather an "output-centerd" concept (how much output per unit of water as input).

Water productivity is defined as output per unit of water consumed, either in agronomic and physical terms, amount of crop per unit of water or, in economic terms, value per unit of water. It can also be used to assess nutritional water productivity, number of calories or of protein calories for instance per unit of water used (Molden *et al.*, 2010). Table 4 shows a range of average values of water productivity for sample crops and products from poor to improved management.

Water productivity can thus be defined more broadly as the benefits derived from a unit of water and be used as a holistic concept to analyse water management (Molden *et al.*, 2007). Water productivity can evaluate returns to water for various sectors and across scales (such as accounting for multiple uses of water) and help relate water productivity to improvements in food security and reductions in poverty (Molden *et al.*, 2007). It is increasingly being used also at water basin level. As the concept of water productivity continues to develop, there is criticism in the literature over its value and practicality. Normalizing the concept and linking it with agricultural productivity are among the key issues. Further research is needed in particular to better take into account multiple-use systems with high water reuse (Lautze *et al.*, 2014).

Table 4 Agricultural water productivity (values of produce by m^3 of water)

Product	Water productivity			
	Produce Kilograms/m^3	**Value** Dollars/m^3	**Protein** Grams/m^3	**Energy** Kilocalories/m^3
Cereal				
Wheat (0.2 USD/kilogram)	0.2–1.2	0.04–0.30	50–150	660–4 000
Rice (0.31 USD/kilogram)	0.15–1.6	0.05–0.18	12–50	500–2 000
Maize (0.11 USD/kilogram)	0.30–2.00	0.03–0.22	30–200	1 000–7 000
Legumes				
Lentils (0.3 USD/kilogram)	0.3–1.0	0.09–0.30	90–150	1 060–3 500
Fava beans (0.3 USD/kilogram)	0.3–0.8	0.09–0.24	100–150	1 260–3 360
Groundnut (0.8 USD/kilogram)	0.1–0.4	0.08–0.32	30–120	800–3 200
Vegetables				
Potatoes (0.1 USD/kilogram)	3–7	0.3–0.7	50–120	3 000–7 000
Tomatoes (0.15 USD/kilogram)	5–20	0.75–3.0	50–200	1 000–4 000
Onions (0.1 USD/kilogram)	3–10	0.3–1.0	20–67	1 200–4 000
Fruits				
Apples (0.8 USD/kilogram)	1.0–5.0	0.8–4.0	Negligible	520–2 600
Olives (1.0 USD/kilogram)	1.0–3.0	1.0–3.0	10–30	1 150–3 450
Dates (2.0 USD/kilogram)	0.4–0.8	0.8–1.6	8–16	1 120–2 240
Others				
Beef (3.0 USD/kilogram)	0.03–0.1	0.09–0.3	10–30	60–210
Fish (aquaculture[a])	0.05–1.0	0.07–1.35	17–340	85–1 750

a. Include extensive systems without additional nutritional inputs to superintensive systems.

Source: adapted from CA, 2007, using data from Muir, 1993; Verdegem *et al.*,2006; Renault and Wallender, 2000; Oweis and Hachum, 2003; Zwart and Bastiaanssen, 2004

2.6.3 Water footprint

According to Hoekstra *et al.* (2011: 46): *"The water footprint of a product is defined as the total volume of fresh water that is used directly or indirectly to produce the product"*. It builds on the concept of virtual water (Section 2.6.5). It is estimated by considering water consumption and pollution in all steps of the production chain. It brings together three components: green water, defined as rainwater stored as soil moisture; blue water, for surface and groundwater; and grey water, defined by the volume of freshwater required to assimilate pollutants to ambient water quality standards (Hoekstra, 2009). For a determined product, the water footprint can be an indicator of the total water needed for production and that can be provided by rain (green water) or irrigation water (blue water), and of the water needed to dilute pollutants resulting from the production process (grey water), the three main categories of impact from food production and consumption.

The water footprint is one of several environmental footprints that were popularized in the early 2000s to evaluate the impact of consumption on natural resources. These aim to address growing natural resource scarcity, poor governance of these resources and to remedy the limited knowledge of the relative carbon/water and other natural resources needed to produce (embedded in) our goods and services. Such tools enable calculation of the impact of individual or national consumption of goods and services. The major innovation, but also the challenge, of the water footprint concept is to accurately measure how much water is used at different steps along the production process, which is particularly challenging in today's often globalized value chains.

The water footprint is playing an important role in raising awareness of the importance of water for the production of goods and services and therefore of the fact that consumption of food and other items is also, indirectly, consumption of water. For instance, frequently mentioned are the water footprints of certain food items, such as a steak or a soft drink, but also of irrigated fibre, such as cotton. For example, Ercin *et al.* (2011) estimate the water footprint of a 0.5 litre soft drink with a sugar content of 50 grams at 169–309 litres per bottle, depending chiefly on the origin of the sugar. For this product, close to 100 percent of the total water footprint is accounted for in the supply chain and not the actual direct product (the 0.5 litres of water in the bottle). Other often mentioned examples include 1 cotton T-shirt (2 720 litres of water) and 1 pair of cotton jeans (10 850 litres or water) (Chapagain *et al.*, 2006), or 1 kilogram of beef (15 415 litres of water) (Mekonnen and Hoekstra, 2010). The values used are generally averages, adding the three components of the footprint (green, blue and grey), which, as pointed out by some critics does not reflect accurately the environmental impact of any real product.

The reliability of the information provided by the water footprint, as with all indicators, very much depends on the precision of the data and the way they are presented. Often, as in the examples presented above, a global average figure is used, which does not convey the difference in impact between, for instance, green water in an area where rain is abundant and water irrigation in a water-scarce area. Some authors (Antonelli and Greco, 2013) propose to distinguish water coming from non-renewable sources or from water-scarce areas. But there is no agreed approach to incorporate scarcity in water footprints (Perry, 2014). Another limitation is that while the actual water footprint of a crop can vary, depending on the agro-climatic conditions in the farm and the agronomic practices that were used to produce it, water footprints of crops are generally calculated using macro-level data, and do not capture these variations resulting from production methods and farm conditions.

Some authors also point to the limits of the notion of grey water, as the quality required for downstream use very much depends on the type of use and there is no agreed water quality standard to use (Perry, 2014).

Thus, while virtual water footprints provide a generic snapshot of water use for a particular product, more detailed analysis is needed before water management decisions can safely be made.

2.6.4 Water in life cycle analysis

Life Cycle Analysis (LCA) is a tool to measure the resource use and environmental impacts caused by the production, consumption and disposal of a product from cradle to grave, i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

For a long time water consumption was most often omitted in LCA analyses. There where various reasons for it (Berger and Finkbeiner, 2012):

- First, LCA has been first developed for optimization of industrial processes and related products, for which net water consumption is generally not the major intermediary or input cost item, nor the main environmental impact,
- Second, it was used initially in countries where water consumption was not the main environmental concern,
- Third, because water raises some specific methodological difficulties as shown above

However and especially for LCA of agricultural and food products, water consumption could not be omitted at the risk of not respecting the comprehensiveness of the analysis of environmental impacts.

Recently several important initiatives, like the UNEP/SETAC Life Cycle initiative and work towards an ISO standard, thrived to build common principles and methodologies in order to facilitate the integration of water consumption assessments in LCA analyses. These efforts led to the development of comprehensive methods for water accounting for both inventories of water use and assessments of impacts (Jefferies *et al.,* 2012; Berger et Finkbeiner, 2010) and to the publication in 2014 of an ISO standard (ISO 14046).

The water footprint and LCA approaches share the objective of evaluating environmental impacts of water consumption in order to inform practitioners and give the means to assess and improve environmental performance. There are however some major methodological differences between the two approaches (Boulay *et al.*, 2013, Pfister and Ridout, 2013), including the inclusion or not of green water (included in WFN, not in LCA), and the way to account for water pollution.

2.6.5 Virtual water and virtual water trade

The concept of virtual water, as a measure of water "embedded" in produce, i.e. water necessary to produce a specific produce (Allan, 1993) was developed to show that trade can compensate for water scarcity in a country by enabling it to import products that need significant amounts of water for production. This leads to "virtual water trade" (Allan, 1993, 1996, 2003).

The concept of virtual water shows the important linkages between agricultural water use, water scarcity and the global economy and how existing water shortages can be at least partially alleviated by importing food (Allan, 2011). It also illustrates the potential impact of export-oriented agriculture on local water availability. In water-scarce areas, the concept of virtual water allows countries to assess water need for producing a specific crop locally as opposed to importing it. The concept is now widely used to describe how water-short countries achieve food security by importing food from water-abundant countries (Wichelns, 2010). Several authors have noted that most of the virtual water is green rather than blue (Chapagain *et al.*, 2006). It has also been shown that international cereal trade reduces global water use and especially irrigation water use (de Fraiture *et al.*, 2004).

However, importing virtual water, although logical and efficient, means that the importing country faces certain risks, such as potential shortages on international markets, as occurred during the food price crises of 2007/08 and 2011, or political sanctions by the exporting countries. There are also challenges in distribution of imported food to impoverished areas and, from a FSN perspective, there are arguments that support local production where possible, enabling localized food systems and thriving rural communities. Aggregating volumetric values of water used in very different products with different underlying opportunity and environmental costs can distort the policy recommendations resulting from the analysis (Gawel and Bernsen, 2011). The partial nature of the concept makes it insufficient to determine the role of water scarcity as other factors, such as labour and capital, also matter for economic growth and social welfare (Wichelns, 2001). Finally, while water endowment might increase in importance in global trading relationships, it is at this point not always a good explanatory factor for net virtual water imports (Wichelns, 2010), although it may well be a factor when food is imported into particularly water-scarce areas.

2.6.6 Different tools, different purposes and different users

There have been considerable discussions about tools and methodologies to assess impacts of water use and management. As exposed above, reflecting appropriately all the impacts of water use would require considerable amount of data and would result in information difficult to communicate. The more precise the methodology, the more data requirements are hard to satisfy. Methodologies have thus to arbitrate between technical/scientific accuracy on the one hand, and communicability of results on the other side (Berger and Finkbeiner, 2010), taking into account data availability. All of the methodologies can thus be criticized, and are. It is important not to forget what they are useful for, and not to expand their use beyond what they are devised for. These tools and methodologies are mainly descriptive; they should not be considered as universally applicable decision tools whatever the issue, objective and actor concerned.

In fact, most of the tools and methodologies briefly presented above have been developed for a precise use, having in mind a specific category of users (see Table 5). Engineers have developed methods to assess the efficiency of their action, now getting also increasingly oriented towards an assessment of full productivity. They need to be precise and accurate but, given their public, can be quite complex, especially when they are to be used to guide technical decisions at local level. The notion of virtual water is a very useful tool to show how some countries rely in fact on trade to compensate water scarcity, while there are of course lots of factors explaining and determining trade fluxes.

Table 5 Comparison of metric tools for water management and use

Tools	Description	Purpose	Main users	Advantages	Limitations
Water efficiency	Indicator of water used by a system with respect to water as input.	Measure the efficiency of systems (such as irrigation systems) in their capacity to provide water where intended, in order to compare options and improve the system.	Engineers Practitioners Farmers	Simplicity and well adapted to its specific public	Needs to be very clearly caracterized (pipe level, basin level etc..). Only indirecty linked to output or to FSN
Water productivity	Indicator of output (physical, economic social, etc.) of a system with respect to water as input.	Measure the benefits provided by liter of water in a certain system, in order to compare options and improve the system.	Engineers Practitioners Farmers (the case being, other decision makers)	Focused on output, and as such clearly of interest for FSN.	Diverse approaches of the concept , especialy how to treat multiple dimensions. Important data needs.
Water footprint	Indicator of the total volume of fresh water that is used directly or indirectly to produce a product	Measure the aggregated direct and indirect water consumption of countries or individuals (given their consumption). By extension, evaluate the impact of the consumption of a certain product.	Consumers	Simplicity of the information provided. Concept aligned with other footprint indicators Popular	Does not properly account for local-specific impacts Very data-intensive
Water in Life Cycle Analysis	Indicator of the resource use and environmental impacts caused by the production, consumption and disposal of a product from cradle to grave.	Measure of the efficiency (economy) of a process with respect to resource use and/or impacts (generally environmental).	Businesses	Comprehensive, detailed method Well described methodologies	Very data intensive Results often challenging to communicate to non-specialists.
Virtual Water	Measure of the water “embedded” in produce.	Describe indirect consumption of water by countries, through trade, exports and imports.	Analysts	Simple, popular	Does not properly take into account local specific impacts.

The water footprint concept, to a great extent historically derived from the one of virtual water, is extremely powerful to raise awareness on indirect consumption of water "embedded" in products. The water footprint of products was originally calculated to construct the complete foot print of a consumer.

Mainly oriented towards assessing consumption foot prints of countries, regions and individuals, it cannot take into account all the local specific impacts of water use in production areas, which would require full traceability from production to consumption. On the other hand LCA is very much product-focused, or rather process focused it was originally a tool for producers to assess their environmental impact and identify hotspots, in order to improve their production process to reduce their environmental impact. To do so LCA needs to assess as accurately as possible local specific impacts for each variable. For many, LCA should aim to address environmental issues at large, but in this case the approach and calculations need to be made with respect to several dimensions (such as water, carbon, nitrogen, energy etc.).

All the tools presented above have thus strengths adapted to their original uses and users, as well as weaknesses, particularly in terms of precision. These last years, discussions and exchanges between the various communities linked to each of these methodologies have progressively conducted to better understanding of the methodological issues and to gradual convergence of perspectives and approaches (Boulayi, 2013, Pfister and Ridout, 2013). In other words the tools and methodologies behind them are still different because of their different users but are likely to be grounded on principles which are gradually converging.

2.7 Research and knowledge on water for FSN

There is a critical role for public- and private-sector-funded research and development in the area of water for FSN, to support evidence-based policy improvements, integrated and adaptive management systems that incorporate indirect environmental externalities, and technological and management improvements in water use for food production and food processing. Of equal importance is that the research knowledge is translated into action in the implementation of water for FSN, which requires that the research outputs are appropriate to the needs of and accessible to end-users, whether governments, water managers, large-scale private sector enterprises, or small-scale farmers, especially in the global south. This requires the recognition of the importance of research and development and the investment of public funds into the research sector.

There are significant research bodies operating at the global level that are important in the water and FSN arena, not least the 15 CGIAR centres and the associated multicentre research programmes. Of these, the International Water Management Institute (IWMI) is focused entirely on water, and largely on water and agriculture. The Water for Food Institute is also active in the arena of water and food global governance. Other CGIAR research programmes also deal with issues of water and food.

A Global Water Research Coalition exists, with a membership made up of a range of water research institutions from around the world. Interestingly, however, agricultural water use and food security are not priority issues, despite the global focus on the nexus between water for food and energy. It is important to strengthen the research capacities of southern universities and knowledge centres in ways that reflect their own challenges and constraints (i.e. under-resourced university sector, low public funding and unequal access to data and information). Finally, there are several topics that are not usually funded by conventional research that warrant further attention. These include: informal water economies and customary arrangements; human rights approaches to water and FSN; nutritional trade-offs between local food production and that for trade and their impacts on children and women; the local level impacts of climate change on water for FSN and finally, research on water metrics and whether they take into account FSN/livelihood issues.

2.8 Ways forward

This chapter looked across the food chain to suggest how water management practices can be improved across a range of agro-ecological systems. It also examined several approaches and ways to conserve water and improve water use in food processing and preparation. Since the major focus of this chapter is on agro-systems, we provide some suggestions as to how water for agriculture outcomes can be improved before concluding with thoughts on integrating different approaches across scales. De Fraiture and Wichelns (2010) have examined several pathways for ensuring that sufficient food is produced while also protecting the environment and reducing poverty. They find considerable potential for investment in rainfed agriculture if inherent risks can be addressed and for irrigation expansion in sub-Saharan Africa and South Asia, and they stress the important role of trade in moving food from water-abundant to water-scarce regions, sometimes even within the country. Combining investments in rainfed and irrigated agriculture with strategic trade decisions would reduce the amount of additional water required to meet food demands by 2050 substantially. They conclude that land and water resources can be adequate to meet global food demands by 2050 if agricultural water management is significantly improved.

A fundamental change in the way water is currently used in agriculture is inevitable. Different strategies are required that recognize, *inter alia*, the wisdom vested in food-producing communities such as fishers, pastoralists and other small-scale producers. Sub-Saharan Africa requires investment in infrastructure, whereas much of Asia needs to increase productivity (Poteete *et al.*, 2010), relocating supplies and rehabilitating ecosystems.

Achieving meaningful improvement in water productivity, however, cannot be done through technological advancement alone. Everywhere, enabling humans and institutions to deal with changes is required (CA, 2007), including to create an enabling environment for gender equality and women's empowerment. It requires enabling policies and a healthy institutional environment to align users' incentives at various scales, to encourage the uptake of new techniques, and to deal with trade-offs (CA, 2007). This very much depends on improving governance mechanisms.

3 GOVERNING WATER FOR FSN

Given the multiplicity of actors involved around water, competing uses and inequalities of access to water, safeguarding and improving the contribution of water (in all its dimensions: availability, access, quality and stability) to FSN (in all its dimensions) will require good governance. This chapter reviews governance issues across the “water to FSN” pathways, and means to address them.

Variable constraints in availability of water – in relation to quantity, quality, seasonality or reliability – drive the need to establish effective mechanisms for determining who may take how much water, where, when and for what purposes, as well as for protecting water quality through regulations on return fluxes. A challenge to water for food security is the growing perception that, as competition over water increases, the agriculture sector, as the largest user of water, must reduce its water use as other sectors are increasing their water use. Agricultural water use is often seen as low-value, low-efficiency and highly subsidized. These issues invite a rethinking of the economic, social and FSN implications of agricultural water use and water allocation more generally.

There are also competing policies, interests and actors coming from numerous sectors, with different degrees of political or economic power. Access to water, control over water resources or water pollution can cause disputes and conflicts at various levels. Increasing scarcities and growing and competing demands on water by a multiplicity of users and sectors make water governance for food security and nutrition particularly challenging, from local to broader levels.

Several organizations have proposed working definitions of water governance. For the purpose of this report, the HLPE retains the following definition of water governance, adapted from the one forged by the Global Water Partnership and used by OECD (2011), the World Bank and many other agencies.

Definition 1 Water governance

Water governance is the set of political, social, economic and administrative systems, rules and processes (i) that determines the way decisions are taken and implemented, by the various actors, regarding the management and use of water resources, and the delivery of water services and (ii) through which decision-makers are held accountable.

Water governance covers both water resources and water services. Depending on the situations, the governance of these two issues have been either linked or separated. The modernization of water provision, when it happened, often led to differentiated governance schemes for water services. Governance issues are different for resources and for services. For resources, the dominant challenges are competition between uses and users of different economic and political power, the rules of this competition and how FSN is taken into account, as well as the links with land. For services, the dominant challenge is the regulation, control and monitoring of the service provider, public or private, including how physical and economic access to water for different users, especially marginalized populations, is enabled, conditioned and performed.

Water governance covers issues of equity and efficiency of the allocation and distribution of water resource and services; the formulation, establishment and implementation of water policies, legislation and institutions. Water governance sets the rules, access rights, economic tools, and accountability mechanisms for all actors involved in the management and use of water; it determines: how water is allocated across sectors, regions, countries; which decisions are taken (or not) regarding infrastructure and water development, return flows, ecosystem regeneration; as well as the alignment (or not) between water, energy, food, trade and wider environmental policies (e.g. forests, biodiversity), etc.

Water governance systems are embedded in administrative and legal structures, and are immersed in often overlapping informal and formal institutions, which can result in ambiguity and conflicting rights and rules (Mehta *et al.,* 2012; Cleaver, 2012). Wider political, economic, social, cultural and even ethical contexts, as well as formal and informal rules of power, shape and condition any water governance system (see Water Governance Facility, 2012; Groenfeldt and Schmidt, 2013).

This chapter looks at water governance with the perspective of FSN, and therefore at ways to improve water governance for improved FSN, which means water governance ensuring equitable and secure access to water for FSN for all including for more vulnerable and marginalized populations, in an equitable manner.

Key questions framing the current discussion on effective water governance include:

(1) What determines access to water for FSN and how can access be strengthened for vulnerable and disadvantaged groups including food insecure people?

(2) What are the advantages and disadvantages of diverse allocation regimes (including pricing tools) to enhance water for FSN?

(3) What are the trade-offs and competing objectives around water for FSN (including local FSN dynamics, investments)?

(4) Which are the diverse actors, powers and paradigms that influence water for FSN and how does a wider political economy influence water-related decisions and investments? What is the role of the private sector both as water user and as a service provider?

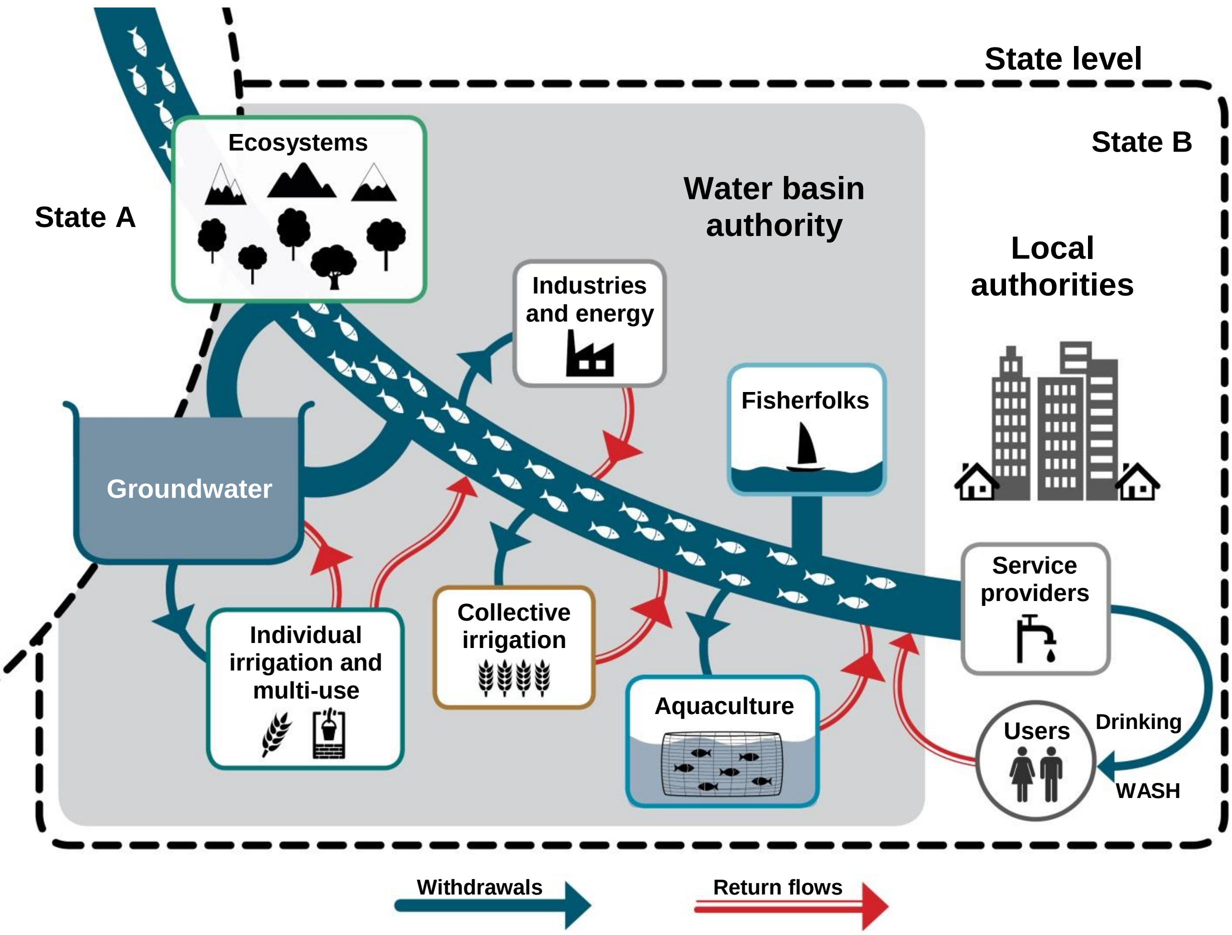
(5) How can national governments integrate water issues more centrally in food security concerns and vice versa?

(6) How could governance systems (policies, institutions, tools, etc.) better deal with conflicts around water, or be adapted to conflictual situations with power imbalances?

(7) How are changes, both inside the water sector and out of it, affecting water institutions and governance and what incidence on FSN?

This chapter addresses these questions by considering institutions and actors in changing contexts, tools to manage scarcities and competition, ways forward for better governance, including links between land and water, and a rights-based approach to water for FSN.

Figure 11 Key actors influencing the allocation and use of water for FSN



This figure represents schematically some of the main types of actors and institutions contributing to water governance as they intervene over the water cycle at various geographical scales, and for diverse uses. This, combined with the diversity of local situations, determines relations between actors that can be quite complex.

3.1 Institutions and actors in changing contexts

3.1.1 A multiplicity of institutions at national levels

Institutions dealing with water resources are extremely diverse, depending on countries and situations. They can be formal or informal/customary, part of the local, subnational or national administration; they can be specific water institutions, eventually linked to a water body (or not); they can be linked to an investment; they can be public or private; they can associate to various degrees the different users in the management of the resource. Water governance is generally multilevel. OECD (2011) defines multilevel governance as the explicit or implicit sharing of policy-making authority, responsibility, development and implementation at different administrative and territorial levels. It could be: at central government level, between ministries and agencies (upper horizontally); between different layers of government at local, regional, provincial/state, national and supranational levels (vertically); and across different actors at the subnational level (lower horizontally). It is often a combination of these.

As shown schematically in Figure 11, water governance is often primarily organized by uses and services, either unique or multiple, such as for provision of collective irrigation or of drinking water and sanitation, and or around the shared uses of a particular resource, such as a river, with multiple uses from provision of water to fishing and waterways, or the protection of an ecosystem key to water resources protection, like wetlands. At broader levels, water basin authorities manage resources for multiple uses and types of actors. Local authorities have various roles in managing or controlling resource and services. The State makes the general rules and has generally an overall role of control on the various institutions and actors, including service providers. Some water resources being transnational, there are also various types of international organizations fulfilling part of these roles.

Water management in practice is not confined to formal institutions (supported by laws), but often also involves informal arrangements, such as those governing common pool resources (Ostrom, 1990) and those governing negotiation arenas through which different stakeholders defend, increase and influence access to water (Meinzen-Dick and Bruns, 1999; Spiertz, 1999; Roth *et al.*, 2005). At the local level, customary law and practices, kinship networks, gender, caste and patronage may dominate or run in parallel to formal systems (Cleaver, 2000; Mosse, 2003; Movik, 2012; Mehta, 2005). Furthermore, systems of land tenure, use and management can also contribute to shaping access to water resources in a variety of ways (see Hodgson *et al.*, 2004a).

Informal arrangements for access to water use often provide more vulnerable users with low-cost services for domestic water, water for agriculture (irrigation, rainfed as well as home gardens), water for livestock, habitats for fish and other aquatic resources and rural enterprise water supplies (van Koppen *et al.*, 2014a; von Benda-Beckmann, 1981; Chimhowu and Woodhouse, 2006; Meinzen-Dick and Pradhan, 2001). Women in particular have most of their water use rights vested in these informal systems. These informal arrangements are often undervalued and neglected by planners and policy makers (see Cleaver, 2012;). The introduction of formal water use allocation systems and/or of exclusive land rights may hamper customary users' access to water and aquatic resources. Access for new commercial users may eclipse that of non-registered users who are not always visible in the formal awarding of water use rights (see Van Eeden, 2014). Recognition and protection of the range of customary rights and right holders, including those with subsidiary rights, is important for food production for household and market purposes and for supporting the food security and nutrition of poor rural communities.

The State is playing a central role because of its responsibility for providing public goods, for ensuring equity of access to water resources and for using water management to reduce poverty as well as to protect ecosystem services particularly because of their importance for poor people's livelihoods (CA, 2007). As such it designs the rules for allocation of resources, governance at lower levels, governance and management of water services, as well as for the protection of resources and ecosystems on which they depend and sets and enforces rules to protect the quality of water. It also ultimately fixes the rules to resolve conflicts. The way these various roles are performed has a huge impact on food security.

Centralization to decentralization

Decentralized governance allows to take better into account the needs of users and the state of the resource, and to better responsibilize users especially with secure rights and when they are associated with the resource management decisions. Decentralized governance often involves strengthening local organizations and/or the setting up of specific institutions, such as water user associations (WUAs), or river basin organizations (RBOs). However, even at such levels, principles of good governance need to be put in place to ensure equitable access, and not exclude less powerful actors, including informal water users.

Supported by the IWRM framework (see Section 3.1.3), in many regions water reform has led to the decentralization of water management, involving re-organization of water governance from administrative units (regions, provinces, districts) to areas with hydrographical boundaries: watersheds, catchments or basins. This provides an opportunity to deal with the dislocated effects of water use (pollution, downstream reduced or peak flows, timing peak uses and releases). It also enables better management of the impacts of upstream land use and activities on downstream water availability and quality.

Decentralization policies and approaches often involve the setting up of WUAs, catchment management platforms (CMPs) and/or RBOs (Molle, 2008). These can play a critical role in improving water management practices, ecosystems and their various functions and can lead to better outcomes in terms of water for FSN, especially for poor women and men.

Collective management of water resources

In many countries, WUAs can play an important role in the management of water resources and water services, especially at local and community level, including in irrigation schemes. There is however often a divide between different categories of users, having different objectives: farmers, fisherfolk, urban users, environmentalists and recreational users, etc. Governance has to provide for mechanisms to arbitrate between diverging interests and to solve conflicts in a fair way.

WUAs can play a central role in managing water at the irrigation scheme level and below. These institutions were successful in some cases and have contributed to improved water services. In the Philippines, for instance, WUAs make up over 30 percent of water utilities and provide an alternative to privatization (Dargantes and Dargantes, 2007). These community-managed systems are often set up in areas where main services either do not reach or do not provide satisfactory service, and they often have lower tariffs and higher use than government operated systems (World Bank, 2006b). They have additionally provided opportunities for participatory decision-making and technical planning, as in the case of planning for irrigation canals in the Visayas Communal Irrigation Project (FAO, 2001). In other cases they failed partly because of communities' low capacity to manage irrigation systems and partly because the public sector did not give management authority to the WUAs (Metawie, 2002). Nonetheless, management of water at the local level is a critical element of improved water management.

A review of several irrigation management transfer programmes has shown that there is no blueprint for enhanced irrigation water management; instead the approaches need to be tailored to local conditions (Garces-Restrepo *et al.*, 2007; Merrey *et al.,* 2007). WUAs are pivotal in reforming large surface irrigation systems, but require the empowerment of water users, especially women – mechanisms to resolve local conflicts and improved mechanisms for involving women in running the WUAs (see also Box 10). However, when such systems are built on the basis of traditional arrangements of collective ownership or sharing of water resources, such as in the case of the *warabandi* (rotational method of water distribution) in India and Pakistan, they function better, but even here caste inequities may continue to persist (Bandaragoda and Firdousi 1992).

The multiple use approach

As shown above, the governance of water tends to be divided among different institutions, although in many communities households use available water for both domestic purposes and food production.

Research on multiple water user services (MUS) shows that when communities invest in infrastructure, they build cost-effective multipurpose infrastructure to enable a range of uses for well-being on multiple dimensions, which all contribute (directly or indirectly) to food security (see van Koppen *et al.*, 2014a). Most communities efficiently use and re-use multiple water sources, and manage these in conjunction, thus mitigating water variability (Shah 2007; van Koppen *et al.*, 2009).

In contrast, provision by public water sector authorities is often done through different tiers, departments, divisions and programmes operating through top-down silos, focused on a single use, such as water services for domestic use and sanitation, or irrigation, or fisheries, etc. Although the water services sector seeks to provide safe water for domestic purposes to everyone, the sectors focused on water for productive purposes often overlook the water needs of small-scale producers

Box 15 Multiple uses of domestic water

In many local contexts, domestic water use includes subsistence gardening and livestock, crucial for ensuring food security (see Langford in Woodhouse and Langford, 2009). Under Zimbabwe's 1999 Water Act, reasonable uses of water over and above domestic use that no longer require a permit include water for animal life (non-commercial) and water for making bricks for private use. In Colombia, Kenya and Senegal, 71 to 75 percent of households use domestic water supplies for productive activities including food gardening, while 54 to 61 percent use piped water for these productive activities (Hall *et al.,* 2013). In the cases of Senegal and Kenya, this happened even though households only used a median of 23 and 31 litres per capita per day, respectively (20 litres per capita per day are seen as the minimum for domestic use globally; see also Section 3.4 on human rights). A way to answer such needs would be to ensure provision of between 50 to 100 litres per capita per day to support homestead-based productive use as well as domestic use. According to Renwick *et al.* (2007) the incremental investments in such expansion could be repaid from the increased income in half a year to three years. Such examples show the need for integrated approaches

involved in directly providing basic food security. Aggregate production figures do not reveal food-insecure women and men, and therefore give no basis for any public authority to take responsibility for water development for realizing the right to food at the household level (van Koppen *et al.*, 2014a).

3.1.2 International level institutions and initiatives

Water governance is exerted at national and subnational levels. However there are also international issues especially because of transboundary resources (Figure 12).

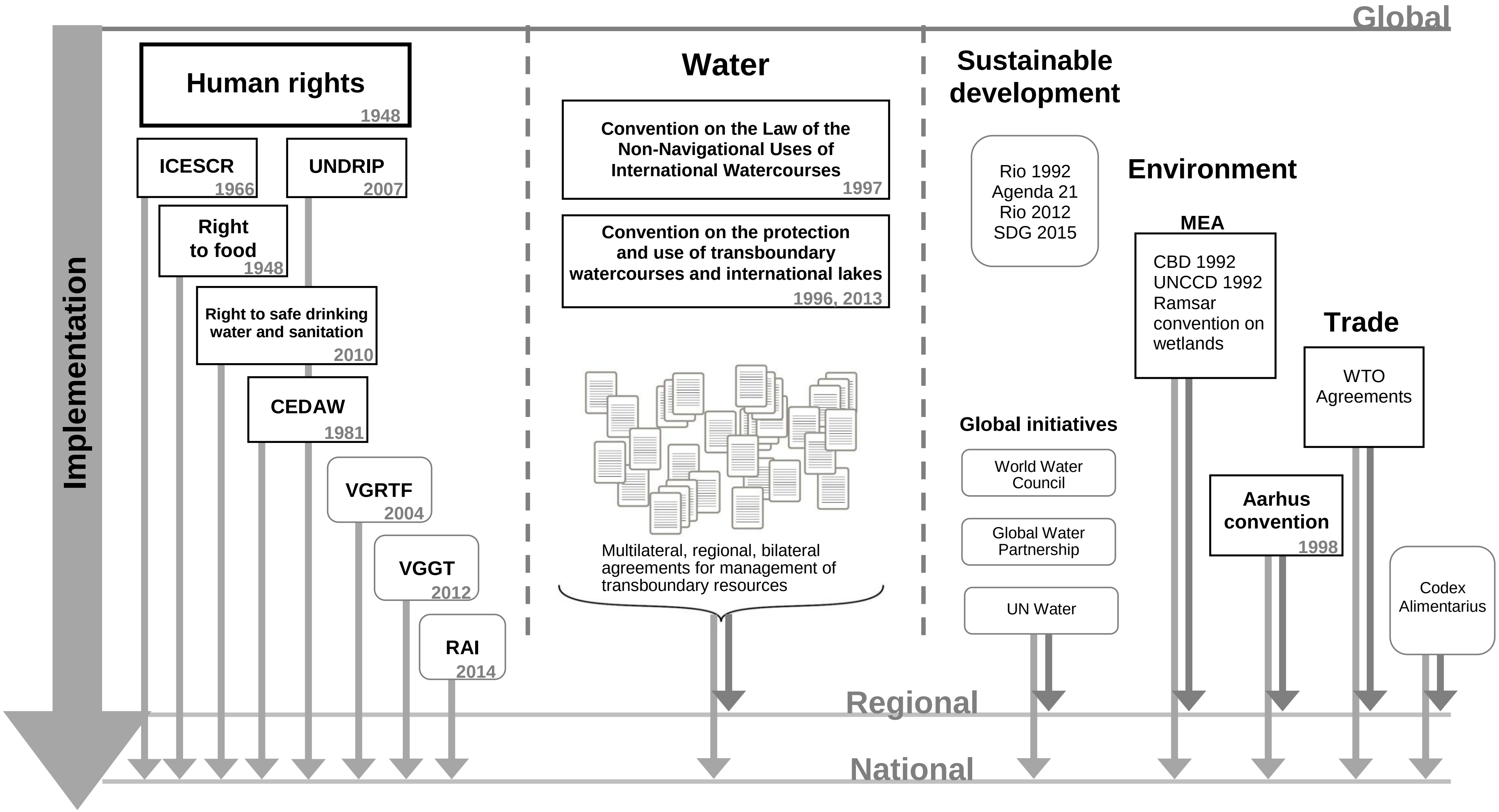
The 263 transboundary lakes and river basins account for an estimated 60 percent of freshwater flows. In addition, approximately 300 groundwater aquifers are transboundary (UN Water, 2008). The 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses is the main treaty governing shared freshwater resources that is of universal applicability. It introduced the principles of equitable and reasonable utilization and participation in the use, development and protection of the international resource, the obligation not to cause significant harm to other states, principles of prior notification of planned measures, and provisions concerning management and settlement of disputes.

The United Nations Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) was adopted in Helsinki in 1992 and entered into force in 1996. Almost all countries sharing transboundary waters in the region of the UNECE are Parties to the Convention. The Convention fosters the implementation of integrated water resources management, in particular the basin approach. It requires Parties to prevent, control and reduce transboundary impacts, use transboundary waters in a reasonable and equitable way and ensure sustainable management. Parties bordering the same transboundary waters are obligated to cooperate by entering into specific agreements and establishing joint bodies. As a framework agreement, the Convention does not replace bilateral and multilateral agreements for specific basins or aquifers; instead, it fosters their establishment and implementation, as well as further development. An amendment entered into force on 6 February 2013 opened it to all UN member states, turning it into a global legal framework for transboundary water cooperation. It is expected that countries outside the UNECE region will be able to join the Convention as of early 2015.

Close to 700 bilateral, regional or multilateral water agreements in more than 110 basins cover different types of activities and objectives, from regulation and development of water resources to the setting of management frameworks (UN Water, 2008).

The management of transboundary basins is complicated when there are *"different national (sometimes conflicting) interests, power disparities between riparian states, differences in national institutional capacity, limited information exchange and lack of sufficient basin scale knowledge and institutional capacity to make decisions"* (Bach *et al.*, 2012: 15). Additional complexity occurs when attempting to balance local and basin needs. However, international water governance and food security at the regional level can be essential building blocks towards regional cooperation and economic integration (see examples in Box 16).

Figure 12 Main international texts and agreements related and connected to water for FSN



Legally binding texts and agreements are in rectangles.

ICESCR = International Covenant on Economic, Social and Cultural Rights; UNDRIP = United Nations Declaration on the Rights of Indigenous People; CEDAW = Convention on the Elimination of All Forms of Discrimination against Women; VGRTF = Voluntary Guidelines on the Progressive Realization of the Right to Adequate Food in the Context of National Food Security; VGGT = Voluntary Guidelines on the Progressive Realization of the Right to Adequate Food in the Context of National Food Security; RAI = Principles for Responsible Investment in Agriculture and Food Systems; SDG = Sustainable Development Goals; MEA = Multilateral Environmental Agreements; CBD = Convention on Biological Diversity; UNCCD = United Nations Convention to Combat Desertification

Box 16 Transboundary cooperation for FSN

The Mekong River Commission provides one example of successful transboundary water governance to promote food security. Food security for 73 million people living in the basin requires regional water planning and cooperation, particularly since 85 percent of the population in the basin is dependent on agriculture for livelihoods (Jacobs, 2002) and get 80 percent of their calories from rice and 15 percent from aquatic based food (Bach *et al*., 2012) making their food security highly dependent on water. Although regional cooperation in the basin has a long history, the Mekong River Commission, made up of Cambodia, Lao PDR, Thailand and Viet Nam, recently shifted the focus of this cooperation to smaller-scale programmes that include food security concerns. Integrating agreed upon procedures among these four countries provide opportunities for pro-poor water management approaches with the aims of maintaining sufficient water flows, safeguarding water quality, monitoring water use, ensuring equitable use and exchanging quality data. Implementation of these procedures, however, remains a challenge (Bach *et al.*, 2012).

The Nile Basin Initiative, initiated in 1999 (Nile Basin Initiative, 2015), has attempted to establish several regional cooperation projects in a transboundary river-basin context to advance socio-economic development in the basin countries including food security and water productivity. The approach still faces challenges in addressing sustainability and it is hard to avoid State interests being given precedence over regional plans and commitments.

Another example of successful coordination is the Mexico-United States of America International Boundary and Water Commission that was established in its current structure by treaty in 1944 and provides for “minutes”, or binational decisions adjusting water allocation based on local and temporal circumstances (McCarthy, 2011).

There are many other instruments and processes at the global scale that are relevant to water issues. These include multilateral environmental agreements (MEA) such as the Ramsar Convention on Wetlands of International Importance, the United Nations Convention to Combat Desertification, and the Convention on Biological Diversity, global trade policies, global climate policy, global energy policies, financial policies, development policies and related international processes (such as the World Commission on Dams), and sustainable development processes (Rio+20 and the Sustainable Development Goals). They also include human rights (see Section 3.4) as well as several instruments providing voluntary guidelines for land tenure, sustainable small-scale fisheries and responsible investments for agriculture and food systems (RAI) (see Section 3.3.2).

Several international initiatives have emerged, particularly in the aftermath of the Dublin Conference in 1992. The Global Water Partnership aims at promoting integrated water resource management, and providing advice, helping with R&D and training. The World Water Council – a multistakeholder association, best known for its flagship conference, the World Water Forum – aims to promote awareness, build political commitment and trigger action on water issues. In addition, UN-Water has been created to strengthen coordination and coherence among the UN agencies, programmes and funds that have a significant role in tackling global water concerns.

3.1.3 A diversity of actors with contrasting powers

Many different actors, public and private, operate in water use and management. There is often confusion, and a need for clear rules and common understanding on their roles and functions, the way they interrelate, their different responsibilities and how they can be made accountable.

Each institution is in itself an actor with diverse roles and powers according to situations. Also, each institution, formal and informal, is often constituted of a set of actors. And each institution engages with other actors. The respective powers of these actors have a considerable influence on the way water contributes to FSN, in particular of the most vulnerable. In many cases, inclusiveness of governance schemes, accountability and control mechanisms do not function in such a way that the efficiency and fairness of the system can be fully guaranteed.

In the last 60 years the growing demand for water of non-agriculture sectors and the construction of numerous infrastructures have led to the emergence of important actors that have considerably modified water governance at every level, particularly in developing countries (see also Section 3.1.3). In particular the private sector, international agencies and donors are increasingly influencing decision-making at every level.

Corporate actors, such as from the energy and industrial sectors, cities, the food transformation and beverage industry, or large-scale agriculture/plantations, have an increasing influence on water governance and management. First, some of them, like the big providers of services for drinking water, act as water managers. Second, large enterprises enter in competition for the allocation of the resource with agriculture and small users. Third, in some cases, the scale of the intervention or investment, or the economic and political influence, is such that the resource itself is controlled.

A number of models offer different levels of private sector involvement in the provision of water, from services delivery, including management contracts, and infrastructure design and construction, both in household water services and in water resources infrastructure for commercial use. Private companies can provide know-how, processes and technologies, and investment, as well as involvement in implementing cooperative water management processes with government and other stakeholders. While there is a role for the private sector in ensuring the effective and sustainable provision and management of water, in most countries there is no effective regulatory oversight. The absence of effective legal and institutional frameworks to protect and promote the interests of low-income, marginalized communities and indigenous/customary rights holders in decentralized water governance and protection of aquifers for drinking water and other uses, is likely to reduce their control over water sources and undermine their access to the human right to water (Cullet, 2014). Public accountability needs to be built in.

In recent years, water has increasingly been seen as both a business risk and a business opportunity; private sector involvement is growing, extending out to the catchment level, and even in national and international water governance. In 2007, the UN Secretary-General launched the CEO Water Mandate as a private–public initiative focused on the role of business and water (UN, 2010a). As of 2013, at least 100 major companies had signed up to the Mandate (Newborne and Mason, 2012). The Water Resources Group, a group of multinational companies concerned about water issues, launched at the World Economic Forum, promotes water governance with a focus on economic efficiency in water use (Varghese, 2012).

Four types of private enterprises have a strong interest in improving water productivity and either produce or use innovative products and processes:

1. seed companies who are developing and promoting crop varieties that enhance water productivity, including drought-tolerant crops;
2. irrigation companies that develop and manufacture high efficiency drip or pivot irrigation systems;
3. information technologies companies (e.g., mobile phones or soil moisture sensors) that can be coupled with irrigation technology to further improve water productivity; and
4. food and beverage companies endeavouring to use water more efficiently in all aspects of the food production process.

One area of private sector engagement in water issues is the bottling and selling of water (as water or in soft drinks). In disaster relief, bottled water clearly has an important role to play for FSN. In countries with high rates of per-capita consumption of soft drinks, the economic importance of the industry comes with proportionate challenges related to how resources needed for production are dealt with, especially water resources (Box 17).

Box 17 Responsibility engagement of the bottled water and soft drink sector

Some beverage companies operating in water-scarce areas have established a dominant presence, such as in sub-Saharan Africa where a single company is the largest non-oil private sector employer (Cotton and Ramachandran, 2006). Yet the production and bottling of beverage products has been linked to reduced water quantity and quality, including water table levels and quality (IATP, 2010; Upadhyaya, 2013).

In India, after sustained protests, one company began requiring that its bottling plants conduct assessments of local water source vulnerability and develop sustainability plans as part of a water resources stewardship programme (Hwang and Stewart, 2008). An independent review of six of the 49 bottling plants operating in India recommended at the time taking into account the community's water needs and the rights of farmers (TERI, 2008).

A number of large companies (food processing companies in particular) have sought to improve their water-use efficiency, reducing pollution impacts, and working at the catchment scale to improve catchment-level water management. It is important to monitor progress achieved by companies in reducing water use in their own plants and premises and supply chains as well as to look at partnerships and relationships with local communities and monitor issues such as inclusion as well as local impacts (Newborne and Mason, 2012).

In the early 1990s, a number of countries have engaged ambitious reforms of water and sanitation services, including the delegation of services to private enterprises, leading in 2011 to about 13 percent of the world population (Pinsent Masons, 2012), and 7 percent of the developing countries urban population (Marin, 2009) being provisioned by private operators, often foreign (Varghese, 2007), under different contractual modalities, with the idea that public–private partnerships could support the re-establishment of a more efficient service, sustainably funded, including through the provision of commercially oriented services. Increasing private sector involvement in water provision was guided by the belief that public control had failed to establish universal access to water services (Easter and Hearne, 1993), be it because of financial resources, political interference, poor management and oversight, among others (Rees, 1998), and given the prospect that *"competition promotes efficiency and provides users with options that, in turn, make infrastructure providers more accountable"* (Easter and Hearne, 1993). Private sector involvement in water provision often accompanied structural adjustment programmes required for debt-ridden countries in the 1980s and 1990s.

Experiences with privatization of water services have not always been poor-friendly (Bakker, 2010; Finger and Allouche, 2002; McDonald and Ruiters, 2005; Marin, 2009). While it is often emphasized that poor people are willing to pay for water (Altaf *et al.*, 1992), it is often the case that the poor do pay proportionally far more for water than wealthier segments of the population. The UNDP's Human Development Report in 2006 notes that *"the poorest 20% of households in Argentina, El Salvador, Jamaica and Nicaragua allocate more than 10% of their spending to water. In Uganda water payments represent as much as 22% of the average income of urban households in the poorest 20% of the income distribution"* (UNDP, 2006: 51).

Private sector aims of profitability may not align well with the ambition of universal public service, in terms of appropriate infrastructure investment, to provide access to unsolvable or disconnected populations, especially in cases of absence of compensation of the investment through progressive tarification schemes or by public support (Bayliss, 2014). The high level of monopoly and low competition do not naturally lead to high responsiveness to user needs and there is often little incentive to service non-profit-making demand (such as rural areas and the urban poor) or to invest in unprofitable sectors (such as wastewater and sanitation) (see Finger and Allouche, 2002). Too often, prices rise beyond agreed levels within a few years of privatization, and people who cannot pay are cut off. Some contracts with water corporations have failed, such as the one in Cochabamba, Bolivia, in 2000.

In recent years, a retreat of the private sector in some areas has given rise to remunicipalization of water services (Pigeon *et al.*, 2012; Lobina *et al.,* 2014) or to public–public partnerships (see Box 18). Between 2000 and 2015, researchers have found 235 cases of water remunicipalization in 37 countries, North and South, affecting over 100 million people (Kishimoto *et al*., 2015). The pace has doubled over the last five years. For example, in France there were eight cases between 2005 and 2009 as compared with 33 cases since 2010.

Box 18 Public-public partnerships

Community aqueducts in Colombia demonstrate the potential of public–public partnerships as an alternative to privatization. For instance, the community aqueduct in La Sirena was one of the first formal partnerships between community members and public utility workers, formed as an alternative model of water delivery (Dumontier *et al.*, 2014). This public–public partnership was formed between the community aqueduct and a union that represented workers from the public water provider after years of trust building and agreements that guaranteed the autonomy and independence of community partners. The partnership has allowed for shared knowledge, particularly regarding water laws and environmental impacts of water use, and improved infrastructure and services for the community.

Box 19 Water in conflict situations

Conflict situations can threaten water provision and exacerbate lack of access to water. They also fall victim to the cascade of effects that conflict has in terms of disrupting and diverting established water management practices, and ultimately resulting in hunger and water-borne diseases. Water and agricultural projects are often either ignored or destroyed by conflict that becomes long term, leading to, for example, the salinization of once fertile irrigated lands after drainage systems were destroyed or became derelict (ICARDA, 2014).

Long-term conflict can weaken state capacity to oversee water management, including regulating community allocation post-conflict, which in some cases has led to corruption and has reinforced unequal access (Thomas and Ahmad, 2009). Insufficient attention to water in post-conflict situations can undermine peacekeeping efforts (Palmer-Moloney, 2011), and create opportunities for insurgent forces to destabilize fragile political environments (Centre for Policy and Human Development, 2011). The CGIAR and FAO have sought to play a positive role by supporting agricultural production during conflict, through improved water management and seed supply (Varma and Winslow, 2005).

Conflict-related water insecurities may deepen in situations of occupation. In such situations, restricted water withdrawals, combined with discriminatory practices in water sharing, can create new inequalities or exacerbate existing ones with regard to access (see Gasteyer *et al.*, 2012, for example). This can impact disproportionately on local households that are dependent on the water to produce food for themselves and for local markets. Households in conflict-affected areas may encounter water shortages even where water is relatively abundant, suggesting that unless the underlying imbalances in water governance are also addressed, initiatives to increase the supply are unlikely to bring improvements in basic water security or FSN (Elver, 2014; see also Kershner, 2013). Power asymmetries arising in situations of conflict, including occupation, that are left unaddressed can restrict access for less powerful groups even where there is nominal cooperation over water in matters such as the approval of new wells or other water projects, for example (Zeitoun, 2007; Selby, 2013).

In some cases, situations of conflict have been transformed into opportunities for cooperation to determine new rules of allocation. For example, Lake Biwa occupies a central place in the history of development and urbanization of post-war Japan as witness to a series of conflicts among competing uses. Originally set up to focus on protecting the rights of downstream water users, the Lake Biwa Comprehensive Development Project responded by expanding to address other aims such as flood control, water level control, irrigation and agricultural development, forestry, fisheries and nature conservation (see Kamal, 2009).

At international level key actors include the UN system, intergovernmental organizations and international financing institutions (such as the World Bank and the Global Environmental Facility), bilateral donors, international non-governmental organizations (such as the Global Water Partnership, World Water Council, World Wide Fund for Nature), and international networks of these organizations (such as IUCN), global knowledge networks (such as the CGIAR research bodies and programmes), private sector actors and global networks of social movements. International development agencies and donors play a major role to influence regional and national policies and investments (see also Section 3.1.3).

Water has been a strong focus of social movements around the world. The issues that have mobilized communities have included struggles against mining-related pollution, the displacement caused by large dams and the privatization of water services. The focus has often been to safeguard local livelihoods, food and water security as well as to strengthen the capacity of the public utility to fulfill its responsibilities and remunicipalize privatized water systems. Many struggles focused on food security issues also recognize water as crucial for the realization of the right to food. For example, La Via Campesina, an international peasant’s movement, that is strongly focused on issues of land rights and sustainable agricultural practices, refers to the issue of water among the resources that need protection from corporate control. It calls for peasants and small farmers to retain the control over “commons” such as water, biodiversity and agricultural knowledge (see the Declaration of Nyéléni, 2007).

3.1.4 New challenges for institutions confronted by changes: do institutions fit to new actors and new dynamics?

Revisiting the recent history of investments trends in water enables an understanding of some of the new water governance challenges.

Big programmes means big actors: the top-down approach (massive investments) with an engineering approach and technological package (irrigation, dams) was driven by a context where the construction of equipment and supply of water services was priming over consideration of access. The guiding idea was to first create supply. Access would come later, as a necessary consequence of supply provision, which was a prerequisite.

Big actors and investments do not constitute in themselves a governance system, but they operate over existing governance systems, often without appropriate consideration of underlying mechanisms and the implication of their actions on them, such as impact on pre-existing local governance, and how a pre-existing scheme, or a local governance system with a multiplicity of actors, can absorb “big actors”.

There have been important upward trends of increase of investments in the 1960s and 1970s in water for agriculture, and with irrigation investments as one of the key drivers, representing a big part of the importance of agriculture in ODA. During this period more than half the agricultural budget of many countries, particularly in Asia, was devoted to irrigation as well as more than half of the agricultural lending of the World Bank (Rosegrant and Svendsen 1993). After 1985, World Bank support for this type of projects was considerably reduced (Donkor, 2003).

Investments in various economic activities, and in particular in energy, industry and large-scale plantations, by corporate actors, often have an important impact on water. Mobilizing the investment potential of businesses can benefit FSN by providing development opportunities. They can also, when directed to water supply and water services, increase the provision of water. Investments in water for agriculture have had positive impacts on rural livelihoods, food security and poverty reduction (CA, 2007), with some studies indicating multiplier effects of 2.5 to 4.

However, some interventions have had high social and environmental costs (CA, 2007), including inequity in the allocation of benefits and loss of livelihood opportunities. Some projects have benefitted upstream users at the expense of downstream users; others have appropriated common property resources or displaced communities. Often investments can bear a very important negative impact on the local population, especially on the most vulnerable, marginalized, indigenous peoples and women. There is a need to ex-ante assess impacts on the FSN of all, including vulnerable populations, and to create mediation and dispute settlement mechanisms in case of negative impacts. Tools recently developed such as the CFS principles for responsible investments in agriculture and food systems can serve as a guide to maximize FSN outcomes of investments in the water sector and of investments in activities having an impact on water.

In agriculture, a technological package around irrigation (“ready to use”) prevailed, for several reasons:

- the idea that it was easier to imagine impact on yield and production and benefits, though sometimes overstated (notably competition between investments within a single basin – for the same resource – can limit benefits);
- the simplicity of implementation of the investment, and its adaptation to large-scale systems;
- the suitability of the projects to existing tools and schemes to accompany investments (credits, etc);
- the idea that it was triggering modernization and technological progress.

But a consequence of this “primer” of irrigation and associated technological package often led to neglect or abandon of support to rainfed agriculture and of lesser consideration for systemic issues on how to deal with water in the functioning of agriculture systems in general.

In addition, big investments come with maintenance costs, often big ones. And the suspension of maintenance has important consequences (such as on drainage, salinization, etc.). The need for continuity of funding for functioning has often been overlooked.

There has also been a trend of privatization of water services and of delegation of public service to agencies and private entities, which took place in the context of structural adjustment (Easter and Hearne, 1993). This trend, for municipal water provision, is currently being partially reversed, with a significant number of municipalities going back from previously privatized water supply and sanitation services to direct management of water provision by municipal authorities (see previous section).

Provision of water services, whether for irrigation, multiple uses or drinking water, often involves creation, maintenance and operation of infrastructures as well as water resource management. In the initial phase of investment, often dominated by financial and technical constraints, actors with important economic and/or political weight generally play an important role. This has immediate consequences on the way interests of small and marginal actors are taken into account. Potential effects have been well described in the case of large dams, for instance (see Chapter 1). It can also have long-term effects on the way infrastructures are then maintained and operated. Systems designed for the initial phase of investment and construction are not always well adapted to day-to-day management of the service itself. It is for instance often easier to find external financial resources, as well as technical support, from public or international donors (both ODA and international organizations) to finance investments rather than management. The heavy focus on infrastructure sometimes led to institutions tailored for construction rather than for the adaptive management of multipurpose infrastructures (CA, 2007). This can result in bad maintenance and operation.

In some cases, the maintenance of infrastructures is delegated to local communities, while property of the infrastructure is kept by the State. In such cases ambiguity about ownership and responsibilities often lead to neglect of the maintenance of the infrastructure (CA, 2007). The Office du Niger provides a good example of the institutional changes that can lead to better management of the system. Between 1982 and 2002 a series of reforms, including security of tenure, full cost recovery and joint management of the scheme by elected farmers' representatives, resulted in rice yields increasing by a factor of four, total production by six, with increased incomes and new businesses, including for women (Aw and Diemer, 2005).

Water management and governance have evolved considerably from the hydraulic imperatives and supply-driven approaches of the 1950s to 1970s that focused on technical solutions and the building of large dams. By the early 1980s, the UN Water Decade (1981–1990) aimed at achieving universal coverage for drinking water and sanitation. The UN global consultation in New Delhi in 1990, convened to assess progress and to look towards future pathways for collective action (Nicol *et al.*, 2012), resulted in the New Delhi Statement with its emphasis on equity and universality.[28] Two years later, the1992 Dublin Statement signalled the beginning of a shift from water resources development to water management and demand-driven approaches; it recognized: (i) the finite nature of water and its key role in sustaining life, development and the environment; (ii) the importance of participatory approaches in water development and management; (iii) the central role played by women in the provision, management and safeguarding of water; and (iv) the economic and competing values of water and the need to recognize water as an economic good (International Conference on Water and the Environment, 1992). While well-received in some respects, the Dublin Declaration raised concerns in other respects, particularly its stress on water as an economic good versus important non-economic uses, values and meanings (Franco *et al.*, 2013; Nicol *et al.*, 2012).

From integrated water resources management (IWRM) to the water-energy-food nexus

The integrated water resource management (IWRM) approach arose from the Dublin principles. One definition of IWRM comes from the Global Water Partnership: *"a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"* (GWP, 2000). The concept of IWRM, following the Dublin principles (1992), was invented to bring together social, environmental and economic objectives in a cross-sectoral approach of water management, combining users, planners, scientists and policy-makers. It has been widely used and promoted. Eighty percent of countries around the world have IWRM principles in their water law or policies and two-thirds have developed IWRM plans (Cherlet, 2012).

[28] Under the slogan, *"Some for all rather than all for some"*, the New Delhi Statement stressed: (i) protection of the environment and safeguarding of health through the integrated management of water resources and liquid and solid wastes; (ii) institutional reforms promoting an integrated approach; (iii) community management of services, backed by measures to strengthen local institutions; and (iv) sound financial practices, achieved through better management of existing assets, and widespread use of appropriate technologies (Nicol *et al.*, 2012).

Box 20 Frameworks for transboundary and regional water management: the European Union Water Framework Directive

The European Union Water Framework Directive (WFD), adopted in 2000, shifted the scope of water governance in the EU. Whereas previously it was conducted primarily within national boundaries, the WFD emphasized common objectives and principles at European scale, as well as a coordinated approach across national boundaries based on river basin management – an approach similar to that already practised in a few river basins such as the Maas, Schelde and Rhine (European Commission, 2014). This shift required changes to management plans and programmes as well as to measures of quality, although the methods for institutional implementation were left up to individual member states (Moss, 2004). Such changes represented a challenge since many member states had different methods of management already in place (Page and Kaika, 2003).

IWRM has allowed different water professionals (i.e. from irrigation, water supply and agriculture) to talk to each other and to attempt integration across sectors, including environmental flows for ecosystem services. At the local level, this approach has also allowed for synergistic relationships across these sectors. For example, the MACH project in Bangladesh introduced community-led natural resource management in 110 rural fishing villages. Following an integrated approach, the project was able to build consensus among diverse groups that depended on wetlands, both economically and nutritionally, and thus achieved aims of both conservation and livelihood security among the fisher groups (Renwick and Joshi, 2009).

Yet difficulties encountered in implementing IWRM in many countries in the global South have raised concerns that it is too abstract and complex as an approach (Biswas, 2004; Bolding *et al.*, 2000; Conca, 2006; Molle, 2008; Mehta *et al.*, 2014a). A further concern is that in its original conception it ignored the issue of infrastructure, especially in areas with underdeveloped water infrastructure, such as sub-Saharan Africa, where the need for infrastructure, or the continuation of the hydraulic mission, remains urgent (van Koppen and Schreiner, 2014). South Africa has thus refined its IWRM approach as developmental water management, specifying that water management must support the State's developmental aims and be integrated into national rights-based development plans and policies (DWA, 2014).

IWRM also grounds integrated approaches at national and regional levels such as the European Union Water Framework Directive, however mainly focused on the preservation of the quality (including quantity) of water bodies and aquifers (see Box 20).

Building on IWRM, the water-energy-food nexus approach (Hoff, 2011; WEF, 2011) looks to integrate decision-making across these three sectors in the face of increasing resource constraints and trade-offs among the different sectors. As shown in Chapter 1, energy production is globally the second largest sector in terms of water withdrawals and rapidly increasing, particularly in developing countries. There are also important links both in terms of investments such as for dams as well as for management of water infrastructures. Energy is also key for water management for agriculture as well as for agriculture more broadly. And as shown above, production of biomass for energy will require more water. All these links call for integrated consideration of these three sectors. However, it still needs more work to ground practical decision-making.

An integrated approach and intersectoral collaboration is key to confront different sectoral needs, including the need to enhance ecosystem governance involving, for example, the conservation and sustainable use of forests, wetlands, mountains in order to ensure the continued availability of water (Varghese, 2009).

IWRM has also been the subject of numerous criticisms. While the critics of IWRM recognize its value as a comprehensive framework, they argue that it is too abstract when addressing implementation challenges. This makes it less operational and practical, especially in developing countries' contexts. Critics also point to IWRM's difficulty to recognize conflicts and to enable proper prioritization of issues, especially those most important for people locally, including water for FSN.

Gender and social justice in access to water

Even though equitable access is a goal of most water policies and initiatives, it is seldom clearly defined either in relation to access to water for productive purposes or water services. Even when clearly defined, achieving it remains a challenge. Even when the necessary infrastructure and services are in place, social exclusion of, for example, rural communities, women, particular castes or ethnic minorities, older persons, persons with disabilities, people with chronic illnesses or the extremely poor can prevent an individual or the community from accessing water, or from accessing it in a dignified manner, see Box 21). Stigma and discrimination, alongside power imbalances, can impede the realization of water and food security for all. The caste system in India, for example, continues to shape water management practices on the ground, hampering equity in water-harvesting schemes and watershed management (see Mehta, 2005; Naz, 2014).

In some cases rules regulating access resulted in exclusion from access to water. In the United Republic of Tanzania, for example, where all land and water is state-owned, water extraction is fee-based and requires a permit (Lein and Tasgeth, 2009), potentially excluding the poor from water use rights. Although customary rights are recognized (but require conversion to permits), recognizing them alongside formal rights has meant in practice poor treatment of customary users of land and water (Vorley *et al.*, 2012). Legislation favours *"the estate sector, formal irrigation and hydropower over farmer-managed irrigation"* (Lein and Tasgeth, 2009: 210) despite the fact that smallholders produce most of the food in the country (Vorley *et al.*, 2012) and farmer and community water management play key roles in local farming systems (Lein and Tasgeth, 2009).

Norms based on socio-cultural traditions as well as new laws may restrict women's control over land and natural resources. Allocation and water use authorization systems (see Section 3.2) often allocate water and/or land to the adult male in the household, even where women are the primary farmers, resulting in situations where land and water resources used primarily by women are formally controlled by men. For instance, in the Dominican Republic, deeply rooted patriarchal culture has influenced an agrarian reform law that limits women by establishing the male as the administrator of the entire estate.[29] Given women's significant role in agricultural production and FSN, this gender gap in access to land and water has significant negative impacts on food security, particularly since women produce most of the food for home consumption (FAO, 2012a).

Many national policies around food, water and the environment are informed by international frameworks that implicitly or explicitly recognize gender concerns (see Section 3.4). However, equality understood simply as formal or legal equality is clearly insufficient. Substantive equality requires the adoption of positive actions to level the playing field. Still, women's equality has too often translated into tokenism or co-option. There is a need to challenge and re-work the discourses, cultures, practices, biases and gender stereotypes that beset policy institutions and organization across scales (e.g. the notion that women cannot own land and are not productive users of water). This can happen through feminist action within bureaucracies (see UN Women, 2014) where informal alliances and relationship networks prove key in the complex process of translating policy into practice for desired outcomes. It can also be assisted by "external" pressure from social movements and activism.

Box 21 People with disabilities and the elderly

Agricultural water management projects can promote the integration of the extreme poor, and marginalized, including people with disabilities and the elderly. Poverty and disability are connected: poor people have a higher exposure to the risks that cause disability, be it from diseases or accidents. Left behind when others migrate to cities, but with less access to labour, people with disabilities and the elderly are often among the most vulnerable. Their enablement and integration can be promoted through:

- Prevention – reducing the exposure to disabling (water-borne) diseases and occupational risks.
- Adjustment – promoting farming systems (horticulture and fisheries) and techniques (micro-irrigation, small-scale mechanization) that are high value but lighter on labour requirements.
- Special integration – positioning the elderly and people with disabilities in special services (trading, training) or functions (supervision) in the operation of agricultural water management programmes.
- Special support – using safety net programmes to provide extra assistance to these groups of vulnerable persons.

Source: see MetaMeta and Enablement, n.d.

[29] See http://www.fao.org/gender

Box 22 Male biases in African water management policies

Policies on water, land and food security in sub-Saharan Africa still reflect discriminatory gender conceptions inherited from the colonial past when European rulers promoted the notion of the unitary household, headed by the man, entitled to exclusive individual control over all productive resources (land, water and infrastructure) and their wives' labour. Women were seen as non-earning housewives (Rogers, 1981). Today, public support for ploughs, power tillers, fertilizers, irrigation pumps and financing facilities is primarily allocated to men as the supposed household head (World Bank/FAO/IFAD, 2009). Resource entitlements, irrigated land and membership in water user associations are vested in men as a rule, and only by exception to women heading households (van Koppen, 2002). Women are, at best, the target group of domestic water services, supposedly fully responsible for the health of all household members (Van Wijk-Sijbesma, 2002).

This conception clashes with rural and peri-urban realities in most of agrarian sub-Saharan Africa where both women and men have resource use rights that ensure the tiller's control over the produce, while protecting communal interests (Dey, 1984; van Koppen, 2009). Under matrilineal land tenure, women's stronger land rights further strengthen women's bargaining powers to maintain control over the benefits of their labour (Peters, 2010). Matrilineal tenure remains ignored even though it is widespread in countries like Ghana, Malawi, Mozambique, the United Republic of Tanzania and Zambia. Land, water and food security projects tend to follow male-biased targeting strategies that erode women's rights. In contrast, when projects vest resources in the tillers, often women, resources are used better. This needs to be recognized in water rights allocation systems.

For example, in Burkina Faso, the EU supported project "Opération Riz" aimed at improving the agronomic practices and water management in rice valleys. With some variation along ethnic lines, rice was mainly cultivated by women, who also had strong land rights and managed water infrastructure. Yet, in the first schemes, the project re-allocated the improved land to male household heads. As women refused to provide labour on men's fields, and men were more interested in their traditional upland activities, the first schemes collapsed. In later schemes, the improved plots were given back to the original women cultivators and other volunteers (mainly women). With control over the output, women not only produced well, but also ensured regular canal maintenance (van Koppen, 2009).

3.2 Tools to manage scarcities and competition

Many mechanisms and tools can be used to manage water scarcities and competing demands, such as: mechanisms to set maximum withdrawals; allocation tools, including access rights; permits and tradable permits; licensing systems; pricing schemes; and other tools to protect the resource and its quality, such as to regulate water abstraction and discharge, protected areas, catchment protection, water quality and resource protection regulations. The choice of the tools and the way they are implemented can have diverse effects on FSN through the impacts on water available for agricultural uses, and on access to water for poor, vulnerable and marginalized populations. In particular, the impacts of tools on FSN and on populations depend on the social and legal systems in which they are implemented (formal and informal). Badly adapted tools can disrupt existing community-based systems. Market-based tools tend to give priority to the sectors that offer the highest economic value for water use, often at the expense of food security.

Governance of water resources, especially in water scarcity contexts, goes with the establishment of an allocation scheme, including allocation tools and rules. In the context of FSN, the challenge is to ensure that allocation systems give adequate priority to water for food production as well as for the basic needs of poor and marginalized populations.

Allocation mechanisms, ideally, operate at a pertinent hydrological level where the resource is contained and shared. This can be particularly challenging because the institutional arrangements are not often aligned on hydrological bodies. A water resource can spread on different administrative entities including on different countries. Also, institutional arrangements do not always take into account interconnections between various water resources, such as between surface water and groundwater.

Allocation of, and access to, water are determined not only by formal institutions (supported by laws) but also by informal arrangements such as customary law. In a context of increasing formalization of access rights, the rights of poor and marginalized women and men, often of a customary nature, are often overlooked and threatened, with impacts on FSN.

3.2.1 Water allocation and FSN

Allocation of water takes place at different scales, ranging from identification of national sectoral priorities explicitly or implicitly and, the case being, allocation between countries in shared river basins, to allocations to individual water users at basin or management unit level. There are broadly four types of water allocation mechanisms: marginal cost pricing, public or administrative water allocation, water markets and user-based allocation (Dinar *et al.*, 1997). Marginal cost pricing sets a price for water equal to the marginal cost of supplying the last unit of that water, aiming through this to achieve economically efficient allocation of water resources. The challenge of this tool relates to difficulties in defining the marginal cost of water.

In public or administrative allocation systems, the State decides how much water can be used by different water use sectors and water users, and does the allocating. Permits or water use licences are a common element of administrative allocation systems.

Water markets facilitate the transfer of water use rights between users, with demand and supply determining the quantities to be transferred and the unit cost. Water markets are seen as a way of driving water use to higher value water uses, but require certain conditions to function well, and may require the intervention of government for this. They allow the most profitable industries to command a greater share of the water allocation, which is important for efficiency outcomes but without strong regulation carries the risk of undermining the production of staple foods in particular. In Chile for instance, where in 1981 a water code based on a free market for water rights was introduced, the allocation of new water rights was auctioned off to the highest bidder, with effects on subsistence farmers (Boelens and Vos, 2012).

User-based allocation is made through collective, user-governed institutions with authority to make decisions on water rights that may include informal or customary allocation practices. The most common example of user-based allocation is within farmer-managed irrigation systems where farmers determine who is to use how much water and when. It can also be seen in the domestic water supply systems in community well and hand pump systems. Usually, allocation mechanisms include a mix of the approaches described above. Water use rights are different from the human right to water (as described in Section 3.4)

Box 23 Water regulation reform in Maharashtra

In 2005, the State of Maharashtra (India) embarked upon an ambitious water pricing reform strategy by allocating water entitlements for various categories of uses. The central principle of this reform package was to ensure cost recovery in a loss-incurring water sector through the pricing tool of entitlements to be overseen by an independent regulatory authority. Entitlements are defined as use rights on water and are not ownership rights (Government of Maharashtra, 2005a). It was intended in the long term to create formal water trading (both intra- as well as inter-sectoral) thus leading to water use efficiency in this water-stressed Indian state (Government of Maharashtra 2005b; World Bank 2005). Introducing entitlements in western Maharashtra, which lies at the heart of the sugar-cane economy, had multiple challenges: (i) resistance on the part of head-end farmers who had previously benefitted from an earlier regime of property rights called the block system and the underpricing of water; (ii) measuring devices established for the calculation of entitlements were destroyed by farmers due to poor system performance ; and (iii) the top-down character of the water user associations did not allow for participation and equity in decision-making , thus creating information asymmetry. Growing a water-intensive crop such as sugar cane in a drought-prone area also produced differentiated access to water and situations of socially-induced scarcity whereby water demands at the tail-end for staple crops such as sorghum and household needs often competed with the politically powerful and rich sugar-cane farmers at the head (see Srivastava, 2014).

In a rapidly urbanizing and industrializing State such as Maharashtra, determining water allocations between different uses has often led to prioritizing water for industry over agriculture (see Wagle *et al.*, 2012). Thus conflicts abound between water for industry vs water for agriculture; water for agriculture vs drinking water and water for sugar cane vs water for sorghum and livelihoods. Thus, decision-making needs to be made as part of a wider democratic process. The Maharashtra regulator has made a moderate start towards this goal by organizing public hearings on entitlements but allocations are no longer under its regulatory mandate. In sum, the reform processes and defining and enforcing entitlements must bear in mind the diverse patterns of water use and values that people associate with water (see Srivastava, 2014).

Water scarcity often triggers short-term (re)prioritization of competing uses, which may then become permanent according to national policy priorities, or modified anew when new situations of temporary water scarcity or tension over the resource arise. In these cases, allocation (or “re-allocation”, through administrative, market-based or collective negotiation processes) generally tends to favour higher value water uses, and more politically and economically powerful users (see Meinzen-Dick and Ringler, 2008): cities, industry and power generation, at the expense of agriculture and food production. At the time of writing, a recent example is California in the United States of America, which entered into the fourth year of consecutive drought. In February 2015, authorities announced that they will not deliver water to farmers in the system who lack senior water rights. At the same time, water was assured to maintain the health and safety needs of the municipal and industrial sector (US Bureau of Reclamation, 2015).[30] Given the importance of California for certain products, such as vegetables, fruits and nuts, such water restrictions for agriculture in the region will have an impact country-wide. Similarly, deprioritizing the agricultural use of water can have food security consequences for rural and urban populations, as shown by the example of water allocations in the drought-prone areas in Saurashtra and Kutch Gujarat, India (see Counterview, 2014). The food security implications of taking water away from the agriculture sector and from informal food production systems need to be borne in mind in the allocation of water.

3.2.2 Water use authorization

Permit or licensing systems, including tradable permits (see Section 3.2.3), are increasingly being used to regulate water abstraction and discharge. To ensure water for FSN in poor rural communities, such mechanisms need to address the formal recognition and protection of customary water rights, while ensuring gender equality within customary arrangements. Such recognition often includes communities’ procedural rights and some form of documentation and quantification of customary water rights, with some studies suggesting the need for approaches capable of capturing the dynamics of customary arrangements (cf. Boelens and Zwarteveen, 2005). Licensing can be an important instrument in the global South if redesigned into a well-targeted regulatory tool focused on the minority of high-impact users while protecting the priority of use of small-scale users whose water uses are vital for vulnerable livelihoods (van Koppen and Schreiner, 2014) (see also Section 3.4).

In practice, formal administration-based water use rights systems in sub-Saharan Africa have tended to dispossess the informal majority of small water users who manage their water under community-based arrangements (van Koppen, 2007). Many of these rights are not (and often cannot be) included in the formal system, leading to a weakening of the position of historical smallholder use. Complicated and expensive license registration procedures tend to *“favour the administration-proficient”* (van Koppen, 2007: 46). This raises the issue of the capacity of poor countries to roll out such permits in ways that do not disempower the already weak and marginalized (see Box 24).

Small-scale water use, mostly for drinking water, but sometimes also including small productive use, is excluded from licensing requirements in many systems, (Hodgson, 2004b). In South Africa this is called a “schedule 1” use (van Koppen *et al.*, 2009); in Mozambique it is called “*uso común”*, or common use (Veldwisch *et al.*, 2013); elsewhere it is also referred to as “primary use” or in Islamic law as a “rights to thirst” (Meinzen-Dick and Nkonya, 2005). However, this type of *“entitlement cannot lawfully prevent anyone else from also using the resource even if that use affects his own prior use/entitlement”* (Hodgson, 2004 : 92). Formal permits create first-class water use rights in comparison with other water use rights (van Koppen, 2007), with the result that such use has stronger protection than the use of water by the poor, including the use of water for small-scale food production. It is this lack of protection that impacts on the food security of the rural poor where such water would enable the growing and selling of food. In Kenya, nomadic livestock keepers and fisherfolk without formal water licences were dispossessed of their traditional rights when large-scale investors started developing the Tana River Delta (Duvail *et al.*, 2012). Williams *et al.* (2012) demonstrate for three cases in Ghana that smallholders were not aware that their historical agricultural water rights are not recognized in national legal frameworks favouring commercial and large-scale users of land and water. In the context of limited registration of smallholder water use, poor hydrological knowledge, and/or weak enforcement, permits provide an “easy way in” for newcomers, while giving them the formal backing of the State (van Koppen, 2007). The gendered nature of permitting systems, and the dispossession of women’s water rights in this manner (Box 22), impacts the security of women farmers in particular.

[30] http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=48986 issued on 27 February 2015.

Box 24 Administrative water law: dispossession and discrimination of vulnerable and disadvantaged groups

Research in the United Republic of Tanzania shows how governments generally lack the capacity to process the tens of thousands of applications from small-scale users, while microscale users who are exempted from that obligation are relegated to a second class entitlement. This fear was expressed by villagers in the Uluguru mountains who operate complex networks of local farmer-managed springs, canals and wells for highly productive irrigated horticulture, cropping and domestic uses. While government wants to vest permits in the few formalized male-dominated water user groups, villagers predicted that this would create “chaos” as the majority would continue managing water according to their informal local laws, even if it was declared to be illegal water use. The villages were adamant that the permits should be vested in local government (van Koppen *et al.*, 2014b).

3.2.3 Tradable water permits systems

A few countries (Australia, Chile, United States of America, China and South Africa) have explored decoupling water-use rights for irrigation from land-use rights and enabling tradable water permits in order to facilitate the reallocation of water in response to the increasing scarcity of water (Saleth and Dinar, 2000). The introduction of formal water-use rights can create security for water users, promoting efficiency of use and opening opportunities for water markets (see Briscoe *et al.*, 1998). In addition to clearly defined water rights (including transfer rights), water markets require physical infrastructure to transfer water between users (CA, 2007).

At the same time, the use of tradable permits for water allocation (and for pollution control) has raised concerns. The attachment of significant monetary value to water can undermine equitable distribution (OECD, 2000). A further concern relates to impacts on ecosystems and other parties affected by the transfer of water-use entitlements and the possible externalization of costs. For example, the diversion of water towards higher-value crops or non-food crops such as cut flowers can have negative impacts on national and local food security and nutrition particularly for vulnerable communities, as well as impacts on indigenous peoples’ way of life (Jackson and Altman, 2009; Varghese, 2013). Evidence from Chile and elsewhere suggests that introducing formal entitlements and permit systems may not always and everywhere be the best legal device to address the challenges of water scarcity today (van Koppen, 2007; Bauer, 2004). Challenges encountered in the implementation of tradable permit systems suggest the prior need for clearly structured and recorded water-use rights and an effective administration system (Borghesi, 2014). Finally, the advantages of such systems may be limited in African and Asian countries where customary systems abound and the financial, institutional, metering and remote sensing capacity to support water trading is low (Meinzen-Dick, 2007).

The physical geography of water can also limit the scope for water markets. For example, water can often only be traded downstream, while it may be too costly to move water from one location to another. Nonetheless, in certain contexts water markets have been shown to be effective in driving the economically efficient use of water (see Box 25 on tradable permits in Australia).

3.2.4 Water pricing

The provision of water has significant costs, particularly where infrastructure is required, and the costs of capital, operation and maintenance, as well as of water management, must be covered from one of three sources: tariffs, taxes or transfers. Tariffs refer to charges for water use, while transfers refer to external funds such as money from donors. The issue of what should be paid for through direct water charges and what should be paid for through taxes or transfers has important implications for the cost of water for food production and for household water use.

Water pricing policies can create incentives for water conservation and raise resources for construction and operation and maintenance (CA, 2007). It can improve the efficiency and sustainability of water use when combined with appropriate supporting policies (Rosegrant *et al.*, 2002). But there are significant barriers to water pricing, especially in developing countries, mainly due to the administrative requirements and the challenges of developing a billing system that effectively balances issues such as affordability, cost recovery and targeted subsidies. Poorly constructed pricing regimes can result in subsidies not being available to those who need them most. Adding to the difficulty of pricing reform, often long-standing practices and cultural and religious beliefs have treated water as a valuable, but free, good.

Box 25 The Australian water governance regime

Australia, the driest continent, has pursued far-reaching water governance reforms for over two decades. Against the backdrop of climate extremes of droughts, floods and fires, competing claims over water and overallocation in the Murray-Darling Basin, extensive reforms of water governance have been implemented (see Australian Water Act, 2007). The reforms include development of water plans using transparent and participatory processes to establish how much water can be allocated for users after meeting priority environmental, social and cultural needs. The plans set seasonally adjusted limits on abstractions (both surface and groundwater) in stressed watersheds and use market-based allocation mechanisms to improve sustainability of supply and the environmental health of the water systems. The Australian strategy is the most developed in terms of separation of the water access right from land title. It includes tradable water rights, and further unbundling of water rights that *"may contain a combination of water access entitlements; water supply works rights and water use rights"* (Australian Government, 2014). Reforms since the 1980s allowed seasonal water allocation and permitted trading in geographically defined areas. The 1994 nationally coordinated reform agenda was a major turning point in the evolution toward market-based allocations. In the wake of the Millennium drought, the National Water Initiative (2004) took this further in an agreement between national and state level governments. The environment was firmly established as a legitimate user of water and environmental recovery was put at the centre of the allocation arrangement. Enforceable limits were set on irrigation extractions of water from the Murray-Darling Basin system and public funding was provided for purchase of water to be returned to the river system. The essence of Australian water policy has thus been to find the right balance between the environmental and consumptive uses of water (NWC, 2011).

The Australian experience has gained traction on several accounts. Australian water markets have allowed irrigators to achieve the highest possible return from their variable seasonal water allocations while reducing the economic hardships associated with declines (Bjornlund and Rossini, 2010). Price signals on traded water, changing with seasonal availability and demand, encourage farmers to reduce wastage and scarce water can move to its highest value use, leading to changes in crops planted or location of production in response to water prices. In South Australia, for example, 90 percent of additional water purchases were used to expand high-value horticultural production. The benefits of water trading during the recent Millennium drought were indicative of significant economic efficiency gains while providing cash flow to individual farm businesses, which sell their water allocations (Fargher, n.d). Studies indicate that water trading has increased economic activity in the Murray-Darling Basin, including a NWC estimate of a $370m increase for 2008–09 (Horne, 2012).

Notwithstanding these improvements in Australia's water management, challenges remain and there is lively debate about the extent of further reform required. Grafton *et al.* (2014) suggest that the trade-off between water extractions and water essential to the long-term ecological function of a river system especially in the wake of increasing climate variability is often neglected (Grafton *et al.*, 2014). Others argue that the arrangements for capping surface and groundwater abstractions are inadequate (Young, 2012). Problems that are unrelated to pricing and trading also exist in the intersection of water management with developments in other sectors including mining, unconventional gas extraction and nutrient leaching affecting fisheries or marine assets such as the Great Barrier Reef. The National Water Commission also accepts that more needs to be done to recognize cultural values associated with water on the part of indigenous peoples (NWC, 2012). Water trading has provided for public purchases of water for environment especially under the Water for Future Programme of the Australian Government and significant investments will be made to restore the health of the Murray-Darling Basin. The evidence of how far the water buyback programme has led to positive outcomes on environmental recovery and the health of the river systems remains limited (Grafton *et al.*, 2014; see Pittock, 2013).

Several attempts have been made to replicate the Australian experience across the global South (Saleth and Dinar, 2000), with varied results. Water markets may be less useful as a management tool when there is no water constraint (Varghese, 2013). As discussed in Box 20, in Maharashtra, the first State in India to experiment with tradable water entitlements, poor regulatory capacity, political opposition to market-based reforms and the prevalence of small landholdings prevented the uptake of such reforms (Srivastava, 2014). Similarly, Movik (2012) in her study on the South African water allocation reform notes the impermeability of the idea of formal water markets. Both cases, influenced by the Australian experience, raise questions regarding wider replicability especially in Africa and Asia where customary systems abound, and the financial, institutional, metering and remote sensing capacity required for such reforms is low and the State has poor regulatory capacity (Meinzen-Dick, 2007). Large investments in infrastructure and administrative capacity would be required to replicate the Australian arrangements in full. Nevertheless, new technologies for low-cost metering and remote sensing of water offer promise for establishing market-based allocation systems in lower-income countries. It might also be easier to apply pricing principles for allocation at local level than through fully developed national schemes where users in specific watersheds can agree on principles for sharing constrained water that include reliable enforcement mechanisms.

Water pricing is now generally well established for the domestic sector, where it can contribute to cost recovery and water savings. Appropriate pricing systems can also provide incentives for water-use efficiency. Implementing polluter-pays regulations can generate revenues to better manage water quality. But it remains controversial in terms of affordability criteria, and especially regarding its impacts on the poor. In practice, it is not always effective. In public surface irrigation systems, such as the Indus Basin Irrigation System, for example, farmers have little (if any) control over when and how much water arrives at their field intake (Akram, 2013), and thus little motivation to pay for a service that is not provided on-demand. How to combine the use of taxes, tariffs and transfers to cover the costs of water provision in a manner that supports the achievement of food security and nutrition is a key challenge. A requirement to pay a water fee may cause some poor farmers to give up farming (CA, 2007). In many cases, prices high enough to induce significant changes in water allocation (or recover capital costs) can severely reduce farm income, and price irrigators out of business (de Fraiture and Perry, 2007). A sliding-scale pricing strategy is one possible solution (Schreiner and van Koppen, 2001).

Where groundwater is a source for irrigation, energy subsidies and tariffs play a key role in access. In such a case energy pricing can also influence water withdrawal levels.

3.3 Ways forward for better governance

3.3.1 Address the challenge of integration and priorization

Numerous policies have an impact on water resources: environment, energy, trade, food and agriculture, including fisheries and forests, industry, etc. Policy coordination is managed differently according to countries' institutional settings. At national level, when it exists, the coordination is assumed either by a lead ministry, or an interministerial coordination mechanism, or a dedicated body. In some cases, this leads to an integrated water policy.

According to the responses given by 13 Latin America and Caribbean countries to a survey conducted by the OECD (2012), all of them have adopted institutional mechanisms for upper horizontal coordination of water policies, primarily with line ministries, followed by interministerial bodies, committees and commissions, that often act as platforms for dialogue and action among public actors at central level. There are also formal coordination bodies such as CONAGUA in Mexico and many countries have created national water agencies, including Brazil, Cuba, the Dominican Republic, Guatemala, Panama and Peru. Significant efforts have been undertaken to coordinate water policies with regional development, agriculture and energy policies. There are also different forms of coordination of water policies between levels of government and across local and regional actors, including some consultation of private actors, civil society and water users. However countries still report significant challenges to coordination.

In many cases national water policies do not prioritize water for food security. While some do outline the order of priorities for water allocation with a focus on FSN, fully implementing it remains a challenge, not least due to the lack of integration in decision-making, with decisions on irrigation, industrial or power generation development being taken in different departments with little consideration for the cumulative impacts on water. Some countries however have put in place improved intersectoral decision-making, a critical process in ensuring sufficient water for FSN.

Sustainable management of water resources for FSN often depends on the protection and conservation of specific ecosystems, particularly wetlands and forests, which themselves also contribute to the FSN of local populations. Similarly, quality water streams and bodies are important for inland fisheries and aquaculture. The ecosystem approach as defined by the Convention of Biological Diversity provides a good model. It requires specific integrated governance mechanisms.

A critical policy interface for water and FSN relates to the issue of water allocation (see previous section) between and within economic sectors and how this relates to food security policy. This is particularly true where there are constraints on water availability, and choices must be made whether to allocate water to agriculture or to other water use sectors such as the industrial, power generation or municipal sectors (Box 27).

Box 26 Innovative international stewardship and governance in the Yukon River watershed

The Yukon River watershed is the third largest basin in North America and supports the longest inland runs of Pacific salmon in the world. The region's indigenous peoples depend heavily on culturally significant, locally harvested foods such as fish, moose and caribou for subsistence.

The watershed's primary local presence is Tribal and First Nation governments, whose citizens face collapsing salmon runs and declining subsistence resources. Several federal, state and/or provincial agencies have some regulatory responsibility for managing the river and its watershed. But because none of them are specifically dedicated to the well-being of the river, its watershed and the peoples therein, in 1997 tribal nations, leaders and citizens along the river established the Yukon River Inter-Tribal Watershed Council (YRITWC)*.

The YRITWC is comprised of 72 Tribes and First Nations in Alaska and Canada united through an unprecedented Inter-Tribal Accord – an international treaty that commits its parties to use their governmental powers to protect the environmental integrity of the Yukon basin and the cultural vitality of the indigenous communities that are dependent upon the basin and river for their food security and livelihoods. The Accord signatories span several distinct cultures, languages, and geographies. They consult together and collaborate on actions that range from conducting water quality monitoring throughout the watershed with training and equipment provided by the YRITWC and the US Geological Survey, to applying traditional knowledge for determining adaptive strategies in the face of climate change.

Flagship projects include hazardous waste backhauling/recycling, comprehensive water quality monitoring, and contaminants assessment and cleanup. The YRITWC has facilitated the establishment of 55 Tribal environmental programmes with strengthened scientific capacity throughout the watershed. And it has hosted and facilitated training on water quality monitoring, solid waste reduction, military contamination, community development and more. While the Tribes and First Nations set priorities and identify unmet community needs, the YRITWC assists with identifying and securing funds, bringing in expertise for local execution and skill enhancement, and aggregating outputs such as data collection and analysis for better scientific understanding. The data collected are respected and used by federal agencies, in particular the US Geological Survey, which now depends on the YRITWC to continue baseline water quality monitoring and measure climate change indicators through changing water chemistry.

Source: YRITWC correspondence, and Harvard Kennedy School, Ash Center for Democratic Governance and Innovation Web site.

In Ecuador, constitutional reform in 2008 clearly outlined the order of priorities for water allocation: *"(1) water for domestic use, (2) irrigation for food sovereignty, (3) ecological flows, and, lastly (4) productive activities"* (Harris and Roa-García, 2013: 24). These principles can orient decisions in investment, infrastructure, productive activity and social programmes that address water. In Spain the "plan hydrologico del Ebro" of 2014 explicitly describes sustainable water management for food, energy and nature.

Where water is allocated to agriculture, the choice must be made whether it is allocated to large irrigation schemes, or to smallholders, or to a range from small to large. For example, if national policy is to grow sufficient food for at least a large portion, if not all, of the national food security requirements, then the allocation of water must take this into account, particularly where irrigation plays an important role in ensuring food security.

In the United Republic of Tanzania, the Kilimo Kwanza policy of 2008, also known as the "Agriculture First" vision, calls for a greater role for the private sector and commercial agricultural development. Despite smallholders' livelihoods being protected on paper by two Land Acts, loopholes in the law have led to vast tracts of "Village Land" being transferred to "General Land" for investors, and there have been cases of water permits granted to companies to grow sugar cane for ethanol production without sufficient water being available for such operations. These issues have caused conflicts between farmers and pastoralists and displacements from local land and water resources as well as livelihoods (Van Eeden, 2014).

In Bangladesh, national water management policies have been criticized because of contamination of groundwater by arsenic aggravated by overexploitation of groundwater resources (UN, 2003a; Alauddin and Quiggin, 2008). Historically, water management in Bangladesh focused on agriculture and flood control in order to achieve food security and support rural agrarian livelihoods (Ahmad, 2003; Das Gupta *et al.*, 2005; Pal *et al.*, 2011). However, while Bangladesh's successful use of groundwater resources through shallow and deep tubewells for irrigation has allowed it to achieve cereal-based food security (Pal *et al.*, 2011), since groundwater supplies 95 percent of domestic and industrial use and 70 percent of irrigation water (Das Gupta *et al.*, 2005), policy-makers are now concerned that overreliance on groundwater for agriculture *"is pre-empting the possibility of environmental replenishment and balance"* (National Strategy for Poverty Reduction II, 2008: 68), illustrating one of many relationships between national policies that must be addressed with regard to water security and FSN.

While the water implications of such decisions are specifically considered in some countries, in others there is a lack of integration in decision-making, as decisions on irrigation, industrial or power generation development are taken in different departments with little consideration for the cumulative impacts on water demand or water quality. For instance, impacts on water quality of waste discharge by a particular user are aggravated by reduced river flows and hence reduced dilution of existing waste discharge.

The complexity of water governance for FSN is exacerbated by devolution to subnational entities, such as provincial or district governments, or basin-level institutions, resulting in the need for both horizontal and vertical integration in decision-making across water, land and agriculture institutions.

The China case highlights how success in achieving irrigation and food security water meets with challenges and competing demands. China feeds 20 percent of the world's population on 10 percent of the world's farmland using 6 percent of the world's freshwater (Doczi *et al.*, 2014). China's food security policy is based on self-sufficiency targets for staple grains, especially rice, wheat and maize. The food security policy and a focus on developing the rural areas led to high levels of public investment in the agriculture and water sectors, but there have still been clashes between economic and environmental targets and challenges in balancing water use efficiency with equity in access.

While policies at national level may not be able to take full account of different local realities, quality intermediation between stakeholders and mobilization to demonstrate the effect of these policies has been effective. For instance, when management of the Angat reservoir in the Philippines was privatized and had detrimental effects on agricultural production, civil society mobilization and a widely distributed study demonstrating these effects led to the Supreme Court making water available to farmers during critical times in the growing season (CGAAER, 2012).

As has been discussed, water-related ecosystem goods and services make important contributions to food security. Poor ecosystem governance leading to their degradation can negatively impact on food security. This impacts particularly on the rural poor and vulnerable groups including women and children (IUCN, 2013). According to the IUCN, an ecosystem-aware approach to food security policy-making is needed at the national level to go beyond the conventional focus on productivity, trade and macro-economic issues to develop an approach to sustainable food systems to build long-term food resilience. This requires the integration of aquatic ecosystem good governance into food security policies.

Box 27 Water governance in Jordan

Jordan has water availability of 130 m^3 per capita annually compared with the world average of 7 000 m^3, necessitating strict water management policies (Wardam, 2004). All water is state-owned and agricultural use is limited through allocations and tariffs with some recent reallocation of water from agricultural use to urban use (Alqadi and Kumar, 2014). Water policy has focused on managing water for efficient use (Wardam, 2004), mega-projects like desalination, micromanaging supplies and exploiting available resources, particularly through wastewater reclamation for agriculture (Alqadi and Kumar, 2014). Use of wastewater for agriculture has been increasing, significantly reducing agriculture's use of freshwater (Alfarra *et al.*, 2011). However, even with these strict controls, concerns regarding food security remain. Since Jordan imports 90 percent of its food, the population is vulnerable to global price shifts (Alqadi and Kumar, 2014). Additionally, the increasing population and large number of refugees resulting from regional tensions mean that Jordan continues to face a water crisis that requires further work to maintain water and food security.

In the prioritization of water uses, the most important issue is what are the responsibilities of other water users with regard to maintaining ecosystems. South Africa's second National Water Resources Strategy, for example, is clear about this: the first priority is for the ecological reserve and the reserve for basic human needs; the second priority is water for international obligations; the third priority is for water for poverty eradication and redress of inequities from the past; and the fourth priority is for electricity generation, which is followed by water for other economic uses. Here, those who need water in order to be able to enjoy their human rights to water and to food are freed from the restrictions in water use required to ensure that there is sufficient water for ecosystems (DWA, 2014).

3.3.2 Integrate water and FSN concerns in land and ecosystems governance

Primary access to water resources very often goes with access to the land on which they are situated or to the land near the source, the shore of the lake or the river bank, or the land on top of the groundwater reservoir.

Access to a secondary source of water is often independent of access to land providing access to water, such as in cities (for drinking water), or for irrigation of lands not traversed by a stream. In this case, the issue at stake is how the primary access to water (the source, situated inland) is transferred to the secondary users who do not "board" the resource in the first place.

It is in this context that access to land and access to water resources need to be seen as being interrelated, but as being also fundamentally different.

Under formal or customary riparian laws, which allow landholders reasonable water use from a water resource on or adjacent to a property, as long as it does not affect the reasonable water use of adjacent riparian landholders, water rights are by definition attached to a land right and obtaining a water allocation is conditional on obtaining access to riparian land. In these systems, land tenure is a key determinant of access to water, and if land tenure discriminates against women, or the poor, it also discriminates against them in access to water (Srivastava, 2014; Joy *et al.*, 2011).

When land and water governance are not adequately linked, changes in land ownership and tenure at one location can have impacts on water access rights elsewhere, with impacts on agriculture and FSN. Conversely, loss of access to water can impede the proper use of land. In particular, large land acquisitions can lead to the re-allocation of water locally or downstream and can negatively affect the FSN of communities – local or remote.

The Voluntary Guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security (VGGT), the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF), and the CFS Principles for responsible investment in agriculture and food systems have not paid much attention to the topic of water resources, despite it having important linkages with land issues, and it being a determinant of fisheries resources.

The VGGT warrant special attention since they constitute the most recent site of struggle between competing views and interpretations of natural resources and the way they should be governed (Suárez, 2013; Seufert ,2013). They are *"the first international instrument which applies an ESC-Rights based approach to the governance of land"* (Suárez, 2012: 37). Yet water is mentioned only once in the document.

Box 28 FSN challenges of prior appropriation systems

Prior appropriation (first in time, first in right), which first emerged in the western United States of America in the 1850s, recognizes the water rights of the first person ("senior appropriator") to claim the water, provided it is put to "beneficial use" (a clause that primarily covered commercial, agricultural, domestic or industrial use). In such a system, water rights are unconnected to land ownership, and can be sold or mortgaged like other property. The first person to use a quantity of water from a water source for a beneficial use has the right to continue to use that quantity of water for that purpose. Subsequent users can use the remaining water for their own beneficial purposes provided that they do not impinge on the rights of previous users.

3.3.3 Consider adaptive management and co-management, while addressing related issues

Another approach that has been widely promoted for improved water management, particularly in the face of climate change, is that of adaptive management. It is often linked to co-management and governance at local level.

Adaptive management[31] (see also Section 2.1.2) uses systematic strategies for improving management policies and practices by learning from the outcomes of previous management actions (Pahl-Wostl *et al.*, 2007). An adaptive management approach allows for adjustments and course corrections arising from the complex and unpredictable interactions in the system and is necessary not only because of the challenges imposed by a rapidly changing climate but because of the complexity of water systems. When water and food systems are overlain, the complexity increases, which demands enhanced adaptive management capacity (see Chapter 3 for a further discussion on the issue).

In adaptive co-management (Stringer *et al*., 2006; Engle *et al.*, 2011; Carlsson and Berkes, 2005), emphasis is placed on the collaborative governance of water resources as well as processes of social learning in complex and dynamic social-ecological systems (see also Pahl-Wostl *et al.*, 2008). The water users group in Ringarooma, North East Tasmania, Australia, for example, has evolved a process to adaptively manage streamflow in the catchment. This process, involving cooperation and negotiation between the regulator and water users, has helped improve both water security and environmental performance (Edeson and Morrison, 2015).

While such examples of co-management and water user groups are positive, there are also mixed experiences with user involvement in water management (e.g. Cleaver, 1999; Wester *et al.*, 2003; Boelens, 2008). The involvement of local users in water management does not necessarily prevent strong actors from capturing unfair shares of water, even at the local level, and excluding informal water users (Warner *et al.*, 2008). Women in particular are often under-represented or have limited decision-making power within WUAs. State and NGO actors establishing user groups must be mindful of existing gender and power imbalances and make special efforts to advance the interests of marginalised groups around water for FSN.

Box 29 Participatory initiatives for accessing water in rural areas in Brazil

In order to overcome a long-standing history of conventional assistance policies for the Brazilian Semi-Arid region, seen as unsustainable due to the lack of rain and water, the Brazilian Semi-Arid Articulation (ASA; www.asabrasil.org.br), a network created in 1999 and gathering today more than 3 000 organizations, has been dedicated to promoting coexistence with the Semi-Arid with the perspective to recognize and enhance the values and possibilities of the region together with the building of the autonomy and life of local people with endogenous solutions.

The main action developed by ASA consists of the construction of rural cisterns, simple instruments for collecting rainwater for human consumption, alongside social technologies for water storage aimed at food production. These technologies were sought among the rural population and systematized by ASA to be converted into proposals for participatory water policies. With the support of the National Council of Food and Nutrition Security (CONSEA) and the Ministry of Social Development and Fighting Hunger (MDS), this proposal became a public programme funded by the Federal Government run by the ASA as well as by State and municipal governments (Program 1 Million Rural Cisterns; Program Water for All; www.mds.gov.br).

In the last 12 years more than 800 000 slab cisterns were built, each with a capacity of about 16 000 litres of water for human consumption, of which close to three-quarters directly by ASA and the rest by state governments. At the same time, close to 120 000 water storage devices for food production were built capable of storing from 50 up to 600 000 litres, of which three-quarters built by ASA and the rest by state and municipal governments. Each beneficiary family has an average of four people and should participate in the own making of tanks and other organizational processes. In the same period, the Federal Government funded the installation of more than 320 000 polyethylene cisterns through the state and local governments. Thus, the social situation of Brazilian Semi-Arid is passing through radical changes, with a democratization of the access to the water.

31 Adaptive management is a methodological approach that views policies as if they were experiments to be studied, such that the results from one generation of study inform subsequent decisions, together with adaptation to change in circumstances change and learning of people (Holling, 1978). The process is iterative, with each stage offering potential to involve different groups and the opportunity for them to learn from each other (Walters, 1986). Consequently, this approach borrows much from Bandura's seminal work on social learning (Bandura, 1963).

3.3.4 Strengthen local organizations and their roles

The value of local governance for shared resources is being increasingly recognized. Ostrom (1990) has described eight design principles ensuring their good functioning and stability (see also HLPE, 2014b). But these models are now facing considerable challenges including the need to accommodate for more diverse stakeholders with diverse interests, often in a context of increased pressure.

Local organizations of farmers and water users are crucial for the management of water resources and related ecosystems. Examples include local watershed management organizations, fishing associations, farmer field schools (FFS), and water user groups. Local organizations are particularly well placed to monitor and respond adaptively to environmental change. This is important because variation within and among the environments in which water resources are located is enormous. Uncertainty, spatial variability and complex non-equilibrium and non-linear ecological dynamics require flexible responses, mobility and local-level adaptive water resource management in which farmers, pastoralists, fisherfolk and forest dwellers are central actors in analysis, planning, negotiations and action (Gunderson *et al.*, 1995).

Such management can be mediated by local groups that coordinate planning and action, often through networks of local organizations (Borrini-Feyerband *et al.*, 2011). Local organizations can facilitate the emergence of institutions that are key for the management of water resources and the ecosystems that sustain them – from agreements on rights of access and use of water resources to sanctions for transgressing locally-decided "rules of the game". These usually include a network of often overlapping institutions, social learning, collective action, negotiated agreements on the roles, rights and responsibilities of different actors, leadership, cultural practices, labour allocation, religious beliefs, and so forth (Borrini-Feyerabend *et al.*, 2011). These help enforce locally (or nationally) negotiated agreements, rules, incentives and disincentives for the sustainable management of landscapes and water resources – from farm plots and the agro-ecosystem around to whole watersheds and landscapes – and the ecosystems they depend on, e.g. forests, wetlands, river plains, mountain ranges (see Pimbert, 2009).

However, even at the local level, differential power relationships inform who controls or influences water allocation and management decisions and, in many cases, women continue to be disadvantaged.

Box 30 Succesful water management across scales

Ethiopia

Cooperation between state and local governance can work to improve irrigation. In Ethiopia, water management policy has focused on upgrading water infrastructure to improve agricultural productivity and, in doing so, has changed traditional management and redefined water rights (CGAAER, 2012). However, in one area, a project additionally undertook local organizational restructuring that took into account local expertise and led to the formation of officially recognized users' associations that combined traditional and new principles, gaining both community support and improved irrigation. Such cooperation demonstrates the potential of projects that recognize real management powers at local levels and how to utilize these powers in national strategies.

Morocco

The Souss Massa Draa region in Morocco is highly dependent on irrigation for agriculture, which is the region's main economic activity (CGAAER, 2012). Pressure on water resources, however, led to restrictive legislation limiting use that did not improve the situation. The formation of the Regional Council of Souss Massa Draa has worked to improve water governance and efficiency by encouraging water users to voluntarily commit to a regional strategy for conservation and control of irrigation. Work has also been done to amend legislation on farmer fees for irrigation. An association that coordinates actions among government departments, private companies and professional organizations has facilitated implementation of this regional strategy. The association additionally undertakes multidisciplinary research to identify farmer priorities, made possible by a common regional fund. Success in this case was achieved by bringing together multiple regional initiatives that addressed local, on the ground realities. It demonstrates the importance of recognizing issues at the right scale in order to mobilize support and action.

3.4 A rights-based approach to water for FSN

The human right to safe and clean drinking water and sanitation was recognized in 2010 by the United Nations General Assembly. It entitles everyone, without discrimination, to access to sufficient, safe, acceptable, physically accessible and affordable drinking water and to physical and affordable access to sanitation for personal and domestic use. It was incorporated in several constitutions and national legal orders.

The right to adequate food has been recognized in the International Covenant on Economic, Social and Cultural Rights (ICESCR), a multilateral treaty adopted by the United Nations General Assembly in 1966. The 2004 Voluntary Guidelines to support the progressive realization of the right to adequate food in the context of national food security (VGRtF) contain dispositions about access to and sustainable use of water.[32]

The human right to safe drinking water and sanitation and the human right to food have close ties because safe drinking water and sanitation are crucial for health and good nutrition, and because access to water is indispensable for food producers, and for the realization of the right to food of producers. There are ongoing reflexions, warranting further exploration and research, on the consequences of these two rights for water governance, and how they can promote a human rights-based approach to water governance for FSN. These reflexions also lead to considerations about the extra-territorial obligations of States to regulate the activities of third parties under their jurisdiction to ensure that they do not violate the human rights of people living in other countries.

3.4.1 A human rights-based approach to water governance for food security

A human rights approach to water for food security explores the linkages between the rights to food and water. It integrates human rights norms, standards and principles into plans related to water and food security at all levels. These include accountability, transparency, empowerment, participation, non-discrimination (equality and equity) and attention to vulnerable groups (OHCHR, 2004).

A human rights approach places emphasis on "substantive" rather than formal equality: that is, all people, regardless of race, class, gender or other differences, should be allowed to enjoy their fundamental human rights, and this may require affirmative actions to favour the most vulnerable. Human rights provide a normative framework that States should follow to achieve effective access to and fairer use of a range of resources and in taking steps to empower people, especially the most vulnerable and disadvantaged. Indisputable causal links exist between the violation of human rights, and the economic, social, cultural and political deprivations that characterize poverty. The realization of all human rights and efforts to eliminate extreme poverty are therefore mutually reinforcing, and human rights norms and principles can guide efforts to reduce poverty (Sepúlveda and Nyst, 2012). Amartya Sen's capabilities approach focuses on "substantive freedoms" – the freedom to choose a life one has reason to value. Human rights for Sen are entitlements to rights to certain specific freedoms, i.e. capabilities (2004) and these include both functioning (i.e. having access) as well as having the opportunity to have a good supply of water. This approach would also take a broad view of water (i.e. not just focused on water for survival and domestic purposes) and would link to local agency, and the right to determine and set one's own priorities and strategies regarding water (see Mehta, 2014; Anand, 2007).

All human rights impose three types of obligations on States: namely to respect, protect and fulfil human rights. With reference to water and sanitation specifically, this means that States must: (i) refrain from interfering with or curtailing the existing enjoyment of these rights – for example, cutting off a person's water supply if the person is unable to pay constitutes a violation of the duty to respect the right to water; (ii) prevent third parties including corporations from interfering with people's enjoyment of these rights – for example, States must ensure that water sources are protected from pollution by industries; and (iii) take action to enable people to enjoy these rights. This does not mean that States have to provide the services directly, unless individuals or groups are for reasons beyond their control

[32] The VGRtF underline that the realization of the right to food necessitates State action to "*improve access to, and promote sustainable use of, water resources and their allocation among users giving due regard to efficiency and the satisfaction of basic human needs in an equitable manner and that balances the requirement of preserving or restoring the functioning of ecosystems with domestic, industrial and agricultural needs, including safeguarding drinking-water quality".*

unable to provide for themselves (see also de Albuquerque, 2012). As with other economic and social rights, the right to water is to be "progressively realized". To this end, States should devote the maximum available resources and move towards it as expeditiously and effectively as possible.

The right to food

The right to food was referred to in 1948 in the Universal Declaration of Human Rights (UDHR) and later again in 1966 in the International Covenant on Economic, Social and Cultural Rights (ICESCR). The human right to food is defined by the Special Rapporteur as the right of every individual *"alone or in community with others, to have physical and economic access at all times to sufficient, adequate and culturally acceptable food, that is produced and consumed sustainably, preserving access to food for future generations"* (UNGA, 2014). The Voluntary Guidelines on the right to food, a key implementation guide, call on States to develop strategies to realize the right to food, especially for vulnerable groups in their societies (FAO, 2005).

These guidelines also urge States to *"take account of shortcomings of market mechanisms in protecting the environment and public goods"* (Guideline 4.10), particularly for women (Guideline 8.3) and vulnerable groups such as indigenous peoples. Indigenous peoples have claimed that the realization of the right to food is interdependent on recognizing not only individual rights but also upholding the collective exercise of these rights – that is, the right not to be subjected to forced assimilation or destruction of their culture, the rights to their lands, territories and resources, their right to non-discrimination (UNGA, 2007) and most importantly their right to *free, prior and informed consent* (OHCHR, 2013). Thus in the case of communities with distinct cultural traditions – where most of the community members are small-scale producers, pastoralists, fishers and so on – the call for food as a human right is intrinsically connected to the call for eliminating harmful policies and practices that prevent them from exercising their right to self-determination (FAO, 2009b).

The right to water and sanitation

Unlike the right to food, the right to water was not explicitly recognized in the 1948 Universal Declaration of Human Rights, and, until relatively recently, acknowledging a human right to water has faced resistance from some States as well as from some private companies (Sultana and Loftus, 2011; Mehta, 2014). The process of recognition of the right to water thus evolved much later than the right to food. While the International Covenant on Economic, Social and Cultural Rights does not explicitly refer to the right to water, on 27 November 2002, the Committee on Economic, Social and Cultural Rights, its supervisory body, adopted the General Comment No. 15 on the Right to Water,[33] defined as the right of everyone *"to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses"*. According to the Committee, the right to water is part of the right to an adequate standard of living, as are the rights to adequate food, housing and clothing. The Committee also stressed that the right to water is inextricably linked to the rights to health, adequate housing and food.

In July 2010 the UN General Assembly recognized the human right to safe drinking water and sanitation (HRSDWS) (UNGA Resolution 64/292) as essential to the realization of all human rights. In September 2011, the UN Human Rights Council affirmed this right as derived from the right to an adequate standard of living, contained in several international human rights treaties and both justiciable and enforceable (UN, 2010b). Resolution 24/18 of 27 September 2013 states that HRSDWS "*entitles everyone, without discrimination, to have access to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use and to have physical and affordable access to sanitation, in all spheres of life, that is safe, hygienic, secure, socially and culturally acceptable and that provides privacy and ensures dignity"* (UNCESCR, 2002, E/C12/2002/11 para. 1). At minimum, an individual should have access to enough water to meet basic needs in terms of drinking, bathing, cleaning, cooking and sanitation, and the cost of water for basic human needs should be affordable even for the poorest households (see also WHO, 2002).

The rights to water and sanitation now enjoy global recognition. These rights entitle *"everyone, without discrimination, to have access to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use and to have physical and affordable access to sanitation, in all*

[33] General Comment 15, The right to water (arts. 11 and 12 of the International Covenant on Economic, Social and Cultural Rights – ICESCR), UN Doc. E/C12/2002/11 (Twenty-ninth Session, 2002). General comments are interpretations of the contents of rights included in the ICESCR by the supervisory body of the Covenant. The Committee stressed the State's legal responsibility in fulfilling the right and defined water as a social and cultural good and not solely an economic commodity.

spheres of life, that is safe, hygienic, secure, socially and culturally acceptable and that provides privacy and ensures dignity" (Human Rights Council Resolution A/HRC/27/72 of September 2014).

Several standards have been developed to assess whether or not States are complying with the rights to water and sanitation: availability, accessibility, acceptability, affordability and quality of water and sanitation services.

Availability. Water and sanitation services must be physically available for everyone in the household or in the immediate vicinity. While the recognition of the right acknowledges that the water supply for each person must be sufficient and continuous to sustain life and health and to meet basic needs, it does not entitle individuals to an unlimited amount of water.

Defining what it means in terms of volumes of water and accessibility remains a challenge (Sultana and Loftus, 2011), with estimation of basic water requirements varying greatly between countries and institutions. WHO prescribes from 20 to 100 litres a day (WHO, 2003) but recognizes that below 50 litres has a "low" level of impact and that 100 is the minimum required for basic food preparation and personal hygiene. This amount does not include water for growing food for home consumption (Mehta, 2014; McDonald and Ruiters, 2005; see also discussion on MUS in Section 3.1.1.

Acceptability. Water and sanitation services must take into account the cultural needs and preferences of users. This means, for example, that water must be of an acceptable colour, odour and taste and sanitation facilities must ensure privacy and dignity of the users.

Affordability. This means that costs of water and sanitation services must not limit the capacity to pay for other essential goods and services such as education or health.

Quality. Water must be safe for human consumption and sanitation facilities must be hygienically and technically safe to use and should not pose threats to health.

Box 31 The right to water in South Africa

South Africa, the first country to recognize the right to water in its 1996 Constitution, also recognizes the right to water for ecosystems (Ziganshina, 2008) through the ecological reserve. Its Free Basic Water Policy provides 6 kilolitres per household per month (25 litres per capita per day based on a household size of eight people) free (McDonald and Ruiters, 2005). However, implementing this right has been fraught with difficulties, with strong debates regarding whether it has had significant impact on the well-being of poor South African citizens (see also Flynn and Chirwa, 2005).

Access to water has been hampered in some areas by lack of infrastructure and poor operation and maintenance. In hearings conducted by the national Human Rights Commission in 2014, people complained of the poor condition of waste and water treatment plants in all nine provinces and many municipalities testified that water treatment plants were collapsing, mainly due to the heavy loads of treatment required (see South African Human Rights Commission, 2014).

In addition, there have been heated debates about whether the right to water is compatible with pre-paid meters, cut-offs and disconnections, which have been presented by many as impacting on citizens' basic right to water while creating new forms of poverty and ill-being (Flynn and Chirwa, 2005; Loftus, 2005; Mcdonald and Ruiters, 2005), and whether 6 kilolitres per household is sufficient, especially if the household number is large. In the Mazibuko case, Mrs Mazibuko and other residents of Phiri in Johannesburg challenged the installation of pre-paid meters in their homes, arguing that they were unlawful and unconstitutional and asked instead for 50 litres per person per day. The South Gauteng High Court stated in 2008 that households often constitute up to 16 members, ordered the removal of the pre-paid meters and confirmed the provision of 50 litres per person per day. On appeal, the Supreme Court of Appeal Judgement stated that 42 litres per capita per day was sufficient and granted the municipality extra time to legalize the installation of pre-paid meters. In 2009, the Constitutional Court reversed the previous decisions, rejected the claims of the applicants and stated that the City of Johannesburg was not infringing on the constitutional human right to water and that the installation of pre-paid meters was lawful. These three judgements highlight the difficulties in realizing and interpreting the right to water.

Improving access to water and sanitation services requires States to take a broad set of measures, from the adoption of legislation on these rights to the implementation of policies and intervention ensuring access by the most vulnerable and marginalized groups of the population. Having a constitutional endorsement of the right also helps give it teeth (OHCHR, 2014). Realizing these rights also requires compliance with the principles of participation, non-discrimination and equality, accountability, access to information and transparency. Examples of South Africa and Bolivia show some of the practical implementation challenges, despite constitutional recognition (see Boxes 31 and 32).

It has been noted that privatisation mechanisms can sometimes impinge on basic rights to water and food (see Sultana and Loftus, 2011). Importantly, whatever the way services are provided, directly by the State, by local authorities or by private companies, the State remains the primary duty-bearer for the realization of human rights

The provision of water and sanitation as basic human rights is critical to FSN in relation to the ability to prepare food, and to avoid the disease burdens in unserved households, which often reduce the ability to retain and absorb nutrition. Thus, the provision of safe drinking water and adequate sanitation as a right is a *sine qua non* for FSN. Beyond the issue of the right to safe drinking water and sanitation, however, is the question of what the implications are of the right to food in relation to access to water. As discussed below, the right to water as a part of the right to food is not obvious (see also WHO, 2002).

Box 32 Linking water and food security in Bolivia

The constitution of Bolivia adopted in 2009 makes provisions for the human rights to food and water and notes the State's obligation to guarantee food security (Plurinational State of Bolivia, Constitution 2009, Article 16). Bolivia also explicitly recognizes the rights of nature (e.g. Pachamama and Buen Vivir, see Walnycki, 2013).

The Zero Malnutrition Program, launched by President Evo Morales in 2007, aimed to achieve the rights to water and food, and recognized several links between water and food security. Potable water, sanitation, irrigation and small-scale agriculture are all given attention in the multisector programme, although these areas received less funding than many local actors believed necessary, with funding instead focused on infrastructure (Hoey and Pelletier, 2011). Bolivia's attention to providing water for domestic and agricultural purposes in its food security and nutrition initiative is especially pertinent given the context of rural poverty and previous failed attempts at water privatization, which have been argued to have increased levels of poverty in the country (Ferranti, 2004). Although Bolivia's poverty has been declining, 45 percent of the population remained under the national poverty line in 2011 (World Bank, 2015), and inequality is widespread (Walnycki, 2013).

Despite recognition of these rights, implementation remains a challenge, in part because of the constitution's ambiguity (Harris and Roa-García, 2013). National prioritization of industrialization, agriculture and extractives has led to competition over water, including tension over water availability for food production (Walnycki, 2013). In some areas, the granting of water rights to mining projects has led to depletion and contamination of groundwater sources used by quinoa growers and indigenous peoples.

While the right to water is constitutionally recognized, in practice community providers fill the gap in water provision in peri-urban areas (Walnycki, 2013) but they experience problems in both water availability and quality (Mehta *et al.*, 2014b). Aquifers for these peri-urban areas are shared with other communities, industry and farmers and safeguarding the source in terms of quality and quantity is challenging (Walnycki, 2013). Tensions remain around competition between water for agriculture and urban water use (Fabricant and Hicks, 2013), and the current legislative system has yet to adequately address such competition (Walnycki, 2013).

3.4.2 Potential relationships between the right to food and the right to drinking water and sanitation and related challenges

The Committee on Economic, Social and Cultural Rights' (CESCR) General Comment No.15 (GC 15) on the right to water highlights how the right to water is inextricably linked to the right to adequate food, and stresses that priority should be given to providing water to prevent starvation and disease (UN, 2003b – E/CN.4/2003/54). Similarly, General Comment No.12 (GC 12) on the right to adequate food notes the importance of ensuring sustainable access to water resources for agriculture to realize this right.

While the recognition of the rights to drinking water and sanitation have been largely focused on domestic water supplies, GC 15 also identifies aspects of the right to water that remain under-explored and underdeveloped but are pertinent to the issue of water for FSN. In particular, GC 15 recognizes that *"water is required for a range of different purposes, besides personal and domestic uses, to realize many of the Covenant rights. For instance, water is necessary to produce food (right to adequate food) and ensure environmental hygiene (right to health). Water is essential for securing livelihoods (right to gain a living by work) and enjoying certain cultural practices (right to take part in cultural life)"* (GC 15, paragraph 6).

GC 15 goes further to recognize the need to develop criteria to give priority in the allocation of water resources to the right to water for personal and domestic uses, and to the right to water in connection with the right to food and health to prevent starvation and disease as well as to meet other core obligations (GC 15, paragraph 6). It also recognizes the importance of ensuring sustainable access to water resources for agriculture to realize the right to adequate food, giving particular attention *"to ensuring that disadvantaged and marginalized farmers, including women farmers, have equitable access to water and water management systems, including sustainable rain harvesting and irrigation technology"* (GC 15, paragraph 6). In addition, GC 15 stresses that a people may not *"be deprived of its means of subsistence"*, and that States parties should ensure that there is *"adequate access to water for subsistence farming and for securing the livelihoods of indigenous peoples"* (GC 15, paragraph 7). This is to be seen in the context of the UN declaration on the rights on indigenous people.

GC 15 also makes reference to the "Statement of Understanding accompanying the United Nations Convention on the Law of Non-Navigational Uses of Watercourses" (A/51/869 of 11 April 1997), which declared that, in determining vital human needs in the event of conflicts over the use of watercourses, *"special attention is to be paid to providing sufficient water to sustain human life, including both drinking water and water required for production of food in order to prevent starvation"*. Additionally, GC 15 notes the importance of protecting natural water resources from contamination by harmful substances and pathogenic microbes, and the need to take steps on a non-discriminatory basis to prevent threats to health from unsafe and toxic water conditions (GC 15, paragraph 8).

Strengthening the interpretation and understanding of these aspects of the rights to water and sanitation, and of their interlinkages especially with the right to food and the right to health, is key to ensuring water for FSN.

For its part, the right to adequate food implies that the accessibility of food must be *"in ways that are sustainable and do not interfere with the enjoyment of other human rights"* (UNCESCR, 1999, E/C.12/1999/5 para. 15). This means that activities and processes undertaken towards the realization of the right to food must respect environmental limits pertaining to water, such as minimum flow requirements and the carrying capacity of resources, and must not be at the cost of other human rights such as the right to water. Conversely, *"human rights standards stipulate that the direct and indirect costs of securing water and sanitation should not reduce any person's capacity to acquire other essential goods and services, including food, housing, health services and education"* (COHRE/AAAS/SDC/UN-HABITAT, 2007).

Reading all these rights together suggest that States parties should ensure that there is adequate access to water for subsistence farming and for securing livelihood needs of indigenous peoples, and that water should not be diverted for other needs at the cost of these communities. The special recognition given in GC 12 to the term sustainability when it comes to access and availability of food implies that food should be accessible for both present and future generations (CESCR, GC 12, paragraph 7).

Windfuhr (2013) notes that decision-making should prioritize the realization of rights by vulnerable groups. While domestic needs (i.e. water for drinking, bathing and hygiene) are usually given highest priority, it is also important to prioritize water for domestic food production where this is the most appropriate mechanism for ensuring the right to food.

There have been growing calls to further elaborate a human rights perspective to land and water access to better encompass the use of water for production of food at the household level to meet the right to food (Franco *et al.*, 2013).

There are also important considerations on how to better realize rights. For instance, whether they are best achieved through an individual or collective rights approach. There are in particular discussions on the benefits of an integrated approach. Brooks (2007), for example, questions the interlinking of water, food and health, and instead advocates for separation – water for household use (drinking water), water for food, and water for ecosystems – on the grounds that this could allow for clearer goals and monitoring. The former Special Rapporteur on the right to water and sanitation, Catharina de Albuquerque, stressed the need to separate sanitation as even if it can be linked to drinking water management it demands different State action and governance systems (Human Rights Council, 2009, see A/HRC/12/24, see also Ellis and Feris, 2014, who call for de-linking the right to sanitation from the right to water).

The Voluntary Guidelines on the right to food are a key implementation guide for the right to adequate food (VG 14 UN – Doc E/C.12/1999/5) and call on States to develop strategies to realize the right to food, especially for vulnerable groups in their societies. No such guidelines exist yet for the right to water. A further addition would be practical guidelines that outline the implications of the right to food in relation to the right to water, and vice versa.

3.4.3 Extra-territoriality of obligations

Extra-territorial obligations are *the extra-territorial obligations of States to regulate the activities of third parties under their jurisdiction to ensure that they do not violate the human rights of people living in other countries.* They can play an important role to address critical issues impacting the rights to water and sanitation such as those occurring due to the lack or limited regulation and accountability of transnational corporations (TNCs), international financial institutions (IFIs) and from the ineffective application of human rights law to investment and trade laws, policies and disputes (ETO-Consortium, 2013).

A major step forward was taken in 2011 with the adoption of the *Maastricht principles on extraterritorial obligations of states in the area of economic, social and cultural rights*, which were elaborated and adopted by a group of experts in international law and human rights (Maastricht Principles (ETOs), 2011). Several of these principles are especially relevant in the context of the right to food and the right to water, namely: *"States have the obligation to protect individuals ESCRs by regulating non-state actors (Principles 23-27). States are obliged to regulate and/or influence the business sector in order to protect those affected by them outside their territory."*

Increasingly, UN human rights monitoring bodies have addressed extra-territorial obligations regarding the right to food and the right to water. The former UN Special Rapporteur on Right to Food, Jean Ziegler (UNHRC, 2008), elaborated on the extraterritorial obligation of states: *"The extraterritorial obligation to protect the right to food requires States to ensure that third parties subject to their jurisdiction (such as their own citizens or transnational corporations), do not violate the right to food of people living in other countries […] With the increasing monopoly control by transnational corporations over all elements of the food chain, […] it is becoming more difficult for less powerful national Governments to regulate transnational corporations working within their territory to respect human rights, making it essential that the often more powerful «home» States engage in adequate regulation"* (E/CN.4/2005/4, 24 January 2005). Similarly, the former UN Special Rapporteur on the right to drinking water and sanitation has written: *"Extraterritorial obligations require States parties to the relevant agreements to respect the human rights of people in other countries. […] With regard to the obligation to protect, States must prevent third parties, for example, a company based in one State and functioning in another, from violating the human rights to water and sanitation in other countries"* (de Albuquerque, 2014). In the context of human rights violations associated with IFI investments, States parties to the International Covenant on Economic, Social and Cultural Rights have asserted in their submissions to the CESCR that *"the right to life not only emanates from specific international human rights treaties but that it now constitutes a general principle of international law. On account of* *this, the rights bind the entire international community and not just States Parties to human rights treaties."* (Gibney and Vandenhole, 013).

3.5 Ways forward for integrated and inclusive water governance for FSN

This chapter has shown that water governance involves multiple institutions and actors, and can mobilize a variety of tools, for diverse objectives: management of a resource, of a service, at different spatial scales and with diverse orientations, for diverse sectors, food and non-food.

Water management and governance is local by nature, but it is highly influenced by national policies and international discourses and actors.

Setting priorities at the highest levels may not adequately or accurately reflect local realities on the ground. Also, lack of integration can be a major impediment to get the priorities right, especially ensuring equitable and sustainable water availability and access for FSN, and for vulnerable and disadvantaged groups.

The challenge of improving water governance for better FSN will need to consider the relevant parts of macro-economic policies, agricultural and food security policies, water supply and sanitation policies, trade policies, rural development and environmental policies in order to better integrate FSN concerns in relevant policies as well as in institutional changes and infrastructure investments. Water policies should explicitly address the issue of water for FSN, with the necessary regulatory mechanisms to give effect to this, recognizing the rights to food, water and sanitation and the relationship between these rights. This will require recognizing the water for FSN needs of vulnerable and disadvantaged communities, to integrate customary rights into the formal system and to recognize the water use rights of women. It will also require careful examination of the interdependencies between access to water and access to land.

Integration and confrontation of concerns is important, but it needs to be at the service of improved and more coherent priorization and focus, within the capacity constraints present in countries: support is needed to develop improved and implementable regulatory mechanisms and institutions adapted to the various institutional settings and situations of developing countries' contexts, and able to respond to the priorities of actors. In line with this, the tools adopted for water management should be examined for their impact on FSN, particularly the FSN of poor and marginalized communities. Policy frameworks should recognize the irreplaceable role of communities for productive and equitable management of water, and give them the relevant rights and responsibilities for such purposes. Water user associations are an important part of the institutional arrangements for better water governance, and training and support should be provided to these institutions to ensure that they operate in an equitable and participatory manner.

CONCLUSION

Water and food are the two most fundamental basic needs of humans. Water is key to human food security and nutrition.

The importance of water for life, for economic development and of water for food security makes the issue one of the most debated, with a range of challenges, stakes, and, very often, conflicts. It is also one of the most complex with very diverse national and local situations.

It is a very timely debate. In 2015, the international community is to agree on its Sustainable Development Agenda for the years to come. At the time of publication of this report, Water and Food Security are two of the most prominent issues. They are also two of the most transversal ones, conditioning and conditioned by the success of many of the other objectives. There is a need to know what should be done, what each actor should do, on the ground, to meet the ambitions.

This report aimed at showing clarity on often obscures and confusing debates. The area to cover when one deals with Water is wide. It is even wider when one links it to food security and nutrition.

This report has framed the issue of water in the perspective of food security and nutrition. Water is multidimensional, with water resource dimensions encompassing water availability, access, competition between uses and stability of the whole. Food security and nutrition is also multidimensional. This report aimed at showing the different pathways and contributions of water to better food security and improved nutrition, the related challenges across the various dimensions, and what could be done, at various levels, to enhance the contribution of water for FSN.

To do so, this report uses the concept of "water for FSN", which designates water's direct and indirect contributions to food security and nutrition in its four dimensions. It covers safe drinking water and sanitation, water used to produce, transform, and prepare food, as well as the contribution of water uses in all sectors to livelihoods and income and as such to food accessibility. It covers also the objective of sustainable management and conservation of water resources and of the ecosystems that sustain them, and that are necessary to ensure FSN for present and future generations.

Our analysis started from two major premises:

First, safe drinking water and sanitation are fundamental to the good nutrition, health and dignity of all. The current global situation of 2.5 billion people still lacking improved sanitation facilities, and 768 million still relying on unsafe drinking water sources is fundamentally undermining nutrition and health, and social and economic development.

Second, water of sufficient quantity and quality is essential for agricultural production and for the preparation and processing of food. Irrigated agriculture accounts for 70 percent of all water withdrawals globally (surface and groundwater). Reliable irrigation is fundamental to increase and stabilize income and providing livelihood resilience for a vast number of smallholder farmers. 40 percent of irrigation uses groundwater sources, some of them non-renewable at human time scale.

Starting from these premises, the report underlines some broad findings which are key to ongoing situations and evolutions regarding water for FSN.

Climate change will modify water availability and crops needs in both rain fed and irrigated systems. Water management in agriculture will be key to adaptation to climate change. Competition between uses is increasing and likely to increase in the future, with other sectors such as energy, industry, manufacturing and cities putting more and more pressure to the overall water system. Very often, agriculture is used as the adjustment variable to fit overall water withdrawals with global availability constraints and with the need to preserve the terrestrial water system and its role in the overall ecosystem. The share of water devoted to irrigation is likely to decrease in front of other uses.

Increased competition and new actors have considerably modified power relations, both between and inside institutions and sectors. Institutions themselves have not always been able to adapt themselves. Often the most in need of access to water, the poor, the vulnerable and marginalized, have been further marginalized by rapid changes and the consequences of broad investments.

How to ensure FSN of all given increasingly scarce water resources, especially in some regions, and the increasing competition for water uses? Given these challenges, the report depicts the pathways between water and food security and nutrition and it proposes ways for all concerned actors to improve water management for agriculture; to improve management of agricultural and food systems for water, and to improve water governance for FSN.

We propose eight main domains for action and related policies and interventions:

1. The sustainable management and conservation of ecosystems, from local to continental levels as key to ensure quantity of quality of water for food security and nutrition in the future.
2. Designing integrated policy approaches to enable proper prioritization for FSN.
3. Putting the most vulnerable and marginalized on top of concerns for policy and action.
4. Improving water management in agriculture, both rainfed and irrigated, and agricultural management to deal with water scarcity to improve agricultural systems' efficiency and resilience.
5. Improve the contribution of trade to water for FSN
6. Knowledge and technologies
7. Inclusive and effective governance, and
8. Promoting a rights-based approach to water for FSN.

They are to be considered taking into account national and local specific contexts.

Water scarce regions are the first concerned, and food security and nutrition should be one priority of their water-related policies.

Water rich regions are also concerned. Global availability of food will not be ensured if they fail to give agriculture appropriate consideration for water use. Here, trade has a key role to play for food security and nutrition, by enabling the compensation of water scarcities.

Increasing scarcities and growing and competing demands on water call for reinventing water governance for food security and nutrition. Much has been written about this. Here we propose an approach founded on the three principles of integration, prioritization, and inclusiveness at all levels. Water governance is at the nexus of competing policies, interests and actors, from numerous sectors.

We propose that governance of water be oriented by clear and shared priorities, established through inclusive and transparent governance mechanisms, with the right to drinking water and sanitation and the right to food as driving principles.

Securing access to water is particularly challenging for vulnerable populations and women. Improving equal access to water and sanitation is a prerequisite for the social development of a significant part of the world population. Local communities are key players to sustainably enhance food security and nutrition, through sustainable, integrated land and water management at landscape level.

Safeguarding water for the dignity, health, food and nutrition security of everyone on the planet is one of humanity's biggest challenges. The analysis and the recommendations of this report are a contribution to this ambitious roadmap.

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APPENDIX

The HLPE project cycle

The High Level Panel of Experts for Food Security and Nutrition (HLPE) was created in October 2009 the science-policy interface of the UN Committee on World Food Security (CFS).

The Committee on World Food Security (CFS) is the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition, for a broad range of committed stakeholders to work together in a coordinated manner and in support of country-led processes towards the elimination of hunger and ensuring food security and nutrition for all human beings.[34]

The HLPE receives from CFS its working mandate. This ensures the legitimacy and relevance of the studies undertaken, and their insertion in a concrete political agenda at international level. The report elaboration process ensures the scientific inclusiveness and the independence of the HLPE.

The HLPE produces scientific, policy oriented reports, including analysis and recommendations, serving as a comprehensive and evidence-based starting point for policy debates at CFS. The HLPE aims at providing a better understanding of the diversity of issues and rationales when dealing with food and nutrition insecurity. It thrives to clarify contradictory information and knowledge, elicit the backgrounds and rationales of controversies, and identify emerging issues.

The HLPE is not mandated to conduct new research. The HLPE draws its studies based on existing research and knowledge produced by various expertise-providing institutions (universities, research institutes, international organizations etc.), and adding value by global, multi-sectoral and multidisciplinary analysis.

HLPE studies combine scientific knowledge with experiences from the ground, in a same rigorous process. The HLPE translates the richness and variety of forms of expert knowledge from many actors (knowledge of local implementation, knowledge based on global research and knowledge of "best practice") that draw on both local and global sources, into policy-related forms of knowledge.

To ensure the scientific legitimacy and credibility of the process, as well as its transparency and openness to all forms of knowledge, the HLPE operates with very specific rules, agreed by the CFS.

The HLPE has a two-tier structure:

1. A Steering Committee composed of 15 internationally recognized experts in a variety of food security and nutrition related fields, appointed by the Bureau of CFS. HLPE Steering Committee members participate in their individual capacities, and not as representatives of their respective governments, institutions or organizations.
2. Project Teams acting on a project specific basis, selected and managed by the Steering Committee to analyse/report on specific issues.

The project cycle to elaborate the reports (Figure 13) includes clearly defined stages, starting from the political question and request formulated by the CFS. The HLPE institutes a scientific dialogue, building upon the diversity of disciplines, backgrounds, knowledge systems, the diversity of its Steering Committee and Project Teams, and open e-consultations. The topic bound and time bound Project Teams work under the Steering Committee's scientific and methodological guidance and oversight.

The HLPE runs two open consultations per report: first, on the scope of the study; second, on a V0 "work-in-progress" draft. This opens the process towards all experts interested as well as to all concerned stakeholders, which are also knowledge-holders. Consultations enable the HLPE to better understand the issues and concerns, and to enrich the knowledge base, including social knowledge, thriving for the integration of diverse scientific perspectives and points of view.

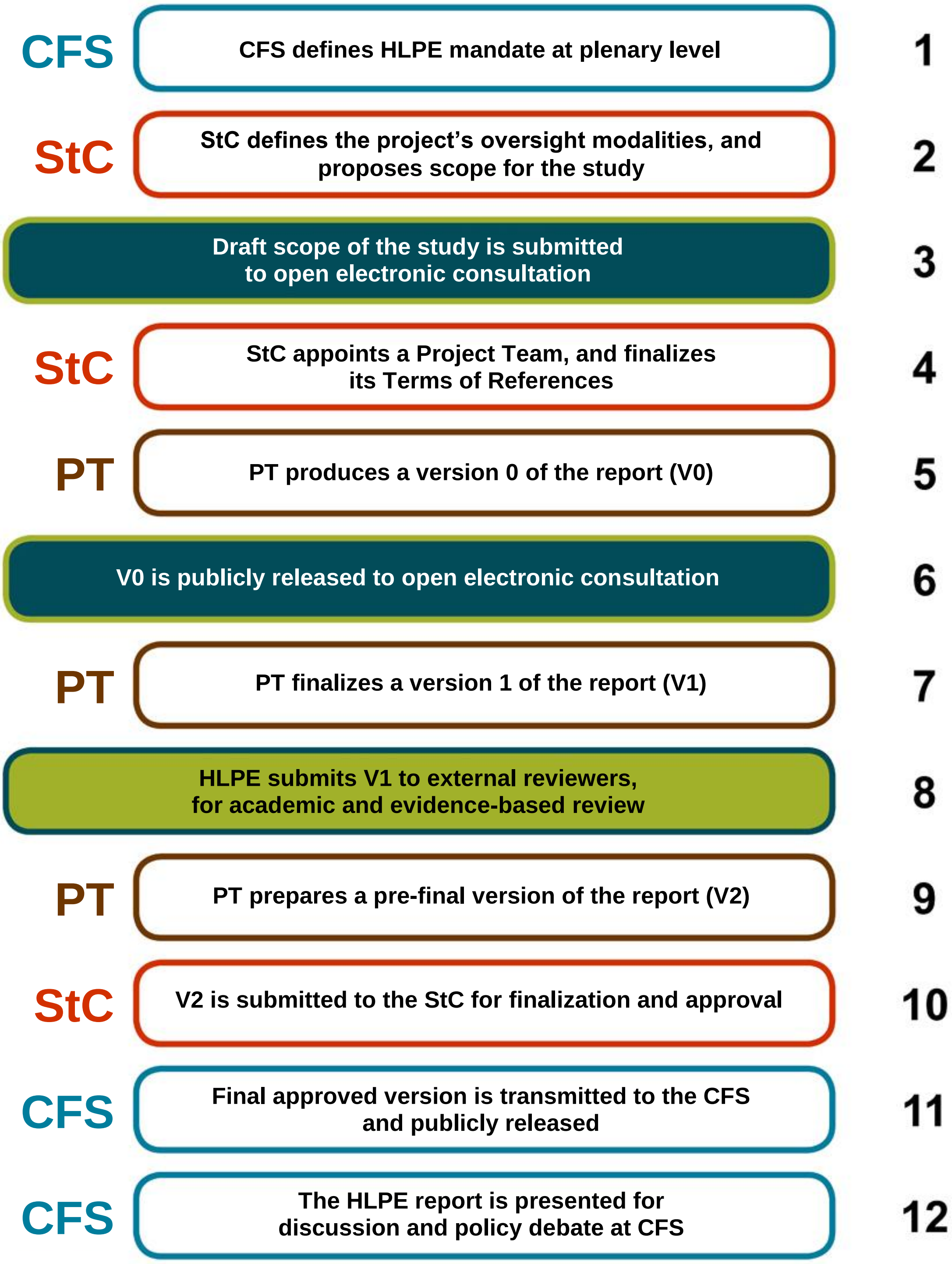
It includes an external scientific peer-review on a pre-final draft. The report is finalized and approved by the Steering Committee during a face-to-face meeting.

HLPE reports are published in the 6 official languages of the UN (Arabic, Chinese, English, French, Russian and Spanish), and serve to inform discussions and debates in CFS.

All information regarding the HLPE, its process and all former reports is available at the HLPE Website: www.fao.org/cfs/cfs-hlpe.

[34] CFS Reform Document, available at www.fao.org/cfs

Figure 13 HLPE project cycle



CFS Committee on World Food Security
HLPE High Level Panel of Experts on Food Security and Nutrition
StC HLPE Steering Committee
PT HLPE Project Team

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Water is life: it is integral to human food security and nutrition, and it is the lifeblood of ecosystems upon which all humans depend. Safe drinking water and sanitation are fundamental to the nutrition, health and dignity of all. Securing access to water can be particularly challenging for vulnerable populations and women. Water of sufficient quantity and quality is essential for agricultural production and for the preparation and processing of food. Irrigated agriculture accounts for 70 percent of all surface and ground water withdrawals globally.

This report explores the relations between water and food security and nutrition, from household levels to global levels. It investigates these multiple linkages, in a context of competing demands, rising scarcities, and climate change. It proposes ways for improved water management in agriculture and food systems, as well as ways for improved governance of water, for better food security and nutrition for all, now and in the future. The report is deliberately oriented towards action. It provides examples and options to be implemented by the many stakeholders and sectors involved, given regional and local specificities.

CFS Committee on World Food Security

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