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Key and Smart Actions to Alleviate Hunger and Poverty through Irrigation and Drainage / Actions clés et intelligentes pour atténuer la faim et la pauvreté par le moyen d'irrigation et de drainage

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Background Paper / Document d'information

Key and Smart Actions to Alleviate Hunger and Poverty through Irrigation and Drainage

Actions clés et intelligentes pour atténuer la faim et la pauvreté par le moyen d'irrigation et de drainage

ABSTRACT

In the pursuit of information to support the policies and actions to alleviate hunger and poverty from a perspective of the role and impacts of irrigation and drainage, this paper attempts to provide correlation between water scarcity, community and poverty. Many reviews have found strong direct and indirect relationships between irrigation and poverty. One of the main goals of the international community is to eliminate hunger and poverty and in this perspective, through the Millennium Development Goals much progress has been achieved and evidence obtained. Sustainable Development Goals and various United Nations and other initiatives, intend to move forward this agenda by making it a part of the broader development frameworks. In this paper, the important elements of the irrigation and drainage that affect the alleviation of hunger and poverty have been discussed. These elements are grouped into governance, rights-based developments, water rights and pricing, management, efficiency improvement, and role of technology. Both the potential and the need to make use of innovative technology and solutions in irrigation are underlined and these can be used to cater the challenges in different sub-sectors. The main focus of these solutions are on maximizing productivity and efficiency, reducing water losses, achieving sustainable intensification and managing demands on water resources and the associated trade-offs.

REUME

Sur la voie de l'information pour soutenir les politiques et les actions visant à lutter contre la faim et la pauvreté du point de vue du rôle et des impacts de l'irrigation et de drainage, ce document vise à établir une corrélation entre la rareté de l'eau, la communauté et la pauvreté. D'après de nombreuses études entreprises, il existe des solides relations directes et indirectes entre l'irrigation et la pauvreté. L'élimination de la faim et de la pauvreté est l'un des principaux objectifs de la communauté internationale et dans cette perspective, le progrès est réalisé et les preuves sont obtenues à travers les Objectifs du Millénaire pour le développement. Les Objectifs de développement durable et les diverses initiatives des Nations Unies et d'autres ont l'intention de faire avancer ce programme en faisant une partie des cadres de développement plus larges. Dans cet article, ont été discutées les éléments importants de l'irrigation et du drainage qui exercent un impact sur la réduction de la faim et de la pauvreté. Ces éléments sont regroupés dans la gouvernance, le développement basé sur les droits, les droits de l'eau et la tarification, la gestion, l'amélioration de l'efficacité, et le rôle de la technologie. Le potentiel ainsi que la nécessité de faire usage de la technologie et des solutions d'irrigation innovantes sont soulignés et ceux-ci peuvent être utilisés pour relever les défis des différents sous-secteurs. L'objectif principal de ces solutions est la maximisation de la productivité et de l'efficacité, la réduction des pertes d'eau, la réalisation de l'intensification durable et la gestion des demandes en ressources en eau et les compromis associés.

1. Introduction

Agriculture is expected to feed an estimated population of more than 9 billion by the year 2050 through 60 % increase over the 2006 food production levels, with 80% of the increase stemming from intensification which is essentially possible under irrigation. At the same time, increasing water scarcity and demand for water resources from other sectors is putting unprecedented pressure on agriculture that uses approximately 70% of the total water withdrawal worldwide to release part of this water.

Internationally, food security has slowly, but markedly, improved during the past years. Approximately 842 million people today are estimated to be experiencing chronic hunger. The 2013 Global Food Security Index (Figure 1) provides a worldwide perspective on which countries are the most and least vulnerable to food insecurity.

Irrigated agriculture has been recognized as one of the important components of the world food security and specifically in reduction of rural poverty. Irrigated agriculture uses some 20% of the total farmland in the world but produces 40% of the food.

Approximately 75 percent of poor people in developing countries live in rural areas. In these areas, agriculture is the main source of income. Access to adequate food in the rural areas of many developing countries depends heavily on access to natural resources, including water, that are necessary to produce food. About 17 percent of global agricultural land is irrigated and contributes about 40 percent of the global production of cereal crops (Bhattarai et al., 2002).

One of the sub-theme of 2nd World Irrigation Forum 'Key and smart actions to alleviate hunger and poverty through irrigation and drainage' focuses on the smart actions and use of innovative technology to provide the catalyst for the broader aspects of agricultural development especially in LDCs to alleviate poverty and hunger. The key is to adopt 'right' actions and technology which enable users to innovate and adapt them in to their circumstances. This background paper is intended to provide the basis for further discussion on these topics under three broad categories:

- Water and climate smart approaches for sustainable smallholder agriculture
- Financing mechanisms for development and management of irrigation and drainage projects
- Adaptation measures for rural water management for water and food security

2. Irrigation and poverty and hunger linkages

Many reviews have found strong direct and indirect relationships between irrigation and poverty (Hussain and Hanjra, 2004). The benefits of irrigation can be attributed to higher production, higher yields, less reliance on weather condition, lower risk, and increase in farming activity year-round. Landless farmers may benefit less in short-term but enhancing productivity, increasing cultivated areas and providing adequate access to water creates more job opportunities for landless farmers, as well. Irrigated agriculture significantly contributes towards generating rural employment and maintaining rural livelihoods (Bhattarai et al., 2002).

The role of irrigation in the alleviation of poverty has been the focus of many international communities and groups in the recent years. It is clear that more investment is going into the modernization of the existing systems to improve the efficiency of water use and increase the crop production. This approach can directly benefit farmers and alleviate poverty. It can also enhance the livelihoods of those who are not the primary beneficiaries (ICID 2014). There is the employment possibilities for the landless poor on larger farm units and in distributive trades, as well as product-processing.

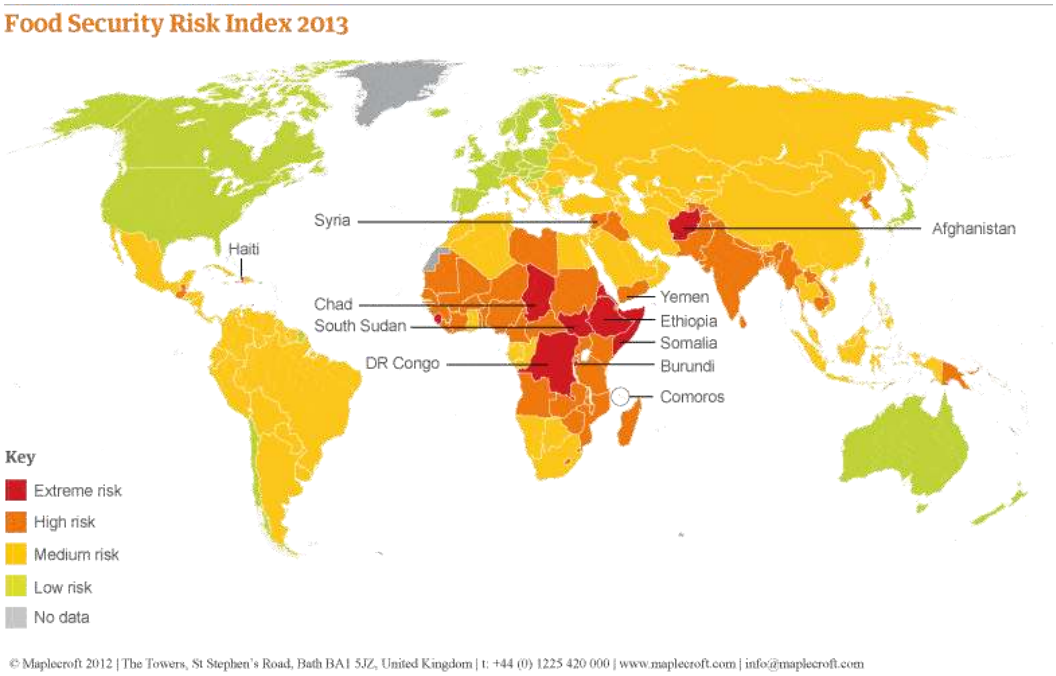

Figure 1: Food security index 2013 (The Economist Intelligence Unit Limited)

Improved irrigation access significantly contributes to rural poverty reduction through employment and livelihoods within a region. Indirect benefits, such as more stable rural employment as well as higher rural wage rates, help landless farm laborers obtain a significant share of the improved agricultural production (Chambers 1988; Barker et al., 2000). Lower food grain prices benefit poor urban and rural landless communities more by enabling them to purchase required food items at affordable prices. Keeping food prices at relatively low levels also greatly assists the industrial sector to avoid the pressure of increasing the real wage rate. In this process, improved agriculture indirectly 'subsidizes' the industrial sector of the economy as well (ICID 2014).

Irrigation enables smallholders to adopt more diversified cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production. Increased production helps make food available and affordable for the poor. Climate change and variability links directly and indirectly to irrigation, though, for example, changes in rainfall patterns, increased scarcity, impacts on land and soil, and increased competition. Irrigation also provides a defense against droughts, which are predicted to occur more frequently. Irrigation played a vital role in green revolution, occurred in twentieth century, that helped saved over a billion people from starvation in many countries, particularly in Asia and South America. However, since then irrigation has been blamed for being highly inefficient and for causing damage to environment and ecosystems. Lack of drainage in many countries is causing water logging and salinity and destroying otherwise fertile lands.

Irrigation development, it has been argued, has displaced marginal and poor farmers and have made them landless laborers driving them to become urban dwellers in certain regions (Chambers 1988). However, the positive social and economic impacts of irrigation far outweigh some of these negative impacts and can be compensated through improved planning, implementation and management of irrigation systems (Bhattarai et al., 2002), and broader safety nets for the urban poor.

As population growth and demand for water use in irrigation rapidly increases, struggle for a secure water supply will become more difficult to administer, especially in arid parts of the world. Large arid areas with absolute water scarcity which affects millions of people, many of whom are poor and underprivileged. It can be stated that there is a strong linkage between irrigation and drainage, and hunger and poverty alleviation, in which the poor benefits from well managed irrigation through higher yield, lower risk of crop failure, adoption of diversified cropping patterns, increased high-value and market-oriented crop production, and fixed employment (Hussain and Hanjra, 2004).

Deliberations in the International Commission on Irrigation and Drainage (ICID) Task Force on the “Role of Irrigation in Poverty Alleviation and Livelihoods” can be summarized as:

- Irrigation professionals need to be more sympathetic to the actions of the poor in making better use of irrigation systems to improve their circumstances (e.g. multiple use of canal banks for farm to market access).
- Many of the poorest members of the community are not able to be farmers, or find their best opportunities in irrigated farming, or in agriculture at all.
- Of those that remain in agriculture, most depend on rainfed cropping or become pastoralists, or may find other employment in towns.
- Most irrigation schemes have multiple use and these additional uses can provide opportunities for the poor, which may be non-agricultural but depend on irrigation development for water.
- The role of irrigation in poverty alleviation may be small in terms of simply providing water to grow crops, but may be significant in enabling other uses of the infrastructure as well as adding to food security.

3. Historical Development

From the 1970 to the 1990, the government sector, with significant intervention by the international development banks, financed large irrigation projects having strong positive effects on economic growth, benefiting the poor. In the late 80s, it became difficult to justify new irrigation development costs due to declining crop prices and increasing of development costs for new irrigation schemes. While on one hand, financial capability has been lacking for new infrastructure as well as for modernizing and rehabilitating present structures, on the other hand, there has been an increase in the private sector financing of large water-sector infrastructure, and small-scale irrigation system with particular interest on groundwater development because of the private level of control it offers. Recently, in order to augment the performance of the irrigation sector, the possibility of involving the private sector through

Public–Private–Partnerships (PPPs) has been explored and adopted with the financial support of development banks (i.e. World Bank and Asian Development Bank).

Despite the significant achievements in irrigated agriculture, water use for irrigation is still generally inefficient. On average, half of the water diverted or stored for irrigation evaporates and percolates into the ground without watering crops. Likewise, consumption for irrigation has lower economic value of water compared to industrial, municipal and domestic consumption. Wherein, there will be a natural tendency to reduce water allocation to agriculture in favour of other uses.

It is imperative to have drastic improvements in irrigation to have a significant impact on poverty alleviation and ensure water allocation for agriculture while sustaining natural resources. Irrigation professionals have an important role in this path. They need to sufficiently recognize the multiple use of water. Developing advance methods and smart irrigation systems can reduce significantly the water consumption and increases the water efficiency. In recent years, the cost of technology has been reduced and it is now a practical approach to use those technology in farm management.

Generally, water shortage leads to several form of cooperative association, especially in isolated farmworker societies. Since individual farmer could not manage to pay all needed equipment to divert or draw water, the community developed centralized irrigation system with specific rules for water distribution. Depending on the farmers' wealth and social status, certain volume of water is allowed to flow on his land. Irrigation has come a long way, from its foundation to the present situation where there is rightful water distribution to all stakeholders. This should continue, and all improvements in irrigation should be geared towards equitable water distribution and poverty alleviation.

4. State of the Art

Water is an integral element to human food security. Water of sufficient quantity and quality is also essential for agricultural production but it is increasingly under stress (HLPE 2015). Traditional surface irrigation practices have in the past been suitable for smallholders who are fortunate enough to have abundant low-cost supplies of water. However, the traditional practices smallholders use do not utilize water very efficiently in terms of crop yield per unit of the water applied (Ayele and Tedla, 2006). Since water is usually the most critical factor that directly affects the crop production, it is critical that smallholders begin using more efficient water supply and irrigation technologies.

Finding right technology is the main challenge and providing appropriate and efficient irrigation system is not an easy task. It usually requires the development of low-cost and easy to operate systems. According to Amadei (2004), an appropriate technology is usually characterized as small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community. In addition to technology, reform in policies and water governance is also required to facilitate the access of poor communities to the irrigation water. Right to water does not justify the subsidized water for irrigation and proper use of water can increase the farmers' income and, in turn, they can pay for the services that they use.

Adapting agriculture to climate change in all fronts is essential for securing adequate and nutritious food for all. It is also a driver for and is impacted by technological change and innovation in a broader spectrum. This includes interventions for deforestation, land degradation and desertification, which result from overuse of natural resources and are exacerbated by climate change, creating, in return, negative impacts on the quantity and quality of reliably available water resources. Measures taken to cope with water scarcity will help alleviate the direct and long-term effects of desertification on land and soil quality, soil structure, organic matter and soil moisture, which collectively contribute to climate change adaptation and mitigation.

Climate-smart agriculture (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, addresses food security and climate challenges through three main pillars (FAO 2013):

i. sustainably increasing agricultural productivity and incomes;

ii. adapting and building resilience to climate change; and

iii. reducing and/or removing greenhouse gases emissions, where possible.

4.1 Water Governance: A rights-based approach to water for food security

A recent report (HLPE 2015) on food security and nutrition (FSN) describes the multiple interfaces between water and food security and nutrition (Figure 2).

It considers four dimensions of water - availability; stability; water quality; and access. These dimensions are similar to the four dimensions of food security and are in line with the Sustainable Development Goals (SDGs), in particular, SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" and SDG 6: "Ensure availability and sustainable management of water and sanitation for all".

There have been both express and implied references to a right to water in public international law. Although human rights to food and clean water have been recognized by most countries, in reality the access to these two basic rights have been elusive for millions of poor people in the least developed countries. Inequity in access to food and to water is evident in majority of the least developed and developing countries, in particular the ones that also suffer from water scarcity.

HLPE has recognized that the limitations of the widely-used concept of integrated water resources management (IWRM) in addressing conflicts, suggesting that IWRM, while providing a comprehensive framework that can bring together economic, social and environmental objectives, is not well-equipped to tackle implementation challenges at the ground level. Instead, they recommend: sustainable ecosystem management and conservation to ensure continued availability, quality and stability of water for FSN; improving the resilience, water efficiency and water productivity of existing agricultural systems; and improving the governance of water for FSN, including promotion of a rights-based approach.

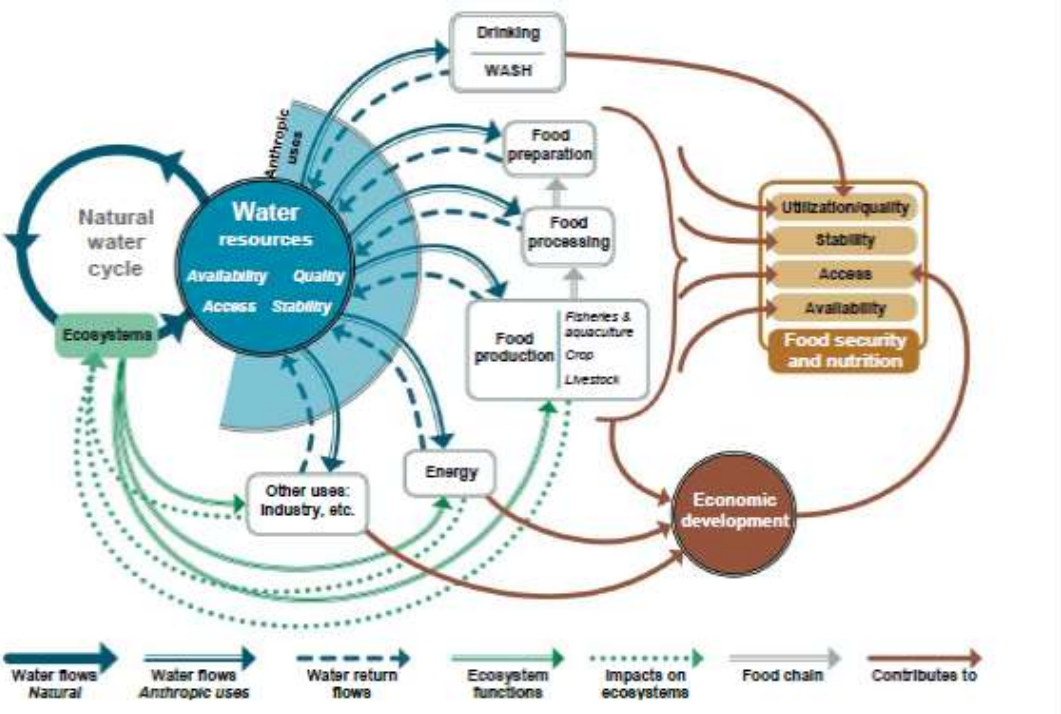

Figure 2: The multiple interfaces between water and food security and nutrition (HLPE 2015)

They refer to relevant guidelines and principles, such as the right to adequate food, the right to safe drinking water and sanitation, the Voluntary Guidelines for Security Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF), and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT), to provide a basis for further action to safeguard water for FSN. Various tools for managing water scarcity and allocation are discussed, including water use authorization, tradable water permits systems, and water pricing (HLPE 2015).

Institutions providing water services and the ones with mandate to protect people's right to food and to water – not only for health and hygiene but for agricultural production as well - are failing and need to be inclusive instead of servicing only to the influential and powerful few. People get access to water not

only through formal water rights and institutions but informal arrangements also determine who gets access to water (FAO 2016). In the context of increasingly formalized water rights, water tenure of vulnerable segment of the population – men and women - has to be strengthened and protected for them to have access to water for food production and for health, hygiene, and sanitation.

Contrasting policies and competing uses of water from different sectors, coupled with increasing impacts of climate change and variability, exacerbate water access issues and have negative impact on efficiencies of resource use, particularly in water scarce situations. It is extremely important to ensure coherence in policies on water, agriculture, and food security in order to address issues impacting smallholders' access to water for agriculture production.

Allocation of water resources is one of the most important components of the governance, especially in water scarce situations. Different countries have different systems, rules and priorities for allocating water to different sectors and different uses at various scales – river basin, national, local. Ensuring water allocation for food production and for fulfilling basic needs of poor and marginalized population is a big challenge, particularly when it is fairly difficult to assess the value of such allocations in monetary or economic terms. Water allocation in river-basins that are shared by different countries or different administrative units is particularly challenging. The first step in good governance and water allocation is to carry out water accounting and understand not only the surface water fluxes but also interconnectedness of surface and ground water.

Considering multiple interfaces that water has with food security and numerous stakeholders and actors involved with competing interests and uses, good governance of water resources is required for achieving SDG 6 and SDG 2. In particular, **enhanced Governance of Irrigation and drainage** sector can go long way in helping countries at national and local levels in achieving food security through providing the poor and vulnerable men, women and children with equitable access to water for health and for 'wealth' – income generation.

4.2 Managing Irrigation and Drainage Systems

Irrigation can help achieve food security however, **expansion of irrigated agriculture** and water development are possible in some countries especially in Africa. In most of the other contexts modernization of irrigation systems is the only way forward to achieve improved water productivity and therefore food security.

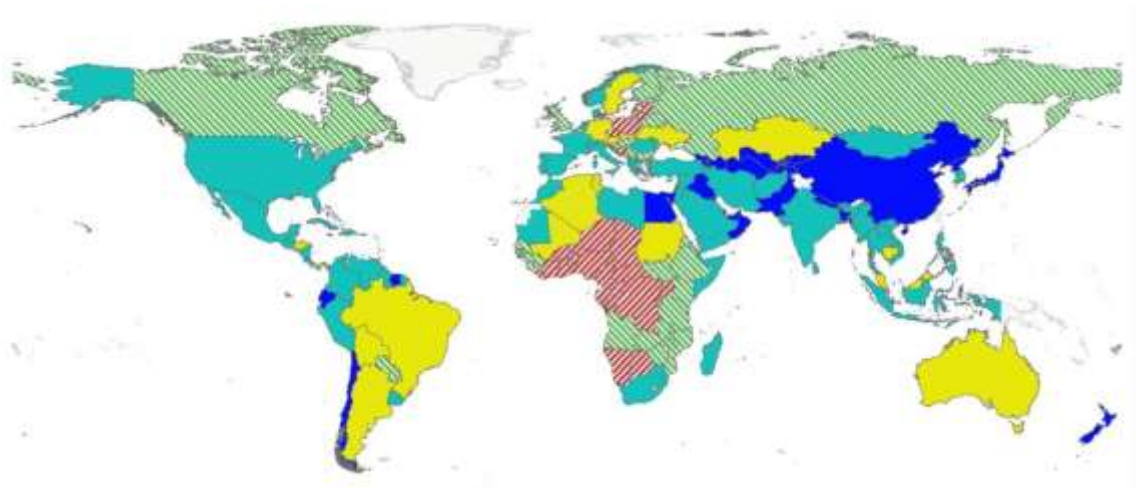

Figure 3. Area equipped with irrigation as percentage of cultivated area (2012) (FAO 2016)

According to AQUASTAT – the largest online database of FAO on water – in 2012 over 324 million hectares were equipped for irrigation worldwide, of which about 85 percent or 275 million ha are actually irrigated. Many countries in Asia, North Africa, Near East, Western Europe, North and South America irrigated area is up to 50% or more of the total cultivated area (Figure 3). This means that potential for expansion of the irrigated areas in these countries and regions is very limited.

However, Sub-Saharan Africa is the region with the lowest percentage of the cultivated area that is irrigated, just over 3 percent against almost 21 percent at global level. At the same time it has the highest prevalence of undernourishment (FAO 2016).

In Africa there is a potential of 43 million hectares that can be irrigated but only 13 million hectares are presently under irrigation. Figure 4 shows the trends in the share of total cultivated area that was equipped with irrigation facilities in the SADC countries between 1990 and 2009 (FAO 2016). It was found that throughout the SADC region, only 8% of the cultivated area was equipped with irrigation facilities. SADC member states need to take serious measures to increase investment in irrigation projects, in order to tap the potential of irrigation to increase agricultural productivity and food security, and reduce poverty.

Groundwater as a source of irrigation water accounts for about 40% - 112 Mha out of total 275 Mha - of the total irrigation in the world (GWP 2012). In South Asia it accounts for more than 50% of the total irrigated area (Table 1). In many countries, groundwater extraction has provided farmers, large and smallholders, with the opportunity to grow crops and use the water for other livelihood purposes – thanks to availability of low-cost water lifting technology. However, in many cases groundwater is not a renewable resource and is depleting fast. Efforts need to be made to monitor groundwater use and changes in aquifers in order to sustainably use the resource.

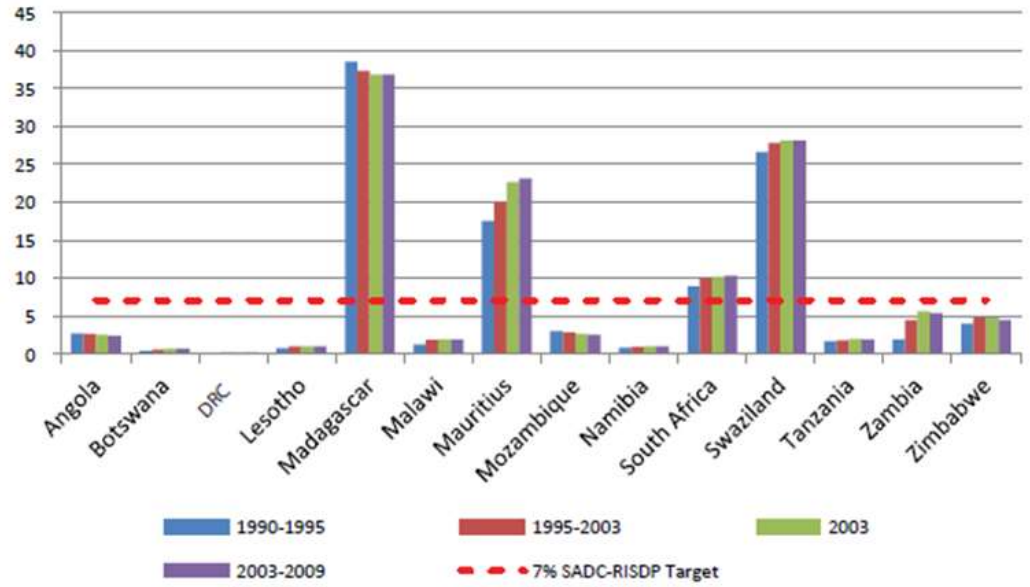

Figure 4. Percentage of cropland area equipped for irrigation in SADC countries (1990-2009). (FAO 2016)

Table 1. Global survey of groundwater irrigation (GWP 2012)

	Groundwater Irrigation		**Groundwater Volume used**	
	Mha	Proportional total (%)	Km^3	Proportional total (%)
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%
GLOBAL TOTAL	***112.9***	***38%***	***545***	***43%***

Efficiency of irrigation schemes, predominantly surface irrigation schemes and systems, is rather low. Far too many irrigation schemes, in particular large scale irrigation systems are performing below their potential - their productivity levels and efficiencies are low and water delivery services to farmers and other water users are often neither reliable nor flexible. According to some FAO estimates, average overall efficiency of irrigation schemes is 56%. Figure 5 shows a high potential for increase in efficiency in many parts of the world. Central Asia, Middle East and Southern and Eastern Asia are particularly important as most parts of these regions also suffer with water scarcity.

Irrigated agriculture needs to perform better and with higher productivity and efficiency in order to feed the world and provide good livelihood to the farmers. This situation requires that the irrigated agriculture sector moves away from the 'business-as-usual' approach and adopts innovative, forward-looking and effective governance to do more with less water. It is even more important if the goal is to achieve a sustainable water and food secure future. This is also acknowledged in the white paper on "Towards a water and food secure future: Critical Perspectives for Policy-makers" produced by FAO and World Water Council for the high level panel discussion at the 7th World Water Forum (2015).

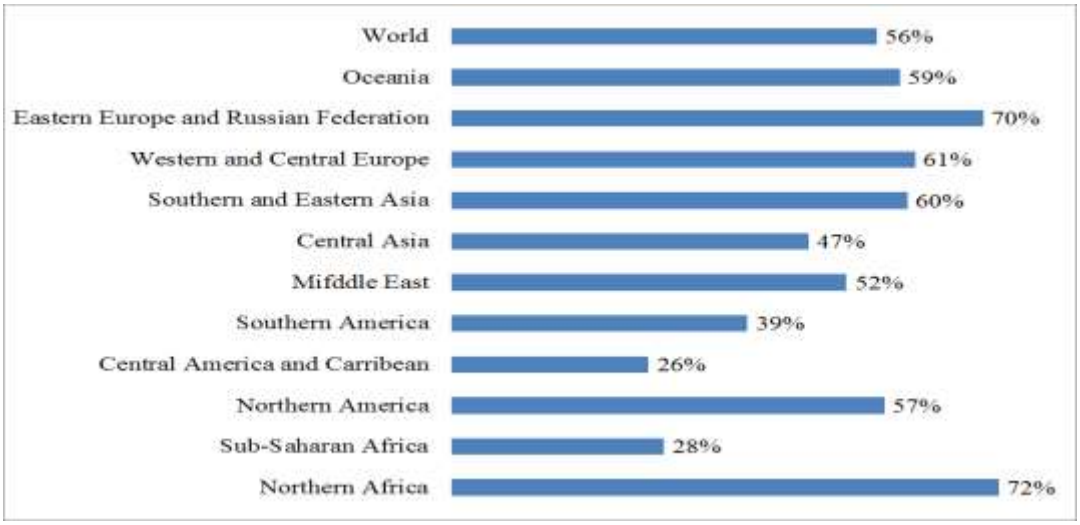

Figure 5. Irrigation Scheme Efficiencies (FAO AQUASTAT, 2016)

Technological and technical solutions to improve efficiency and productivity of irrigation water are available, for example shifting, where appropriate, from low efficiency surface irrigation to high efficiency pressurized irrigation; lining of canals using appropriate technology, etc. These technologies and techniques are site and condition specific; and may not work if not accompanied by good operation and management. For these to be successful much needs to be done on soft side – for example capacity development of not only farmers but whole chain of actors from decision makers to service providers, to farmers.

5. Future outlook

Poverty alleviation needs more attention and the needs are rapidly changing, and irrigation is only one lever to deal with it. In most cases, irrigation is not the most important means to deal with poverty, although some might believe so. To achieve a true and working irrigation and drainage as a catalyst in poverty alleviation, the international community should be guided by the following objectives:

- Increase the productivity of agriculture through effective and well managed irrigation and drainage systems to meet the demands of a rapidly growing population with a finite land and water resources.
- For individual countries to prioritize agricultural self-sufficiency first before being part of the international market economy.
- Revisit existing design of drainage, dams and pertinent structures to be climate change resilient and at the same time environmentally sound.
- Continue extensive research for innovative technology and solutions in irrigation.

In order to achieve a global food and nutritional security, commitments and investments are needed (UNDESA, 2014) to:

- **Produce more nutritious food with less water:** Innovative technologies are required to ensure a greener and more sustainable food production. They are needed to improve crop yields; implement efficient irrigation strategies; reuse of drainage water and use of water resources of marginal quality; produce smarter ways to use fertilizer and water; improve crop protection; reduce post-harvest losses; and create more sustainable livestock and marine production.
- **Focus on human capacities and institutional framework:** Agricultural development in the least developing countries (LDCs) lies mainly in the hands of smallholders, a large majority of whom are women. Therefore, new institutional arrangements are needed that centralize the responsibility for water regulation, yet decentralize water management responsibility and increase user ownership and participation.
- **Improve the value chain:** From production, post-harvest handling, processing, retailing, consumption to distribution and trade, efficient water and food recycling strategies can be addressed. It can help secure environmental water requirements when reuse of treated water is not culturally acceptable for other uses.

5.1 Investing in Irrigation and Drainage

Investment on irrigation has sharply dropped since the eighties. It is critical to understand the reasons behind that trend and react accordingly. It is crucial to show that the inefficiencies in irrigation management are - most of the time fixable; and less severe than a limited rapid look may show when all aspects of the agriculture chain and when multiples uses of water are considered.

For many developing countries, investment in irrigation will continue to represent a substantial share of investment in agriculture, but the pattern of investment will change substantially from previous decades. New investments will focus much more on enhancing the productivity of existing systems through:

- Investing in infrastructure – large and small scale irrigation systems and small land holdings
- Investing in institutions – formal and informal
- Investing in people – capacities starting from the basic education institutions to the professional irrigation and drainage system managers to farmers to decision makers

Modernization of existing infrastructure can lead to making better use of existing infrastructures should be given priority. It should be based on current and future market prospects and water service needs rather than those needs for which the system was initially designed. Modernization requires serious funding, excellent training, a design that has envisioned how the project will operate on a minute-by-minute basis, deliberate and slow implementation, and great attention to detail. There are no quick, magical solutions.

For many years FAO has been carrying out a program on “modernization of irrigation management” with the aim to help develop the capacity on how to assess and improve performance of collective infrastructure management in the technical, managerial and institutional spheres; and how to develop modernization plans. It has yielded to several standard products that are now widely used such as the Rapid Appraisal Procedure (RAP) for auditing, the MASSCOTE methodology for auditing and planning, and the MASSMUS methodology for assessing and modernizing management in the context of multiple uses of water.

The key is the capacity to first tackle the management performance in the right way, and second to improve it with appropriate approaches. While modernization represents a valid investment option in the infrastructure, other investment opportunities will have to be considered. Where possible, agricultural water investments should be targeted at small land holding in poor areas, and new irrigation projects should be designed with the needs and capabilities of the poor in mind. Promoting infrastructure and technologies adapted for smallholders is expected to have positive impact on poverty reduction.

Investment in drainage will continue at relatively modest levels, although waterlogging and salinization problems resulting from past development will continue to require remediation. Thus, there will be considerable tension arising from these financial needs compared with governments’ willingness and ability to finance them.

Investing in sound irrigation institution ensures sustained returns on infrastructure investments and optimize the allocation of water to irrigation, which affect the performance of the system and in some cultures define the performance. Investing in institution includes regulatory measures, transboundary agreements, water pricing, river basin management and devolution of responsibilities to farmers through water user associations (WUAs). Institutions play an important role especially in those region heavily affected by water scarcity, especially sub-Saharan Africa. It is specifically true in areas of economic water scarcity, where there is water available in nature, but limited accessibility due to financial and human capacity constraints. Here it will be fundamental to make sustainable investments in additional water supplies (i.e. through small-scale infrastructures) that help the poor and to set up institutions for sustainably managing the resource (Molden, 2004).

Investment in building capacity of people engaged in irrigation management is central. The tools and the techniques for modern efficient irrigation practices are available but people need to be trained to use them properly. They need to focus on management. FAO well conscious of these needs has already taken together with key partners some initiatives for raising the capacity through promotion of references centres and certification for management, and through better linkages with funding agencies.

In conclusion, investing in irrigation represents a key aspect in order to increase food production and alleviate poverty secure while reducing environmental costs and ensuring water conservation. However, it requires a long-term vision and commitment while several constraints have to be taken into consideration. Table 2 summarizes some of the main challenges that have to be taken into account in irrigation investment.

Table 2: Investing in irrigation and drainage – Challenges and constraints

Sector	Challenges and constraints
Water rights	Without well-defined rights to water, infrastructure repair suffers all the well-known problems of a common property resource, with little incentive for anyone to contribute their share of the financing (Herrera et al., 2006). A major challenge in formalizing water rights is to include traditional (often small) systems and to avoid disenfranchising established small-scale water users (Bruns and Meinzen-Dick, 2000).
Water management	The resulting risks for the environment and for society will require careful management. Growing water scarcity will have to be managed as well, with a strong need to further improve water productivity and strengthen the use of demand management approaches. In many river basins, intersectoral competition for water resources is a critical challenge that will need to be addressed.
Infrastructure subsidies	While the subsidies might have positive impact in promoting new technologies and modernizing the infrastructures, on the other hand, it might have negative impacts on water consumption. A study conducted by Brinegar & Ward (2009) have demonstrated that subsidizing modern irrigation infrastructure, even when intended to promote water conservation can increase consumption and reduce supplies available for use outside agriculture. In this case, shifting to drip irrigation induced the famers to select crops with higher ET and yield, increasing the total water need of the irrigated area.
Maintenance Costs	Governments rarely assign high priority to using taxpayer resources to maintain irrigation, infrastructure already built. A common belief held by governments is that even if it subsidizes the development of irrigation initially, they are less willing to assign adequate budgets to keep infrastructure in top form. Another belief is that farmers should pay for maintenance. Nevertheless, it has proved impossible to recover operating and maintenance costs from farmers, with the result that services have been underfunded and have deteriorated, and improvements in productivity and farmers' incomes have been below target. If systems are to deliver quality service, they have to be profitable enough for farmers to earn an adequate surplus, and arrangements for financing operation and maintenance costs have to be clear from the outset. The optimal arrangement is a farmer-managed scheme with full financial autonomy. If subsidies are required, they need to be transparent and reliable (WB 2005).

Sector	Challenges and constraints
Water charges	The water charges are fundamental to recover the capital costs, maintenance costs and make the project viable. However, it is very challenging to establish a fair and effective rate especially in poor areas, for several reasons such as: (i) Water pricing must be based on measured deliveries. However, it is widely recognized that the applicability of volumetric water pricing to individual farms is limited to a small subset of technologically and managerially advanced irrigation schemes involving huge investments that cannot be afforded in poor areas and countries (IWMI, 2007). (ii) low water charges can have great benefit on farmer incomes but they can also negatively effect on water saving because it increases the consumption and discourages the farmer to use water saving crops. Low charges are not sufficient to recover the maintenance and operation costs. On the other hand, high water charges might encourage water saving and costs recovery but they might not be feasible for the farmers causing social and economic problems.
Water allocation	In the interim, consultative and participatory arrangements for water allocation will be required. Consultation is a key process in water allocation—along with data collection, analysis, and promulgation, and negotiation—to find optimal sharing of benefits. The challenge over the next 20 years is to develop cost-effective arrangements for doing this and erect a functional framework of facilitating laws, treaties, and regulations. Since the water allocation process is inherently political, effective representation is crucial. A major challenge for the coming decades is to develop strong and effective representative voices on behalf of those stakeholders now underrepresented, including small-scale farmers, women, and the environment (WB 2005).
Regulations	Governments can play a constructive role in influencing water allocations and affecting economic efficiency by establishing regulations, standards or requirements for upkeep in irrigation infrastructure. For an existing regulation to be economically efficient and to achieve community support, the economic benefits of the regulation need to outweigh its costs, and the costs and benefits need to be shared fairly (Ward 2010).
Data	In order to offer attractive investments for the private and public sector, good data are required to productively inform decisions on why, when, where, and how to develop and sustain irrigation and its infrastructure. Collecting reliable data in developing countries is often challenging.
Policies	A major challenge in national investment strategies will be arriving at a balance of polices that allow equitable development (for instance, policies favouring cheap imported pumps and motors) but constrain overuse (for instance, by limiting or withholding energy subsidies for abstraction).Investment will be required to more effectively monitor and regulate such private development (WB 2005).

5.2 Innovations

Over the past many years, innovations in agriculture technology (precision agricultural innovations, data analytics and processing, platforms for the collection and distribution of complex data streams, and IT-driven extensions) have been on the rise. Through the use of these technologies along the entire agriculture value chain, the world can increase the productivity of its farming systems while simultaneously transforming agriculture into a source of environmental health. The crop sensing and modelling systems are able to remotely collect data such as humidity, barometric pressure, temperature, luminosity, wind speed, precipitation and soil moisture. These data, in turn, can predict the time and amount of irrigation.

Agriculture is the largest business sector which is highly driven by technologies and tools like satellite imageries, aerial imageries, GIS, GNSS/GPS, automated sensors, high tech machineries and high resolution data. The ultimate purpose of all the technologies is about optimization, precision, and to efficiently produce high crop yields. It can be noted that present innovative technology or solutions in irrigation can be used to cater the needs and challenges in different sub-sectors. These innovative technologies or solutions in irrigation can be grouped into three main categories given below:

Augmenting Water Supply

1. Irrigation utilizing fog collectors; harvesting condensed water from humid air.
2. Cloud Seeding Operation for water supply augmentation.
3. Solar and wind as source of alternative energy in small scale irrigation.

Reducing Losses

1. Subsurface Polyethylene (PE) Pipe Line Irrigation.
2. Irrigation utilizing pressure compensated subsurface drip lines.
3. Low flow spray/ Micro-sprinkler irrigation.
4. Irrigation Canal using Pre-cast method.
5. Precision land-levelling by laser-guided equipment for uniformity of flow of water into the soil.
6. Improving Operation & Maintenance of Irrigation Systems using Farmland GIS.
7. Application of drone technology as a source of valuable information about when and where to apply precise quantities of water to the crop

Managing Water Demand

1. Alternate Wetting and Drying Scheme as Water-Saving Technology.
2. Using System of Rice Intensification Method for Higher Yield with minimum water demand.

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