6. Water management

Agriculture is the largest user of the world's freshwater resources, consuming 70% of the available supply (UNW-DPAC 2011). As the world's population rises and consumes more food, and industries as well as urban developments expand, water scarcity is becoming an important issue that demands improved water management systems. Water management approaches, both within rainfed and irrigated agriculture, are applicable at different scales including (i) farm level, (ii) irrigation system or catchment level, and (iii) national or river basins at the planning level. Many of the options for water management can appear generic at any of these levels. However, when applied in different combinations in specific contexts, unique improved water use efficiency (WUE) systems will emerge that are suited to specific ecological systems.

Under rainfed agriculture, improved water management can be achieved through land management practices that result in the capture and retention of rainfall and through soil fertility and crop management innovations that enhance crop growth and yield and hence water use efficiency (Landolt 2011; Roose et al. 1999; Bationo et al. 2012) or through supplemental irrigation of dry-land crops (Oweis and Hachum 2012). In irrigated systems, improved water management for greater WUE is achievable at many stages in the total process of irrigation, from the source of the water, through conveyance and application systems, scheduling and the availability of water in the root zone of the plant. Nicol et al. (2015) describe many such examples drawn from East Africa. Water management within the livestock sector and fisheries sector also offers substantial potential to increase efficiency, productivity, and resilience.

Contribution to enhancing food security, resilience and productivity in a sustainable manner:

- **Productivity/food security**: In the absence of other limitations to crop growth, all innovations which target reduced crop water stress through improved capture and retention of rainfall or improved scheduling and application of irrigation water (see case studies 1.1, 6.3 and 6.4) will boost crop productivity.
- **Resilience/adaptation through short-term risk management**: Many water management innovations (e.g. supplemental irrigation and rainfall capture) are specifically designed to

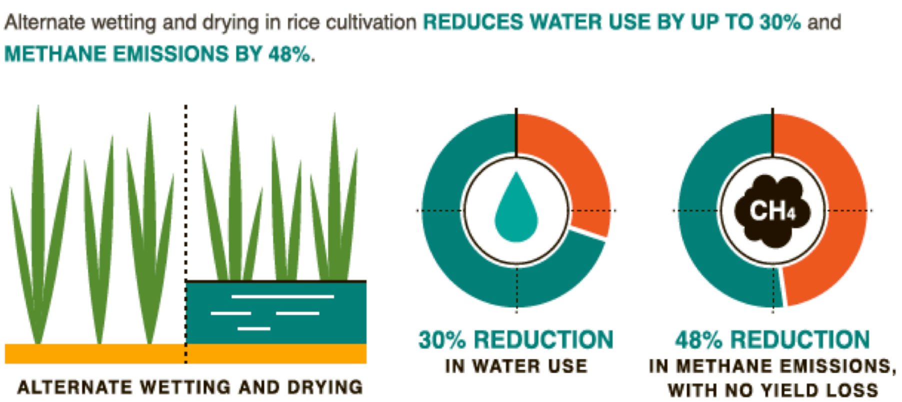
reduce / eliminate the risk of crop water stress and yield reduction (see case studies 6.1, 6.2).

- **Resilience/adaptation through longer-term risk management***:* Climate change implications for water management are context specific. However, in many regions it will likely include increased water demand and reduced water availability. Under such scenarios, especially where human populations are projected to increase substantially, all innovations which target reduced water use through greater water-use efficiency in irrigations systems are an important longer-term adaptation mechanism (see case study 6.5).
- **Mitigation co-benefits:** Flooded rice systems emit substantial amounts of methane. Alternate wetting and drying cycles in such systems not only save water, but also result in greatly reduced methane emissions (see case study 6.1). In addition, irrigation strategies that reduce the amount of water required can reduce energy consumption for pumping, thereby reducing emissions.

Case studies

Case study 6.1: Improved water management in irrigated rice through Alternate Wetting and Drying (AWD)

Flooded rice systems (irrigated, rainfed, and deepwater rice) emit significant amounts of methane (CH_4) contributing about 10–12% of emissions from the global agriculture sector (Richards and Sander 2014). AWD involves the periodic drying and re-flooding of the rice field. About two weeks after transplanting, the field is left to dry out until the water level is at 15 cm below the soil surface. Then the field is flooded again to a water depth of approximately 3–5 cm before draining again. This irrigation scheme is repeated during the crop growth cycle, except during flowering time, when the field is maintained at a flooded water depth of 3–5 cm. When used correctly, AWD does not reduce productivity compared to continuous flooding, and may in fact increase yields by promoting more effective tillering and stronger root growth of rice plants (Richards and Sander 2014). By reducing the number of irrigation events, AWD helps farmers avoid the risk of water scarcity and increases the reliability of downstream water supply, an attribute likely to become more important as populations increase and climates progressively changes. AWD has a significant mitigation potential and is assumed to reduce methane (CH_4) emissions by an average of 48% compared to continuous flooding (IPCC 2006). Combining AWD with nitrogen-use efficiency and management of rice straw can further reduce greenhouse gas emissions.



Case study 6.2: Supplemental irrigation (SI) or Deficit irrigation (DI) of rainfed crops.

Supplemental (or Deficit irrigation) has been widely investigated as a valuable and sustainable production strategy for a wide range of crops in dry regions. By limiting water applications to drought-sensitive growth stages, this practice aims to maximize water productivity and to stabilize – rather than maximize – yields (Geerts and Raes 2009; FAO 2002). It involves the addition of limited amounts of irrigation water to essentially rainfed crops, in order to improve and stabilize yields during times when rainfall fails to provide sufficient moisture for normal plant growth. Unlike full irrigation, the timing and amount of SI cannot be determined in advance given the natural season-to-season and within season rainfall variability (Oweis and Hachum 2012). As well as achieving high water productivity, the productivity and stability of crop production can be greatly increased through the addition of small amounts of SI at the correct time. SI has substantial adaptation benefits through the reduction and /or the elimination of the short-term risk of yield losses, or crop failure, in rainfed crops due to water stress at critical stages, an adaptation benefit which is likely to become even more important in the future in regions where rainfed agriculture is important and where climate change projections suggest lower and more variable rainfall amounts.

Case study 6.3: Building capacity of small-scale farmers in the use of low-cost gravity-fed drip irrigation systems.

With drip irrigation, water is conveyed under pressure through a pipe system to the field where it drips slowly into the soil through 'emitters' which are located next to the plant, only wetting the immediate root zone (Stauffer 2012). It is thus a very water efficient irrigation system compared with others (Ibid.). Water savings result from reductions in deep percolation, in surface runoff and in direct evaporation from the soil surface. The small amount of water used also reduces weed growth and limits the leaching of plant nutrients. Large-scale commercial drip irrigation has a high 'start-up' cost which has led to the wide-scale promotion in Africa (Belder et al. 2007) and Asia (IWMI 2013) of simple low-cost gravity-fed drip irrigation systems more appropriate for small-scale farmers. Such systems typically use raised barrels or buckets placed between 1 and 2 meters above ground level to provide the head required to distribute the water and bamboo or PVC tubes to distribute the water (Stauffer 2012). With proper management, plant nutrients can be added to the irrigation water before conveyance, known as 'fertigation,' enabling very precise timing, placement and availability for plant uptake (IMWI 2013). When successfully managed, low-cost drip irrigation can provide substantial increases in crop and / or tree productivity for small-scale farmers. In addition, in regions where current or projected water scarcity is likely to impact on farmers' welfare, resilience is enhanced through the high water-use efficiency of drip irrigation and the water saved compared with other systems.

Case study 6.4: Participatory approach for land and water development for rice-based systems in inland valleys

Inland valleys in West Africa are commonly preferred for agricultural production since soil fertility and water availability are higher compared to the surrounding uplands (Rodenburg et al. 2014). Still rice productivity is low with values reported between 1 and 2 tonnes per hectare in traditionally managed systems. Environmental risks such as droughts and floods as well as weeds pressure are reported by farmers as major constraints for intensification (Saito et al. 2013). Projects that aim an increase of productivity and income through improved land and water management are numerous, but often do not achieve long-term impact. Farmers are absent in the decision making processes and implementation and often return to old practices of before the intervention.

The Africa Rice Center has developed and validated a participatory approach – *Smart-valleys* – for land and water development in inland valleys. Small-scale farmer groups design a system of bunds, drainage canals and where possible irrigation infrastructure with guidance of trained technicians. Land clearing, construction of the system and field levelling are conducted by farmers using hand work and small tools. In Benin and Togo more than 200 sites have been developed using the *Smart-valleys* approach involving more than 3,000 farmers. Almost all sites are used for rice cultivation under rainfed growing conditions. Yields have improved to 3.5 to 4 tonnes per hectare and income has doubled. Farmers noticed less impact of drought compared to neighbouring traditionally managed sites due to increased water retention and higher investment in fertilizers and seeds.

Case study 6.5: Water harvesting

Water harvesting (WH) is based on the principle of depriving part of the land of its share of rain, which is usually small and non-productive, and adding it to the share of another part. This brings the amount of water available to the latter area closer to crop water requirements and thereby permitting economic agricultural production. WH is a low-external-input technology, particularly advantageous in arid and semi-arid areas where rainfall is low and unfavourably distributed. WH makes farming possible on part of the land, provided other production factors such as climate, soils and crops are favourable. Much of the economy of arid lands depends upon livestock, so most of the work that has been accomplished in WH has been aimed at providing water for livestock. In rainfed areas, WH systems can provide additional water to supplement rainfall to increase and stabilize production. Furthermore, it can alleviate the risk associated with the unpredictability of rainfall in these areas. Various WH systems have been piloted in different geographies, these include mechanized water harvesting systems in Syrian rangelands, small basins and semi-circular bunds in Jordan and Egypt. In Morocco, a system combining trees and shrubs with the use of contour ridges proved very successful in areas with rainfall of 100–200 mm. In the Kurdistan region of Iraq (Nangia 2015), supplemental irrigation has been shown to increase the yields.

Case study 6.6: Low-hanging vegetables in the Climate-Smart Village "Ban Phailom", Lao PDR

Water is scarce during the dry season in Ban Phailom, one of the two CSVs in Lao PDR. Groundwater is too deep and saline. In villages such as Ban Phailom, vegetables play a key role in diets, providing nutrients that are not present in staple foods like rice. Malnutrition is a key problem in Laos, and promoting dry season irrigation of vegetable gardens is a way to alleviate this problem and improve farmers' livelihoods. In November 2015, the National Agriculture and Forestry Research Institute (NAFRI), IWMI and local authorities set up a demonstration site for vegetable gardening around Ban Phailom's community pond. Two electric pumps and various vegetable seeds were purchased. This vegetable garden will be maintained by 12 households nearby a pond. Each of the 12 households is expected to irrigate a vegetable plot of 10m×15m. The volume of water stored in the pond at the beginning of the dry season (about 900 m^3) will be sufficient to sustain the vegetable production through the dry season. This experience exemplifies the concept of low-hanging fruit (or vegetables), and sets a prime example for other villages in the region where community ponds exist and where vegetable production remains moderate.