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Innovative Technologies for Water Saving in Irrigated Agriculture

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Abstract: Crop irrigation is the largest user of water accounting about 70% of global freshwater withdrawals. Increasing food, feed, fiber and bio-fuel demand by continued population growth is handled by expanding irrigated areas, especially in developing countries. However, there has been mounting pressure to limit water supply to irrigated agriculture and to produce more food with less water. Consequently, the search for technologies/ measures to save/ conserve water in irrigated agriculture has intensified. International Commission on Irrigation and Drainage (ICID) launched its global water savings (WatSave) program in the year 1993 with the objective of promoting and recognizing water saving practices across the world. This paper presents some innovative technologies/ practices of water saving in some countries. It was brought out that for successful up-scaling of technologies to achieve larger water saving calls for concerted efforts of policy makers, irrigation officials/ managers, field level staff and farmers. The challenge is how to incorporate innovative technologies and management approaches in decision making and long term water management policy making. Exchange of ideas and communication among planners/ decision makers, financial actors, scientists, local and regional authorities; establishing mechanism for international cooperation and experience sharing among institutions for higher education and research and developing action plans for practical follow-up are some of the possible options.

Key words: Irrigated agriculture · Water saving · Irrigation technology · System modernization · Rice irrigation

INTRODUCTION

Of the world's 1500 million ha of arable land, 288 million ha (19%) is presently irrigated [1]. Irrigated agriculture is by for the biggest water user accounting for more than 70% of global withdrawals and in some countries this share is more than 90%. At global level annually some 2,664 billion cubic meter (BCM) of freshwater is abstracted from rivers and aquifers for irrigation [2]. Water scarcity is not always a result of physical lack of water sources but also due to inadequate or weak institutional organizations.

Irrigated agriculture is often blamed as the guzzler of water. In most countries there is an increasing pressure to limit water withdrawals for irrigation and to produce more food with less water. The demand for food is driven primarily by population growth, which is expected to increase from 6.1 billion in 2000 to 8.1 billion in 2030 and 9 billion in 2050. Between 1950 and 2000, the world population increased threefold, irrigated area doubled, while water diversions to irrigated agriculture increased six fold. Some major river basins approached an advanced level of water depletion. In arid and semi-arid countries, water is already a limiting factor for agricultural production. Climate change is likely to further exacerbate the water scarcity situation. Thus, under a business-as-usual scenario there may not be enough water to produce the food needed to feed the world in 2050. It is therefore imperative to promote water saving practices in irrigated agriculture on large-scale. Consequently many international organizations, national governments, research institutes, farmers' organizations, private agencies, around the world are focusing their efforts in developing and applying various water saving measures.

Water Saving Approaches: There is a vast range of technologies available for improved operation, better management and efficient use of irrigation water - ranging from simple syphon tubes for field water application to sophisticated canal automation and telemetry.

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Water saving approaches/ practices in irrigated agriculture may be categorized as engineering, agronomical, management and institutional. The success of these approaches depends on the level of their integration and socio-economic dimensions of a given locality. International Commission on Irrigation and Drainage (ICID) launched its global water savings (WatSave) program by setting up the WatSave Work Team in the year 1993 with the objective of promoting and recognizing water savings practices across the world. Since 1998, WatSave Awards (http://www.icid.org/index_e.html) are being presented to individuals/ farmers to recognize their outstanding water saving contributions. Some innovative technologies/ practices of water saving in some countries [3] are briefly presented here.

System Modernization: In South Africa, an innovative decision support program called 'Water Administration System (WAS)' has been developed. The WAS is used by 'Water User Associations' (WUA) on irrigation schemes in managing their water accounts and water supply to clients through rivers, canal network and pipelines. It replaces the old manually operated water distribution system commonly used on government irrigation schemes. By enabling water supply of the required volume at the requested time, WAS facilitates efficient water use at the farm level and increase in the water productivity. The WAS has been implemented on irrigation schemes with a total area of 142,843 ha, which is approximately 27.5% of the irrigated area of South Africa serviced by WUAs. Field measurements have shown that losses were reduced up to 20% through improved water releases in canals and rivers. With an average water allocation of 8,147 m^3 per ha and average losses of 15%, an annual water saving achieved was about 41 million m^3.

In South-East of Spain, a traditional irrigation system dating back to the 10^{th} century was practiced in the 'Mula Irrigation system' of the Murcia region. The system was characterized by scarcity of water, obsolete and deteriorated irrigation infrastructure, excessive consumption of electric power, predominance of smallholdings, ageing fruit trees and faulty water management practices. To cope with water scarcity and enhance economic condition of irrigators, the Irrigators Community of the Murcia Regional Government prepared and implemented a project for modernization of the traditional irrigation system of Mula, It comprised a centralized control system which allows monitoring of the pumping station operation, surveillance of wells, filtering status, locating of failures, daily volumes of water delivered to each irrigator, opening and closing of the flow regulating valves, fertigation of plots and billing of the water used. Innovative features of the project consist of a 'Water Teller' and 'Water Account Book' provided to each irrigator. The 'Water Teller' is analogous to bank's ATM and provides irrigators 24-hour service. The key improvements achieved through the modernization project were (a) overall reduction in annual water losses in the 'Irrigation Community' from 1.2 million m^3 to 0.17 million m^3, (b) sustainable exploitation of the aquifer, (c) saving in pumping energy, lower cost of water to irrigators and (d) an increased crop productivity and quality of fruits.

Water Saving Rice Irrigation: In China rice is grown on about 30 million hectares contributing over 39% of the total food grain production in the country. The traditional irrigation regime for rice, namely, 'continuous flooding irrigation' was practiced in China prior to 1970s. This regime was characterized by the use of a large amount of water and low rice yields. Due to decreasing water supply for agriculture, various water efficient regimes for rice irrigation were tested, applied and extended in different regions of the country. The three main types of water efficient irrigation (WEI) regimes of rice cultivation practiced in China are (i) combining shallow water layer with wetting and drying (SWD), (ii) alternate wetting and drying (AWD) and (iii) semi-dry cultivation (SDC). Based on the results of experiments and investigations from 15 provinces and autonomous regions, compared to traditional rice irrigation (TRI), the irrigation water use has been reduced by 3-18%, 7-25% and 20-50% under SWD, AWD and SDC, respectively. Due to adoption of WEI, there is a decrease in the percolation and seepage losses and also in the evapo-transpiration, besides better utilization of rainfall.

The alternate wetting and drying (AWD) irrigation for rice has become popular in Philippines, Bangladesh and Vietnam. In this method, farmers irrigate their fields only after a certain number of days when the ponded water disappears. With the optimal management, this technology reduces the amount of water required by about 25% without reduction in yields. Scientists at International Rice Research Institute (IRRI) have developed a simple tool to help farmers make decisions on when to irrigate. They found that when field water

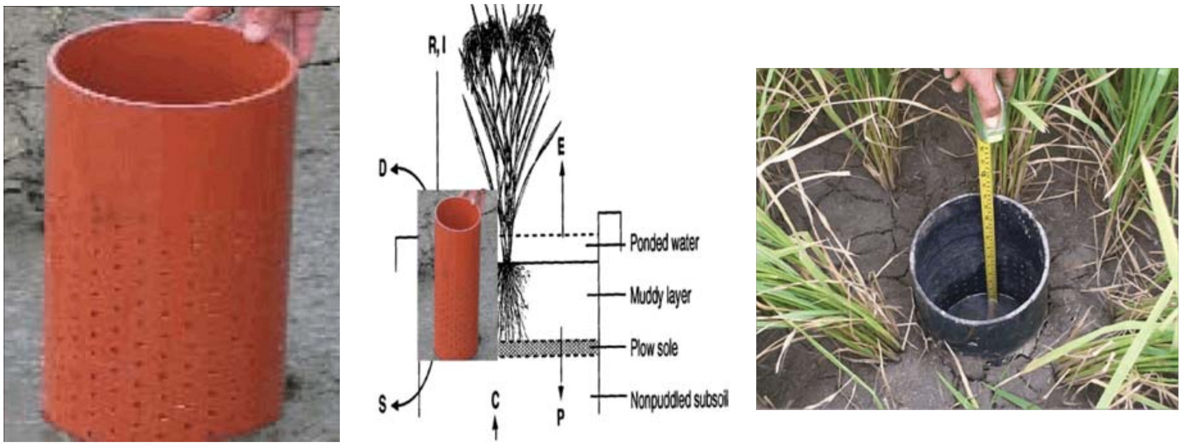

Fig. 1: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface

level recedes to 15 cm below the soil surface, soil water tension in the root zone is always <10 kPa, ensuring good yield. Thus a practical way to implement safe AWD is to monitor the depth of ponded water using a field water tube/ pipe [4]. This tube can be made of plastic pipe or bamboo 30 cm long and 15 cm or more in diameter and having perforations on all sides (Figure 1). After transplanting, farmers would keep the field submerged for about 2 weeks to suppress weed growth. The tube is then inserted into the soil by leaving 10 cm above the soil surface. Soil inside the tube is then taken out. This technology has now reached to about 70,000 farmers in the Philippines and tens of thousands in Bangladesh and Vietnam.

In Pakistan, Paddy is the major cereal crop and is grown on an area of 2.52 million hectares with an annual production of 5.02 million tons. Under traditional agronomic and water use practices, farmers apply much more water for paddy crop than the actual crop requirements. In order to save water, paddy was grown on beds and furrows which utilizes much less water than the traditional flooding method. The results of the experiment carried over three years revealed that the water use efficiency of rice under bed and furrow systems can be raised up to 0.39 kg/m^3 of water compared to 0.20 kg/m^3 commonly obtained under the traditional flood irrigation method. Transplanting of two rows of paddy seedlings on beds (at 22 cm spacing) and compacted furrows gave 32% saving in water. In addition, the weed infestation was found to be much less and there was no significant evidence of salinity build up on beds compared with the traditional method.

Similar practice of growing rice on ridges and furrows has been found successful in Egypt. Here, rice seedlings are transplanted in furrows in hills at 10 cm apart and in two rows 20 cm apart. In the traditional method farmers apply 15,000 m^3/ ha, while in the new method about 9,000 m^3/ ha are applied with average rice yield of 9 tons/ha.

In Brazil, rice irrigation using centre pivot system reduced water use by 50% compared to surface system. With surface irrigation the total application depth was 1100 mm, while with pivot irrigation it was 550 mm. The center pivot also facilitated multiple crop rotations over the years, adding valuable nutrients to the soil and improving its texture. This becomes difficult with surface irrigation because of the amount of labor required to prepare the fields from rice to another crop. With center pivots it became convenient to grow rice, wheat, soybean and oat in rotation. As a result of the various new practices, it was possible to harvest 6500 kg/ha/year, besides reducing pumping energy requirement. It was expected to pay off the cost of center pivot machine in five to six years.

Improved Irrigation Methods: Pressurized water application methods (sprinkler and micro irrigation) are considered as the leading water saving technologies in irrigated agriculture. At present, of the total world irrigated area, about 15% (44 million ha) is equipped with pressurized methods, comprising sprinkler irrigation (35 million ha) and micro irrigation (9 million ha). Most of the pressurized irrigated area is concentrated in Europe and Americas. There is a vast range of sprinkler and micro irrigation systems suiting to small and large farm sizes, soil and crop types. Improved surface irrigation methods like level furrows, dead level basins also provide high application efficiency.

In contrast to widely-held belief that adoption of more efficient irrigation technologies, especially sprinkler and micro irrigation, lead to significant water savings; Ward and Velazquez [5] have shown that these technologies reduces valuable return flows and limits aquifer recharge. Policies aimed at reducing water applications can actually increase water depletions. Achieving real water savings therefore requires designing institutional, technical and accounting measures that accurately track and economically reward reduced water depletions. Conservation programs that target reduced water diversions or application provide no guarantee to water saving.

On-Farm Irrigation Scheduling: South African Sugarcane Research Institute (SASRI), South Africa has developed an innovative decision support system called 'Mycanesim' by deploying the sophisticated information and communication technology. This system combined with participatory methods has achieved substantial improvement in water use efficiency and sugarcane yields for the benefit of small-scale growers. The system consists of a sugarcane simulation model, an on-line weather database and a communication network which automatically provides farmers with near real-time field-specific irrigation advice and yield estimates using cell phone text messages (SMS). More extensive information is provided to the advisory support structure by FAX and internet. The system has been adopted by large number of small holders as well as commercial growers.

In South Africa and Australia, a simple mechanical device called a 'Wetting Front Detector (WFD)', which shows the irrigator as how deep the water has penetrated into the soil was introduced to help better irrigation scheduling. The WFD also captures and stores a soil water sample after irrigation which can be used to improve salt and fertilizer management. The WFD provides information about the depth of water penetration in the soil profile and helps them to make a decision about the timing and duration of the next irrigation, thereby improving on-farm water application efficiency leading to water savings. To help irrigators, an interactive visualization tool 'The Fullstop Game' is provided on a specially developed website< www.fullstop.com.au>. The irrigators can type in their application rate and days since last irrigation and the visualization game shows them how deep the wetting front should penetrate down into the soil for drip and sprinkler irrigation.

In China a new irrigation approach called Controlled Alternate Partial Root-zone Irrigation (CAPRI) also called partial root-zone drying (PRD) was applied to improve crop water use efficiency without significant yield reduction. PRD involves alternate drying and wetting of subsections of the plant root zone by exploring the plant physiological and biochemical responses. It involves part of the root system being exposed to drying soil while the remaining part is irrigated normally. The wetted and dried sides of the root system are alternated with a frequency according to soil drying rate and crop water requirement. In general, the CAPRI reduced the irrigation water requirement up to 50% without reduction of crop yield.

Controlled Drainage: Controlled drainage helps in saving freshwater by providing part of the consumptive use through capillary rise from shallow water tables. The objective of controlled drainage is to reduce subsurface drainage intensity during specific period of time by temporarily raising the level of the drain outlet. Capillary rise from the raised water table contributes in moisture supply to the root zone. Experimental works in Egypt showed that up to 40% of the total water requirement could be saved through controlled drainage. In the case of paddy rice, the water savings could exceed 50%.

Use of Poor Quality Waters: Use of partially treated or untreated sewage water irrigation for growing vegetables, fodder for livestock and paddy is a common established practice in peri-urban areas of most developing countries. International Water Management Institute (IWMI) has estimated about 20 million ha under 'wastewater irrigation' worldwide. As per United Nations Development Program (UNDP) more than 800 million farmers are engaged in urban and peri-urban agriculture worldwide.

In Israel of the 500 million m^3 of the wastewater generated, 50% is treated to secondary level and 40% is treated to tertiary level. The treated wastewater is used for irrigation by blending with freshwater and through drip irrigation. It is obligatory for farmers to obtain permits to use wastewater for irrigation purpose.

The most well known formal program for drainage water reuse is In Egypt, presently, about 2 million ha have been provided with subsurface drainage in the Nile Delta. In 1997 about to $4.4km^3$ of drain water was reused in Egypt. The country aims at doubling the amount of reuse by 2017. Reuse of agricultural drainage water provides an effective option to reduce pressure on freshwater supplies.

Indirect Approaches of Water Savings: There are some indirect ways of demand management leading to water saving in crop production. These are briefly mentioned as follows;

Virtual Water Trade: When a country imports a tonne of wheat or maize, it is in effect, also importing "virtual water", i.e. the water required to produce that crop. Trade in virtual water generates water savings for importing countries. Global water saving as a result of international trade of agricultural products has been estimated at about 350 billion m^3/year [6]. To maintain food security or food self-sufficiency, many countries in the arid and semi arid regions have over-exploited their renewable water resources. Trade can help mitigate water scarcity if water-short countries can afford to import food from water-abundant countries. But political and economic factors are stronger drivers and barriers than water. Many countries view the development of water resources as a more secure option to achieving food security and livelihood of its population. Large water exporting countries may influence the policies of recipient countries. Therefore, there is a strong need to develop a set of principles/rules governing virtual water trade otherwise conflict may prevail over cooperation [7].

Reducing Wastage along the Food Chain: A study by SIWI [8] has shown that by minimizing losses and wastage along the food chain, the need for an additional food production – and therefore water – can be curtailed. A large part of food produced at the field level is lost or wasted before it arrives on our plate. In developing countries, a lot of produce perishes right on the farm, in storage, during transport. Finally, substantial losses occur during consumption and to a lesser extent during retail, from discarded perishable products, product deterioration and the food that gets thrown into the garbage bin. According to the repot as much as 30% of the food produced is thrown away that is equivalent to an estimated 40 BCM of water, enough to meet the needs of 500 million people. A combination of policy measures including investment support in post-harvest technologies, the role of food processing industry and supermarkets as well as strategic efforts to visualize and educate the public about how to practically contribute to the reduction of food wastage is necessary.

The Way Forward: The issues and challenges in adoption of irrigation technologies on wide scale could be technical, economic and social/ institutional. Technical issues include - mismatch between the prevailing technology and local needs, poor or lack of after sales services for maintenance and repairs, irregular or non availability of energy and limited research and development efforts in bridging the technology gaps. Economic issues are – high cost of technology, low investment capacity of farmers, lack of investment support, lack of access to market, low returns on investment in agriculture. Social/ institutional issues include small and fragmented land holdings, poor infrastructure and communication facilities in rural areas, lack of access to technologies. There are many already existing technologies not used by small farmers in the developing countries.

Farmers and field level staff are at the centre of any process of change and need to be encouraged and guided through appropriate technologies and practices towards water saving. Appropriate technology varies from country to country. In most developing countries extension services, especially in water management are either quite weak or simply do not exist. The governments should act as a bridge (through extension services) to promote/ transfer the technologies to farmers and field staff on continuous basis. Capacity building of local academic/ research institutions, besides farmers is essential for development and adoption of the technologies.

Better research–extension–farmer linkage and policies to stimulate adoption of technologies that improves system operation, efficiency, crop productivity and eventually farm income. Effective financing system for purchase of equipments and tools by small holder and resource poor farmers is required.

Technologies alone will not achieve water savings unless supported through innovative management, policy and institutional reforms. Modernization of irrigation systems should not only be restricted to upgrading of physical infrastructure but also integrate improved irrigation services. Water saving measures need to be based on a thorough understanding of water balance and linkages between surface and groundwater and beneficial and non-beneficial uses of water. In developing countries, irrigation infrastructure investment is mostly funded by the public sector. Increasing investment and involvement of private sector is crucial for up-scaling of irrigation technologies.

Irrigation investment strategies should include measures for the adoption of water saving irrigation technologies. Appropriate national guidelines and regulations for treatment and reuse of wastewater for irrigation need to be developed and implemented.

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