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Integrating Precision Farming and Rainwater Harvesting: Optimum Strategy for Sustainable Water Utilization in Arid Lands

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Abstract: Water is increasingly becoming the most limiting resource needed to meet the growing population. Its crucial role in human life is highlighted in arid lands, where is recognized by low annual rainfall as well as uneven temporal and spatial distribution, resulting to dry and wet periods. Such climatic condition influences water availability and crop-yield stability. Therefore farming is problematic due to unpromising water access. The most important component of agriculture in arid lands is agriculture water use efficiency. Under low and variable rainfall conditions, efficient irrigation management is a good way for improving water-use efficiency. Efficient and precision irrigation is a critical factor for sustainable agriculture. Water scarcity, as a major limiting factor in arid and semi arid areas, forces for effective use of limited water, high productivity and field precise management. This applies to both irrigated and rainfed (supplementary irrigation) cropping systems. Adopting appropriate strategy to mitigate water crises is the critical key to development of good agricultural practice (GAP) in such area. This strategy include application of rainwater harvesting techniques during wet period of the year and efficient pressurized irrigation using precision farming concept during dry period of the year. Rain water harvesting systems include techniques for runoff control and utilization during the wet period of the year. Precision farming, which aims at maximizing water use efficiency, is an effective in situ water-harvesting strategy for smallholder farmers in drought- and dry-spell-prone areas. This paper discusses a theoretical framework outlining the fundamental principles of rainwater harvesting techniques and precision irrigation effect on water use efficiency and its agricultural and environmental consequences. Then it gives an overall idea regarding rain water harvesting as well as the importance of precision farming to improve water use efficiency.

Key words: Precision farming • Rainwater harvesting • Sprinkler irrigation • Water use efficiency

INTRODUCTION

It is estimated that almost one billion people live in the dry areas. About half of the workforce earns their living cost from agriculture and water scarcity intensifies their misery. Water shortage in Iran, particularly in central part of Iran, is very serious. [1] asserted that low flow springs and seasonal rivers which usually flow in winter und springtime, as well as storage wells are the main water sources in Iran. In drought years, when precipitation is scarce and rivers dry up, groundwater tends to be the most important source of water for irrigation. In most regions of Iran, water, not land, is the limiting factor in improving agricultural production. Optimizing water productivity is therefore a proper strategy for precise water management under such conditions. It should be noted that in Iran, agriculture accounts for more than 92% of the total consumption of water. Hence, water use efficiency in agriculture has to increase in a sustainable manner by improving the management of all water uses.

While the water shortage in this region is severe, irrigation water use efficiency is only about 40%, with a typical agricultural water use efficiency of about 0.7 kg m^{-3} [2]. It is strongly believed that an increase in the agricultural water use efficiency is the key approach to mitigate water shortages and to decrease environmental problems. Based on inadequacy of natural rainfall in Iran that cannot match crop water requirements, supplementary irrigation is considered necessary to provide water requirement of crop and enhance the yield.

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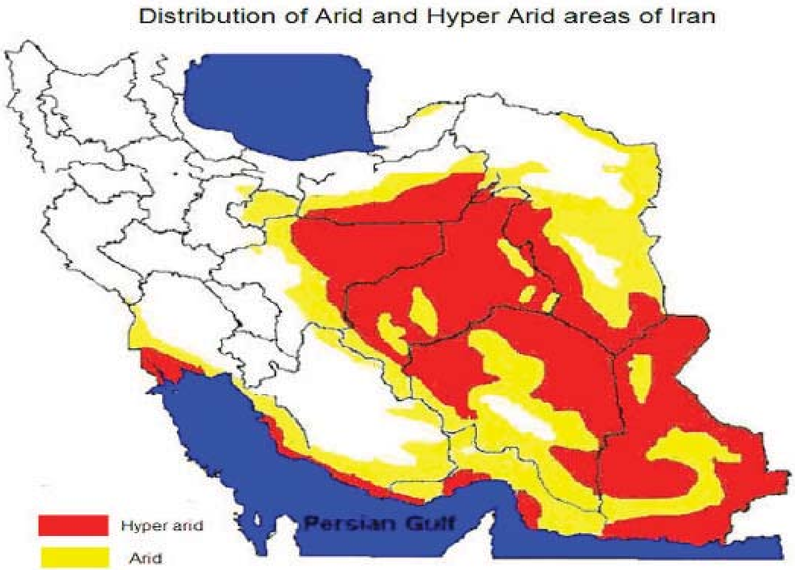

Fig. 1: Distribution of arid to hyper arid area of Iran

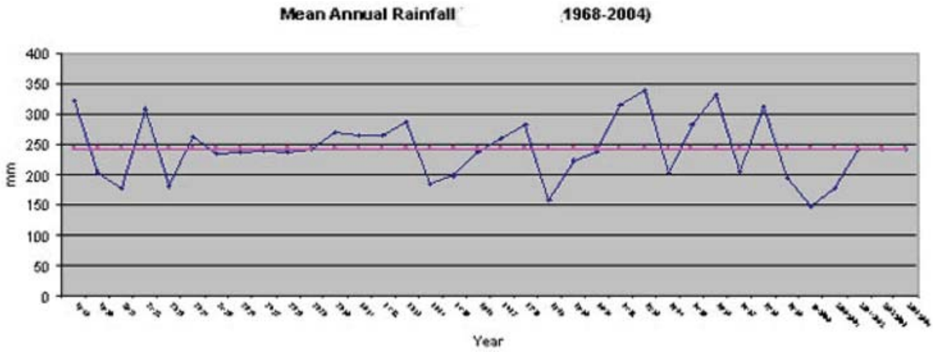

Fig. 2: Mean annual rainfall of the country (1968-2004)

Fengrui *et al*. [3] claimed that there are three main components of rainwater harvesting agriculture which are rainwater harvesting system, water-saving irrigation system and well effective crop production system. Enhancement of water use efficiency in both irrigated agriculture and rainfed fields through water conservation and efficient rainfall utilization would follow sustainable agriculture strategy [4].

Integration of water harvesting techniques (in order to recharge groundwater) and precision farming concept not only can decline farming risk also may optimize application of rainwater harvesting towards increasing the area of uncultivated lands as well as improving crop quality and crop yield.

The Geography and Climate Information of Iran: Regarding the fact that Iran is located in the arid zone, 65% of its territory is arid or hyper arid. The specific features and geographic location of Iran makes it to receive less than a third of the world average precipitation hence approximately 85% of the whole country has an arid, semi-arid or hyper arid environment (Fig. 1). Iran has a total area of about 175 million ha including 51 ha (29%) cultivable area).

Due to geographic location and varied topography, the climate is one of great extremes. Annual rainfall ranges from less than 50 mm in the deserts to 2,275 mm in Caspian Sea. The mean annual rainfall is 228 mm (Fig.2) whereas about 23% of the rainfall happens in spring, 4% in summer, 23% in autumn and 50% in winter. Dams have played a key role in water reserves and flood control. Agriculture is the main water withdrawal sector with 92% consumption of water resources (43% from surface water and 57% from groundwater) [2].

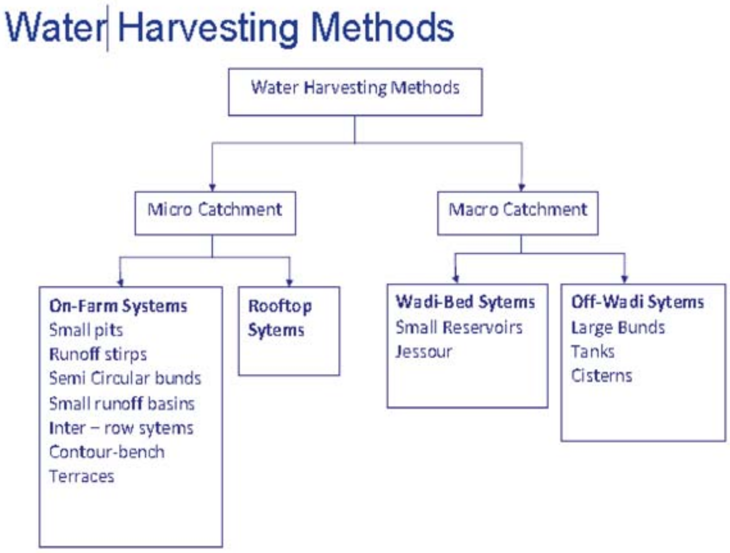

Fig. 3: Main techniques of rainwater harvesting [12]

Water Resources: Water supply has been an important concern since the beginning of the history of the country. Inhabitants find out to implement and employ efficient techniques such as Qanats, dams, weirs etc to strap up their limited water resources. There are more than 42 large dams under operation through the country with a total storage capacity of 33 BCM/year [2]. Most of them are multi-purpose dams for hydropower, irrigation and flood control.

Water availability for development of the agricultural lands is the major constraint. The irrigation potential, due to land and water resources availability, was estimated to 29 percent of the cultivable area which needs precise management for optimum storage and water use. Efficiency of Irrigation is 33 percent on average at national level. In recent decade, it is going to be improved through application of new techniques in water management and also expanding pressurized irrigation [5].

It should be noted that in most part of Iran, rain usually occurs infrequently and unpredictably and lost as evaporation and runoff mostly with no profit which causes dry periods in different stages of crop production. As [6] mentioned, part of the rain goes back to the atmosphere by evaporation, directly from the soil surface after it falls and part flow as surface runoff, usually joins streams and flows to swamps or to ‘‘salt sinks’’ and a small portion joins groundwater.

Water harvesting: [7] defined rainwater harvesting as a technique to induce, collect, store and conserve local surface runoff for agricultural purposes in arid and semi-arid regions. [8] discussed about two main methods of rainwater harvesting including Micro-catchments and Macro-catchments systems (Fig. 3). Micro-catchment is a simple and low cost approach to collect surface runoff from small catchment through contour ridges, semicircular and trapezoidal bunds and small runoff and store it in the root zone to use directly by plants. It signifies application of runoff to adjacent agricultural area while all components of the system are constructed inside the farm boundaries. In this method, farmer can control catchments and the target areas inside his farm. The target area may be planted with trees, bushes, or with annual crops. On sloping and terraced land, water retention facilities are built to collect the natural rainfall so that in the case of a serious drought water can be used to increase soil moisture by drip irrigation. Due to the limited volume of water that can be stored, the technology is usually used together with other water-saving measures such as sowing the plants with a small amount of water at the time of planting, plastic mulching, root-zone drip irrigation and under-mulch irrigation.

Macro-catchment system involves the runoff collection of large areas which are at an appreciable distance from where it is being used. Usually, it used with transitional water storage outside of the cropped basin for later irrigation utilization [9]. Commonly, runoff collection is much lower than micro-catchments (50% of the annual rainfall). Large macro-catchments systems in steppe areas called “floodwater-harvesting systems” divided to two main types of wadi-bed systems and off wadi systems. Wadi bed typically are used to store water through blocking water flow in the surface and slowing down the flow in the soil profile to allow soil infiltration. Structures may be used to force the wadi water to leave its natural course and flow to nearby areas suitable for agriculture [10,11].

In an area with annual rainfall less than 250 mm, in order to sustain agricultural production, water harvesting has vital role in rainfall collection to recharge dams and groundwater accordingly irrigation use. Water harvesting involves concentrating and collecting rainwater from a larger catchment area into a smaller cultivated area. The runoff can either be diverted directly and spread on the fields or collected in some way to be used later.

Precision irrigation as an effective technique in water management.

The agriculture sector is required to provide higher social and economic returns on using water through raising water use efficiency by more production with less water. Effective water management in agriculture signifies taking full advantage of natural precipitation as well as the efficient management of irrigation network. In order to achieve it, it is required to raise water utilization rate and water use efficiency which directs to save water. Water saving agriculture practices three techniques consist of water saving irrigation that is based on actual crop need, limited irrigation which means deficit irrigation in non critical stages of crop growth [13, 14] and rainfed cultivation that means usage of natural precipitation through runoff collection [15].

Precise management strategy in irrigation can diminish wasteful irrigation and shift to more productive agriculture practices. Precision irrigation would be a suitable approach to apply right amount of water at the right time in the right area to increase water use efficiency accordingly develop water saving management technique. In another word, implementing precision irrigation including pressurized irrigation systems (sprinkle, drip, etc), laser leveling and other techniques contribute to substantial improvement in water application and distribution efficiency. Pressurized irrigation with a limited amount of water can result in substantial improvement in crop yield and irrigation efficiency. Adoption of this strategy requires an immediate adjustment to the conventional guidelines on irrigation in the region [16]. Optimizing agronomic practices and inputs, such as appropriate cropping patterns and fertilization, can also increase water use efficiency.

In Iran, efficiency of surface irrigation is less than 40 percent due to governmental subsidization for agricultural water use [17]. Accordingly, increasing water use efficiency is a critical issue as a top priority for government to control desertification. Main effort is focused on promoting pressurized irrigation systems implementation to 70 to 90 percent of efficiency for sprinkler and drip irrigations, respectively as well as providing opportunity of precision farming application (esp. site specific management). The concept of precision farming is to apply the right amount of right inputs at the right time on the right area, conserving water resources while improving production output [18, 19]. While traditional agricultural techniques have tended to apply the same management to an entire field, precision agriculture methods focus on information technology using site-specific soil, water, crop, fertilizer and other environmental data to determine specific inputs required for certain sections of a field. Many of these methods involve the use of technologies such as geographic information systems (GIS), satellites and remote sensing. Precision agriculture has shown great promise to increase crop yields and improve water use efficiency through precise irrigation management [20-22].

CONCLUSION

The role of human in the development of water sources is obliged to be with the capacity of nature to refill and sustain. Water management under scarcity in semi arid and arid lands is a topic of concern due to limiting water resources. Increasing of water use efficiency is an important objective for agricultural water management. Due to the complex influences of multiple factors on water management in agriculture including hydrological variability, soil and crop variation and different management strategies in field and regional scale, it still needs more researches. Enhancement of rainfall utilization is the suitable approach of macro catchment management through harvesting of water for irrigation application in agricultural use. Water-saving agriculture promoting is the supplementary technique to increase water use efficiency and overcome the challenge of yield productivity and profitability per unit of water for water-limited agriculture through precision irrigation. Precision irrigation management and scheduling can apply right amount of water in right area at the right time which provide efficient use of limited water resources.

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