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Environmental sustainability of irrigated agriculture in dry areas: Case study Afghanistan, a review article

Abstract

Worldwide irrigation enables crops productions in temporarily water stressed or permanently water-scarce environments including semi-arid areas (e.g. Afghanistan) and Mediterranean countries. Globally, more than 330 million hectares of land is under agricultural irrigation which accounts for the 20 percent of the total cultivated land, and contributes 40 percent of the total food produced in the world. In coming decades, due to the rapid growth of population, industrialization, urbanization, and climate changes, the demand for irrigation and multi-purpose usage of water will increase in the globe, particularly in arid and semi-arid areas such as Afghanistan. Because of supplying artificial fertilizers, irrigated lands and irrigation have critical impacts on environmental sustainability than rain-fed agriculture. Sustainable water resources and ecosystem quality require the best management of both surface and ground water resources. Afghanistan is a country located in central Asia, with total area of approximately 647,500 km^2 and more than 30 million population. Agricultural development plays a key role in the economic development of Afghanistan. Generally, 12 percent of lands in Afghanistan is cultivatable and only 5 percent lands can be irrigated as agricultural land which produce about 80–85% of agricultural production. Irrigation is an important factor in agricultural development. The main challenges towards water resources are lack of quality meteorological data, mismanagement of irrigation, lack of irrigation

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DOI: http://dx.doi.org/10.31570/Prosp_2018_04_8.

infrastructure, lack of irrigation water conveyance systems and poor on-farm water management. Improvement of on-farm water management, introducing appropriate water conservation techniques/technologies, capacity building, communities' awareness about efficient use of water and the prediction of drought and flood can reduce environmental vulnerability.

Keywords: agriculture, climatic changes, economic development, environmental sustainability, population growth, water management

Introduction

Globally, irrigation makes crops production possible in temporarily water stressed or permanently water-scarce environments, including semi-arid areas (e. g. Afghanistan) and Mediterranean countries (Monteagudo–Moreno–Picazo 2012). Mainly, Irrigated agriculture deals with following sectors: agriculture, land use, water, energy, rural development, and environment (Özerol–Bressers–Coenen 2012). Globally, more than 330 million hectares are irrigated as agricultural land which is the 20 percent of the total cultivated land, and contributes 40 percent of the total food produced in the world. In coming decades, due to rapid population growth (9.7 billion people in 2050), increasing demand for food (60% more food) (Singh 2016), industrialization, urbanization, and climate change, the demand for irrigation and multi-purpose usage of water will be increased in arid and semi-arid areas such as Afghanistan (Monteagudo–Moreno–Picazo 2012). Afghanistan is a country located in central Asia, with total area of approximately 647,500 km^2 and more than 30 million people (Tschudin 2004). Agricultural development plays a key role in the economic development of Afghanistan, as of 2008, 30% of country's GDP is coming from agriculture, while service sector and industry share 28% and 42% of Afghanistan GDP, respectively (Kawasaki et al. 2012). The dominant characteristic of climate in Afghanistan is high temperature in summer, low relative humidity, and ample days without cloud cover (Shroder 2014). Afghanistan's agriculture is still in developing stages and many factors such as soil erosion, deforestation, desertification, high alkalinity, pest and diseases attack, soil compaction, lack of water, traditional method of irrigation, and lack of knowledgeable farmers regarding new tools and techniques, and dry climate have impacts on Afghanistan's agricultural production.

Significance of irrigated agriculture

Agriculture plays an important role in economic growth, employment, poverty reduction, fiscal health and food security of the nation. Certainly, 80 percent of country's population, close to 90 percent of the poor, are living in rural areas, and agriculture is the main sector for livelihood improvement. Afghanistan's 12 percent land is arable which is approximately 8.5 million hectares. Only 5% is used as agricultural land which produces about 80–85% of agricultural production and the remaining 7% is rain-fed agriculture which provides 15–20% of agricultural production; this statement clearly determined that importance of irrigated agriculture in the country (Pedersen 2009). Irrigated agriculture in Afghanistan started about 5,000 years ago. Irrigated agriculture provides higher and more dependable crop production on a per unit area basis than that of dry land systems. Afghanistan's agriculture depends on Irrigation (Habib 2014). Irrigated and rain-fed areas distributed based on river basins and types of water recourse of country are shown in *Table 1.*

Table 1. *Agriculture Land by River Basin (000h)*

Type of land	Amu Darya basin	Kabul basin	Helmand basin
Active irrigated land	1155	450	1079
Inactive irrigated Land	211	99	410
Rain fed agricultural land	2428	9	197

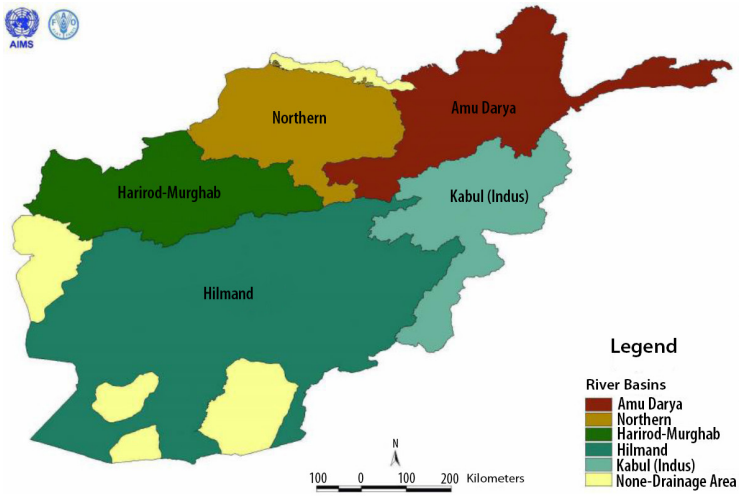
Source: World Bank Working Paper No. 39 Jun2004 (Habib 2014)

Water Resources of Afghanistan

Afghanistan water resources depend on precipitation from mountains during winter. Actually, Hindu Kush Mountains which range above 2000 m, provide 80 percent of country water resource (Qureshi 2002). Generally, Afghanistan has 75 billion cubic meters (BCM) of potential water resources of which 20BCM is ground water and remaining 55BCM is surface water. Although Afghanistan is landlocked country, it has ample water resources. The annual per capita water availability is almost 2500 cubic meters while in neighboring countries such as Pakistan and Iran the annual water avail-

ability per capita is 1200 cubic meters and 1400 cubic meters, respectively (Qureshi 2002). Afghanistan's water resources can be managed by management of river basins of the country. Based on the hydrological and morphological systems, water flow in the country can be divided into five main rivers basins (Habib 2014), namely: **(1)** The Amu Darya river basin **(2)** The Helmand river basin **(3)** The Kabul (Indus) river basin **(4)** The Harirod -Murghab river basin and **(5)** The Northern river basin. Almost 90 percent of total lands of Afghanistan have been covered by these five river basins *(Figure 1)*.

Figure 1. *The five major river basins of Afghanistan*



Source: Habib (2014)

Table 2. *Estimated Surface and ground water balance BCM per year*

Water Resources	Potential	Present Use	Balance	Future use*	Balance
Surface Water	57	17	40	30	27
Ground Water	18	3	15	5	13
Total	75	20	55	55	40

* All existing irrigation schemes rehabilitated and managed efficiently. Afghanistan presently using only 3BCM from total 20BCM ground water resources, it is projected to increase for 8BCM by next 10 years (Qureshi 2002).

Source: Qureshi (2002)

Environmental Impacts of Irrigated Agriculture

In agro-ecological research and sustainability of agriculture, the degradation of natural resources is the major concern (Sabiha et al. 2016). Water and food security is strongly connected with irrigated agriculture in both developed and developing countries. Globally, it is obvious that irrigated agriculture produces higher yields and income compared to rain-fed agriculture, which means that it has positive economic and social effects. On the other hand, irrigated agriculture has unavoidable negative effects on environmental sustainability, particularly, natural resources, soil and water degradation, physical decline of drainage and irrigation networks (Rakhmatullaev et al. 2010), environmental pollution, and over utilization (Özerol–Bressers–Coenen 2012). Indeed, the continuous expansion of irrigation practices creates worry over the long period sustainability of water resources at various levels, with environmental, social and economic concerns (Ronco et al. 2017). Generally, the source of environmental impacts of irrigated agriculture can be divided into following: *a)* establishment of irrigation projects, *b)* water transportation and operation of irrigation scheme, and *c)* the management practices of irrigated agriculture (Stockle 1996). The construction of massive irrigated projects results in modification of the present state of the ecosystem in around rivers, lakes and streams and surrounded environment. For instance; as a result of construction of dam for irrigation of the cotton field on Amu Darya and Syr Darya rivers, the Ara Sea in central Asia is disappearing; recent studies show that 24 species of fish are thought to be eliminated. The environmental impact of irrigation system and operation method relies on the quality of the water, type of water resource, and how water is applied for irrigation. In irrigated areas, the clearest effect on groundwater is over use of this water which is the main cause of decreasing the water table (Tweed et al. 2018). The removal of ground water might cause the negative impacts in the environment including aquifers to become saline, land to descend, and many others ground water pollutions. Certainly, an extreme withdrawal of water for irrigation has effects on the environment for example the Aral Sea surface area declined to 50% and its water volume decreased to 75% (Stockle 1996). Commonly, Salinity occurrence is a natural process but the application of water resource with meaningful salinity may affect the quality of the irrigated land and the sustainable agriculture production which is supported by irrigated land, especially when irrigation and soil are managed poorly.

Commonly, waterlogging takes place because of overusing and poor management of irrigation water. Over all in the world, waterlogging damages almost 10% of all irrigated land. Salinization and waterlogging effects can be decreased by training the crop producers about new management methods rather than more investment on soil improvement and drainage (Stockle 1996). The degradation of ground water quality by salts, pesticides, and fertilizers is a critical environmental problem. Salinization of water resources can cause extremely negative impacts on sustainability of irrigated agriculture than soil salinization. Another important source of water pollution is because of runoff from agricultural land. The application of agrochemicals including pesticides and fertilizer can account as a main cause of water pollution, particularly leaching of nitrate to ground water. Runoff not only transports the nutrients and chemicals but it is the cause of soil erosion and sedimentation. As a result, soil productivity is going to be declining.

The key challenges

The construction of modern irrigation system in Afghanistan has been started since 1970s. These systems are the followings: **(1)** Kunduz_Khanabad's system in the north of the country **(2)** in the south west, Helmand Arghandab systems and **(3)** Ghaziabad systems in the East Nangarhar province. Water resources of Afghanistan are facing several challenges which are needed to be addressed properly. Nicely coordinated plans are necessary for the permanent solution of these problems which would in return solve many other challenges of our country including the creation of employment facilities, management of water resource, providing clean energy, increasing crop production, and food security. The main problems are the followings; loss of irrigation systems in Afghanistan due to four decades of war and conflict, recent drought in 1999, poor management of water resource and lack of water reservoir structure. Second main challenge is climate change, decreasing of Afghanistan's glaciers and the changing of wetlands to dry land. Among 21 determined wetlands of Afghanistan, three of them are globally important which have been dried out, including **(1)** Sistan Wetland- shared between Afghanistan and Iran is almost completely dried **(2)** around 98% of annual average of Helmand and its major tributaries are decreased and **(3)** several species of waterfowl has disappeared on Hamuni-puzak which has worldwide importance for

bird migration (Habib 2014). Another main problem is lack of access to safe and fresh water, according to the recent survey. Only, 13% of Afghans have access to safe water (Habib 2014). Flood can also be accounted as a challenge for water resource management. Due to the deforestation and removing of vegetation cover, the floods have been raised. Indeed, flooding are occurring mainly in June-July and have destroyed hundreds of hectares of land. The lack of sufficient and reliable data for creating a strategic plan for water resource management, weak performance of current irrigation systems, limited financial resources and security problems are also known as critical concerns (Mahmoodi 2008). The climate change, variability of precipitation, lack of awareness, and poor water safety plan are other related problems. The quality of groundwater resources has been affected by following factors: lack of suitable effort for the observation, management and conservation system, improper land use management, lack of strong regulation for the conservation of groundwater, and lack of disposal management and waste treatment (Kohistani 2013).

Dealing with environmental effects of irrigation

Due to rapid population growth, water dams, reservoirs and other types of infrastructures still have to be constructed. Especially in arid and semi-arid areas where the water shortage is in the critical stage. But the establishment of these massive water projects must be based on higher standards with more compatibility to the surrounded environment and ecological condition. Indeed, a few interventions are suggested for the preventing, mitigating, or reversing of soil and water degradation. Possible interventions are irrigation/agronomic practices, system management and engineering interventions. Interventions related to agronomic practices are as following; reduction of sedimentation in runoff, on-farm irrigation management and minimization of water losses during on-farm distribution, improvement the efficiency of irrigation systems, application of irrigation due to crop water requirement, cultivation of the crop based on crop suitability map, and application of high efficient irrigation method such as sprinkler or drip irrigation method. Engineering practices include the consideration of environmental effects in design, construction of irrigation infrastructure, build-up of drainage system, recycling of drain and waste water, and minimization of canal seepage (Stockle 1996).

Conclusion

Several factors affect water resource sustainability in the country including population growth, industrialization, agricultural activities, sanitation, immigration, environmental degradation, and so on. Water resource management in Afghanistan is facing complex challenges. Immediate and easy solution seems difficult, the solution of these problems needs an exact strategic plan at government level, based on data obtained from the survey. The following activities are required for the sustainable improvement of irrigation system **(1)** Establishment of Comprehensive Data Bases for Creating the Strategic Plan, Institutional Set-Up and Capacity Building **(2)** Rehabilitation and Improvement of Meteorological and Hydrological Stations **(3)** Priority Should Be Given to The Reconstruction of Irrigation Systems **(4)** National River Basin Management and River Bank Protection **(5)** Regulated Plans for Drought Combating **(6)** Recycling and Treatment of Used and Waste Water and **(7)** Prevention of Water Aquifer Depletion.

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