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ADAPTATION STRATEGIES TO CLIMATE CHANGE WITH SUSTAINABLE IRRIGATION

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Abstract

Global warming and climate change are the biggest problems of the world today. Agricultural irrigation plays a very important role in both increasing production and reducing the potential risk of drought. However, excessive use of water in agriculture (>10 000 m^3 ha^{-1}), very low irrigation efficiency (35-50%) and the effect of climate change cause a rapid decrease in water resources.In adaptation to climate change, efficient use of water resources in agricultural production, irrigation water productivity (kg m^{-3}), economic productivity of water ($ m^{-3}), farmers' net income ($ ha^{-1}) and total water use (m^3ha^{-1}) should be considered for each irrigated area. Thus, both the farmers, the irrigation authority and the decision makers can choose to implement possible deficit irrigation strategies and/or the most effective water use strategies according to these parameters. Thus, the main categories might be identified under the sustainable resource management, water management, technological developments, farm management, and farm production practices. Adaptation strategies to climate change can be implemented, but the costs and benefits of these practices need to be well understood.

***Key words**: climate change, irrigation, irrigation efficiency, sustainability, water productivity.*

INTRODUCTION

Global warming and climate change are the biggest problems of the world today. Climate change also accelerates more frequent and severe droughts, floods and extreme precipitation, melting of glaciers, reduction of groundwater and deterioration of water quality (Sidhu, 2022).
On the one hand, there is uncertainty about the effect of increasing CO_2 on plant physiology and its effects on agricultural production with climate change. Therefore, the impact of global climate change on agricultural production cannot be measured precisely at present (Gornall et al., 2010).
Agriculture is an important sector in arid and semi arid regions. The rain-fed crop systems are, thus, highly dependent on climatic conditions. For this reason, the rain-fed farming is sensitive to changes in precipitation and temperature that change or intensify due to global warming (Gornall et al., 2010; Rosa et al., 2020). Thus, climate change is expected to affect agriculture differently in different parts of the world and in different ecosystems (Olesen and Bindi 2002; Parry et al., 2004; Finger et al., 2011).
The most important sectors using water are agriculture, industry and domestic use. In the near future, both competition and water demand among these sectors will increase. Moreover, climate change will cause also increasing water demand (Bates et al., 2008; OcCC, 2007; 2008; Finger et al., 2011). Similarly, climate change will bring along many economic and social problems faced by water management in agricultural areas (IPCC, 2008; Iglesias & Garroteb, 2015).
On the other hand, water management in agriculture is very complex. Options in agricultural water management include a wide range of technical, economic, social and infrastructure factors (Iglesias & Garroteb, 2015).
Aforementioned negativities caused by climate change can only be met with adaptation and sustainable use of resources. It is, thus, inevitable to take some precautions or adaptation strategies to reduce the negative effects of climate change, especially on soil and water resources and agricultural production. In this article, the relationship between climate

change and irrigation and adaptation strategies to climate change are discussed.

CLIMATE CHANGE AND IRRIGATION

The increase in population also demands more food production. This gives irrigation an important role in increasing land use. For this reason, it is expected that irrigated agriculture will increase rapidly in the future to provide more production from irrigated agriculture since irrigation provides higher yields than rain-fed agriculture (Chartzoulakis & Bertaki, 2015).

On the other hand, the expansion of irrigation areas increases the pressure on global freshwater resources and often leads to their unsustainable use. In order to meet food needs in the future, it is necessary to adapt to climate and socio-economic changes as well as to manage sustainnably soil and water resources in arid and semi-arid regions (Harmanny & Malek, 2019). A majority of countries have a priority for adaptation in their climate change plans. For that reason, climate change adaptation strategies have over 80% were water-related (Sidhu, 2022).

Adaptation is needed to ensure the sustainability, resilience and reliability of soil and water resources in agriculture. Irrigation water demand and consumption are significantly affected by climate condition, irrigation system efficiency and crop type (Zhao & Boll, 2022).

Under climate projections, low water availability is a challenge water supply for agricultural activities. Clearly, new management strategies and water conservation are required to overcome the effects of climate change on agriculture, especially in arid and semi-arid regions. In this issue, adoption and adaptation are key factors. Adoption of innovative approaches for future uncertainties, supportive policies and financial support for stakeholders can be considered as preventive actions (Zhao & Boll, 2022).

As a result, food demand and safety will increase in the near future and these will become more complex. Increasing temperatures due to climate change will increase water demand in places where precipitation decreases. Therefore, more irrigation will be required for food security and a sustainable life. In connection with these issues, the effects of reduction in irrigation water requirements will be significant in the near future so that further water conservation should be considered at both a regional and global level (Turral et al., 2011).

ADAPTATION STRATEGIES TO CLIMATE CHANGE WITH IRRIGATION

The main user of fresh water resources on earth is globally the agriculture sector. Because irrigation significantly increases crop yield, water productivity (irrigation water use efficiency) and maximizing the farmer's economic return.

Agricultural irrigation plays a very important role in both increasing production and reducing the potential risk of drought. Irrigation can increase crop yield 1 to 5 times depending on crop variety, soil characteristics and other agricultural practices in arid and semi-arid regions although there are many different applications in adaptation strategies to climate change. On the other hand, increasing water demand for domestic and industrial use and environmental sustainability puts pressure on the irrigated agriculture sector.

Figure 1 shows the relationships between crop yield and irrigation water and other inputs. The farmers often aim to achieve maximum yield. This situation may require the use of excessive irrigation water (Figures 1 and 2). In this case, water use efficiency or irrigation water productivity decreases. Therefore, considering possible drought and decreasing water resources, the water-yield relationship of crops should be known so that irrigation water savings, yield and economic losses in possible irrigation water shortages can be known (Figure 1).

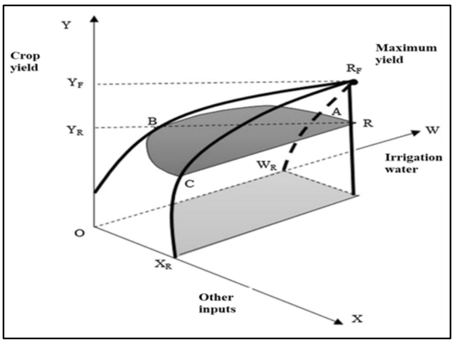

Figure 1. Relationships between crop yield and irrigation water together with other inputs (Reinhard et al., 1999; Hong and Yabe, 2017)

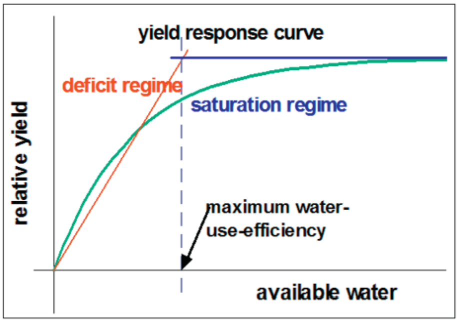

Figure 2. Yield response curve to irrigation (Chartzoulakis & Bertaki, 2015)

The most countries have considered importance to irrigation infrastructures and made significant investments in the 1980s. However, use of mainly surface irrigation methods and ignoring the necessary technical applications for this caused both excessive water use and environmental problems (salinity, alkalinity and drainage etc.). In the last quarter century, the use of pressurized irrigation systems (drip and sprinkler) has increased rapidly depending on the developing technologies. These systems, which are called modern irrigation systems, have provided water saving about 20-40%, an increase in yield and quality, and much less negative environmental effects (Çetin, 2019).

For our future, the most important way of good management of water used both in agriculture and for other purposes is its sustainable use. In addition, economic efficiency should be a priority in water use and soil conservation. As in the past, technological developments and innovation will continue to be critical factors.

Water is a physically scarce resource. This is particularly evident in North Africa, Central and Western Asia, and the Middle East. Moreover, the irrigation efficiency is quite low (35-50%) (SUEN, 2022). Existing water management systems have significant problems due to increasing water demand, complexity of regulations, and excessive consumption of resources. For this, sustainable management strategies based on environmental sustainability in the management of scarce resources should be applied.

In agricultural water use, increasing water use efficiency, increasing the quality and quantity of water source, and digitizing and optimizing localized water management processes on a large scale should be the main objectives. Some adaptation options, such as shifting sowing dates, can be implemented by farmers at no cost. In other options, the application of irrigation technologies requires a certain cost and, in this case, economy should be considered (Finger et al., 2011).

Three categories, infrastructure, management and agronomic issues, are important for adaptation and risk reduction (Iglesias and Garroteb, 2015).

Accordingly, sustainable water management requires appropriate allocation between competing water sector demands and balancing the financial and social resources needed to support the required water systems.

In addition, methods of evaluating water management practices should be, first, based on the complexity of the problem and the efficient and balanced use of resources for agricultural, urban and natural systems.

Varela-Ortega et al. (2016) stated that water availability may decrease and the impact of drought will be more visible in severe climate change projections. In this case, farmers will have to adapt to lower yields and lower incomes. For that reason, the various adaptation measures should be considered such as modern irrigation technologies and new crop varieties.

Some traditional and/or surface/flood irrigation methods are still the mostly used in most of counties, especially Middle East and Asian countries.

However, the modern irrigation systems (pressurized irrigation systems such as drip and sprinkler) have increased year by year. Because, these systems ensured higher irrigation efficiency, less water use, no water erosion and uniformity compared to surface irrigation methods. For this, the Turkish government has subsidized 50% of the total cost of pressurized irrigation systems for the farmers who want to use them.

One of the adaptation strategies is deficit irrigation (DI) which is a strategy for optimizing under yield reduction and some degree of water deficit conditions.

During deficit irrigation, crops are exposed to less amount of water required in a certain period or the throughout growing period. The main objective of DI is to water productivity of the crop by eliminating irrigations that have little impact on yield.

Smart or precious irrigation can improve yield and water productivity and save irrigation water, consequently leading to improved food security for the increasing population (Bwambale et al., 2022).

Subsidization of pressurized irrigation systems by governments, if well controlled and used appropriately, is important for efficient and sustainable use of irrigation water. However, this subsidization should not adversely affect other less costly irrigation water-saving practices (Finger et al., 2011).

The problems and challenges in agricultural irrigation related to climate change and some solution suggestions are given in Table 1.

Table 1. Solutions and recommendations for climate change and irrigation related problems

Climate change and irrigation related problems	Solutions and recommendations
Drought	Drought resistant plant breeding, deficit irrigation
Water scarcity	Use of drip irrigation and treated waste water, water harvesting
Excessive water use	Pressurized irrigation systems, use of water based on volumetric measurement, smart irrigation, digitization, training,
Erosion in irrigation	Contour sowing-planting on sloping lands, use of pressure irrigation system (especially drip irrigation)
Monoculture	Polyculture
Evaporation from the soil	Mulching, subsurface drip irrigation
Salinity-Drainage	Prevention of excessive water use, installation of drainage systems
Inter-institutional cooperation	Increasing cooperation
Sanctions are insufficient	Imposing new regulations and sanctions
Lack of infrastructure	Improving irrigation infrastructures
Insufficient technical capacity	Increasing capacity building

CONCLUSIONS

Basic issues related to irrigation in adaptation to climate change are; to increase water use efficiency, water productivity and capacity building, reuse of marginal waters (reclaimed or brackish) for irrigation, regulation of water pricing, adoption of innovative irrigation techniques and wider and more effective participation. In addition, use of modern technologies such as smart irrigation and fertigation are also important. Extension and training should be also associated with other factors and applications.

In adaptation to drought and climate change, efficient use of water resources in agricultural production, irrigation water productivity (kg m^{-3}), economic productivity of water ($ m^{-3}), farmers' net income ($ ha^{-1}) and total water use (m^3 ha^{-1}) should be calculated and considered for each region and all these data and recommendations should be presented to users as a guidebook. Thus, both the farmer, the irrigation authority and the decision makers can choose to implement possible deficit irrigation strategies and/or the most effective water use strategies according to these parameters.

The use and dissemination of these modern irrigation systems have been necessary for the sustainable use of water resources, which are declining due to the increasing population demand and climate change. However, in sustainable water use and adaptation to climate change, besides the use of modern irrigation systems, effective and continuous management, raising awareness among users, education and support policies are at least as important. In addition, purification and reuse of domestic wastewater and water harvesting are also important in this respect.

As a result, Harmanny & Malek (2019) identified some main adaptation categories such as farm production practices, water management, sustainable resource management, technological developments, and farm management strategies. The results showed that farmers have greater potential to adapt in rural areas where have low rainfall and high temperature. This is evidence that the socio-economic effects of adaptation strategies may also be different as spatial. On the other hand, adaptation strategies to climate change can be implemented, but the costs and benefits of these practices need to be well understood (Sidhu, 2022).

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