Effects of Climate Change on Agriculture Production Under Rain-Fed Condition

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Abstract
Global warming has made a significant impact on water supplies. As a result of warmer climatic conditions, the acceleration of the hydrological cycle, climate change, an increase in precipitation and evapotranspiration (ET) now occur. In recent years, because of the development in industry, and the increased use of fossil fuels, there has been an increase in CO_2 emissions, and in the temperature of the earth. The most significant changes observed also increase with higher temperatures during the summer months in Turkey. Furthermore, summer temperatures in Turkey's Mediterranean and Southeast Anatolia regions are increasing. In addition, in the last 50 years the amount of precipitation during the winter season in the west of Turkey has significantly reduced. Climate change and the scarcity of rainfall limit agricultural production. In the southeastern region of Anatolia, in particular, agricultural production has been hampered by the droughts of 2008 and 2010. The average total of 30 years of rainfall was 344.1 mm in this semi-arid region. Between 1982–2011, the lowest rainfall measured 227.3 mm in 2008, while the highest measured 573.1 mm in 1996. In this study, we will focus on the many years of climate data on dry and under rain-fed conditions in the agricultural areas in the Southeast of Turkey.

Keywords: Drought; evapotranspiration; global warming; hydrological cycle, semi-arid region

1. Introduction

Rainfall in dry areas is generally insufficient to meet the basic needs for agricultural production. Since it is poorly distributed over the growing season and often comes in intense bursts, it usually cannot support economic farming. In Southeastern Turkey, the annual rainfall is generally less than 350-400 mm and occurs mostly in disordered, unpredictable storms. Turkey is located in a semi-arid region, where the average annual rainfall is 643 mm. The significant differences between regions that are observed worldwide in terms of the amount and distribution of precipitation have also been observed in our country. Some regions record up to 3000 mm rainfall, while others do not exceed 250 mm. Therefore, especially during periods of crop cultivation, plants do not provide enough water for their vegetal grow in terms of the desired amount of water. Because of these environmental changes, the development of our country's water resources, the planning of scientific and technical approaches to preserve the environment for today and the future, continue

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to gain greater importance and value. In the case of existing water, an estimated two-thirds of the world's population will face a shortage of water by the 2025s (Çakmak et al., 1999).
Droughts, a natural phenomenon during which rainfall is less than the average for many years can occur at any place and at any time. While it is extremely difficult to predict the duration and time of the effects of drought, the degree to which human activities influence these environmental factors is closely observed. The main reason for this is the fact that since droughts affect practically all sectors of the economy, it does so in such a variety of ways that each sector establishes its own criteria for identifying and characterizing each drought event; thereby, having virtually its own concept of drought (Tsakiris et al., 2013)
The amount of greenhouse gases released into the atmosphere after the industrial revolution, which has increased worldwide, has created an artificial climate change. Globally, the average temperature of the earth and water bodies have been increasing since 1861 (IPCC 2001). The climate, for millions of years, has been unstable and variable; the climate's high variability is just not possible to predict with accuracy. This variability will continue to increase due to the accumulation of atmospheric greenhouse gases, which strengthen the greenhouse effect and global warming. After the 1980s and 1990s, these effects were more pronounced, and reached their highest values. Global warming is likely to occur in conjunction with agricultural drought. Consequently, a decrease in agricultural production as a result of agricultural drought, economic losses, the disruption of ecological balance, and human life, will inevitably be affected. To reduce the negative impacts of agricultural drought, measurements of drought and drought periods need to be taken during the prior periods of planning for sowing. Turkey, as a result of global warming, along with other high risk countries, is expected to remain under the influence of a warmer more arid climate zone. Therefore, as a direct cause of global warming, forest fires, drought and desertification, and ecological degradation, will affect our water resources in particular, as well as our other natural resources. Drought is related to the climatic variability and deficient precipitation in a region.

Hanel et al., (2013) studied the development of referenced climate change scenarios. Recently, research projects represented the "likely" climate change scenario and its uncertainty as a framework for a very basic climate change assessment in the water management and irrigated agriculture planning. Many studies have reviewed the water resources management and agriculture cultivation under changing climate (Xu and Sing 2004; Graham et al., 2007; Terink et al., 2010; Sunyer et al., 2010; Samadi et al., 2013). According to climate change scenarios and future expectations of these scenarios, the increasing warming of the atmosphere and consequently the increase in evaporation will lead to a precipitation decrease in snow and rainfall precipitation according to the seasons and the amount of water available for use around the world as the current distribution deteriorates, and is expected to have a negative effect on agricultural production. Therefore, a combination of drought and flood assessments should be considered, according to climate events. Rainfall characteristics such as frequency, duration, and intensity, are more relevant in regard to the better results of water harvesting technologies than the total amount of rainfall. In semi-arid zones especially, the variability of rainfall or the inter and intra-annual variation is very high. The minimum requirements for the frequency distribution of heavy rainfall are very difficult to establish, and depend strongly on other factors such as the length of the dry spells between such rainfalls. Of critical importance to water harvesting is the duration and intensity of rainfall because a runoff only occurs when certain thresholds are exceeded. Either the rainfall intensity should exceed the infiltration rate, or the rainfall intensity and duration should exceed the storage capacity of the soil. Due to high agricultural expansion, the best land available for agricultural production has reduced. A consequence of the increasing population density is the increasing demand for land resources such as food, fuel and shelter. There is a need for the exploitation of land that is less suitable for agriculture, or land in less favorable climates. Arid and semi-arid regions should be explored as a way of minimizing land scarcity (Hudson, 1987). There is a need for a more efficient method of capture and use of the scarce water resources in arid and semi-arid areas. An optimization of rainfall management, through water harvesting in sustainable and integrated production systems, can contribute to improvements in small production.

2. Climate change and drought

Agricultural drought is closely related to soil moisture, which plays an important role in its definition. Conventionally, drought may be treated as a meteorological, hydrological, or agricultural phenomenon. In each of these expressions the variable representing "water availability" and the selected thresholds related to water availability are different (Tsakiris, 2013).

2.1. Drought

A natural event that is a result of rainfall falling significantly below the normal values of land and water resources, and a hydrological balance disorder that causes negative effects (Fig.1).

Figure 1. *Drought on the soil*

2.2. Meteorological drought

Drought is defined on the basis of the duration and degree of drought. Precipitation, humidity, evapotranspiration, and temperature, as well as climate data, the high, low, or average values, are determined by component of drought.

2.3. Hydrological drought

Aquifer (ISS), available water sources such as lakes, streamflow, recharge of aquifers and capacity of reservoirs, fall below the statistical average. Even in these circumstances, as the use of water in times of average rainfall increases, the reserves may be low.

2.4. Agricultural drought

The soil can be described by the lack of water in it to meet the needs of plants. When there is a meteorological drought, there is an agricultural drought in the cultivation area; these forms of drought appear together (Fig.2).

Figure 2. *Agricultural drought*

2.5. Socioeconomic drought

This definition is used when meteorological, hydrological and agricultural drought coincides, and some of the elements of supply and demand of goods produce an economic effect. When it affects the lives of people and their socio-economic conditions, water shortage is mentioned as socioeconomic drought (Fig.3). This socio-economic drought was studied by (Grigg and Vlachos, 1989; Mishra and Singh, 2010).

Figure 3. *Sosyo-economic drought*

3. Agricultural production in arid areas

Climate is one of the main determinants of agricultural production. Throughout the world there is significant concern about the effects of climate change and its variability on agricultural production. Researchers and administrators are concerned with the potential damages and benefits that may arise in the future from climate change impacting on agriculture, since these will affect domestic and international policies, trading patterns, resource use, and food security. A Climate change is any change in climate over time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods (IPCC, 2007). Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have a significant impact on crop yields and production. Studies have shown a significant effect of change in climatic factors on the average crop yield (Dinar et al., 1998; Seo & Mendelsohn, 2008; Cline, 2007).

As mentioned earlier, vegetation-agricultural drought is directly related to the deficiency of soil water which, in rain-fed agriculture, causes a loss in yield and a corresponding reduction of revenue. For rain-fed agriculture less effective precipitation means lesser crop yields, and therefore revenue loss (Tsakiris, 2013). Apart from the deficient effective precipitation during a period of drought, an important issue is the determination of the "normal" crop production, which cannot be attained due to drought. It is important to note that there are several factors which directly or indirectly influence the effect of drought on vegetation growth or agricultural production (Tsakiris, 2013).

Many studies in the past have shown that India is likely to witness one of the highest agricultural productivity losses in the world in accordance with the climate change pattern observed, and scenarios projected. Climate change projections calculated up to 2100 indicate an overall increase in temperature by 2-40 ^{0}C with no substantial change in precipitation quantity. Within agriculture, it is the rain-fed sector that will be most affected by climate change. Temperature is an important weather parameter that will affect the productivity of rain-fed crops. The climate is being modified at an accelerated rate due to the mushrooming of industries and high cattle population, along with the exploding human population. In order to meet the demand of the growing population, natural resources such as forests are also being exploited at a faster rate. In spite of the rising demand for food and fodder, the climate change will further worsen the condition by reducing the yield of dry land crops (Fig.4).

Figure 4. *Drought effects on agriculture*

In arid and semi-arid regions, precipitation is generally lower than potential evaporation, and non-uniform in distribution, resulting in frequent drought periods during the crop growing season, and usually coming in intense bursts, resulting in a surface run-off and uncontrolled rill and gully erosion. In the cool winter areas, as in the Mediterranean-type climate, precipitation is less than 300 mm, part of which is lost due to evaporation and run-off. The amount stored in the root zone is well below crop water requirements.

4. Effects of climate change on agriculture in Southeast of Turkey

4.1. General climate characteristics in Şanlıurfa

Şanlıurfa and its vicinity show these climatic conditions; summers are very dry and hot, and the rainy winters are relatively mild. This manifests itself in terms of temperature and precipitation. This area does not have a sufficiently moist atmosphere, and the land heats up faster in the day and cools down quicker in the evenings, which results in severe annual temperature differences. The highest temperature measured was 46.5 ^{0}C (in July) in the Ceylanpınar town of Şanlıurfa, Turkey. Şanlıurfa's coldest temperature was-12.4 ^{0}C (in February). The average annual precipitation was calculated as 462 mm. The annual average rainfall varies between 331 mm and 473 mm. The annual average temperature is 18.6 ^{0}C, evaporation is 2048 mm, and wind speed is 2.8 mm. The number of days with snow and frost is very low, and does not exceed 10 days per year. Northwestern and western directions work in the prevailing wind in Şanlıurfa. 60% of the territory and 38% of the cultivated land meadows and grassland consist of areas of vegetation. The forest area is very limited at 0.6%. The city looks like the steppe lands, although tulips, violets, daisies, sorrel, and

Table 1. *Average climate data of research area*

Years	Average Temperature (^{0}C)	Average Precipitation (mm)	Average Moisture (%)	Average Wind Speed (km/h)	Average Evaporation (mm)
2009	20.2	299.2	66.8	5.8	1317.6
2010	20.7	326.0	72.4	6.3	1561.7
2011	19.7	263.2	65.7	7.2	1643.5
Long Term Average (30 years)	18^{o}C	344.1	70.6	6.4	2047

purslane are frequently seen, as well as plants such as hibiscus and mustard. The continental climate prevails in the province of Şanlıurfa. The moisture content is less than the hottest province in Turkey, although the weather is sultry (www.cografya.gen.tr).

Most of the agricultural production is cultivated in dry conditions in Southeastern Turkey. The above, combined with rainwater research in the field, produces agricultural products such as barley, grapes, peanuts and almonds. Many products cultivated in the region were destroyed in the 2008 and 2010 droughts. The rainfall is less in this region and long years of climate data are given below in Table 1.

Climate change and the scarcity of rainfall caused limited agricultural production in Turkey. Particularly, in the southeastern region of Anatolia, agricultural production has been hampered by the droughts in 2008 and 2010. The average of 30 years rainfall was 344.1 mm in this semi-arid region. Between 1982–2011, the lowest rainfall measured was 227.3 mm in 2008, while the highest rainfall measured was 573.1 mm in 1996. Agricultural production's products face in very difficult circumstances under rain-fed conditions. The amount of precipitation from year to year was irregular and also very little (Fig. 5).

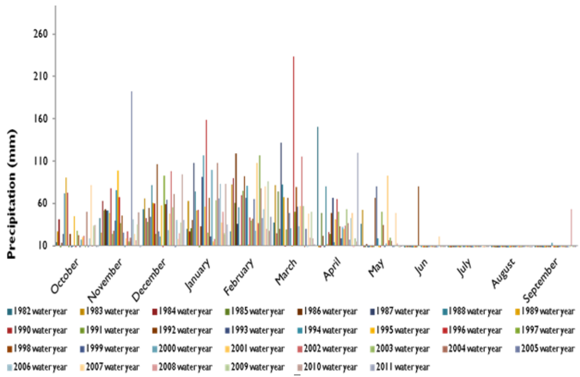

Figure 5. *Long-term precipitation data in Southeast of Turkey*

There was too much evaporation in this semi-arid agricultural area (Fig. 6). When there are high levels of evaporation, plants live in stressful conditions. High evaporation was measured in the 2008 water year for the agricultural drought.

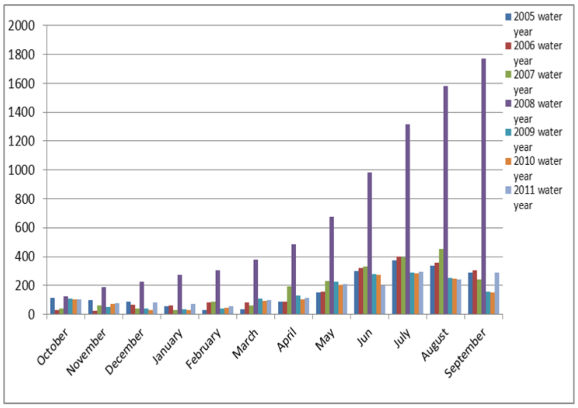

Figure 6. *Long-term evaporation data in Southeast of Turkey*

In this study area, the monthly temperature increased during the summer months. There were high temperatures for rain-fed conditions (Fig. 7).

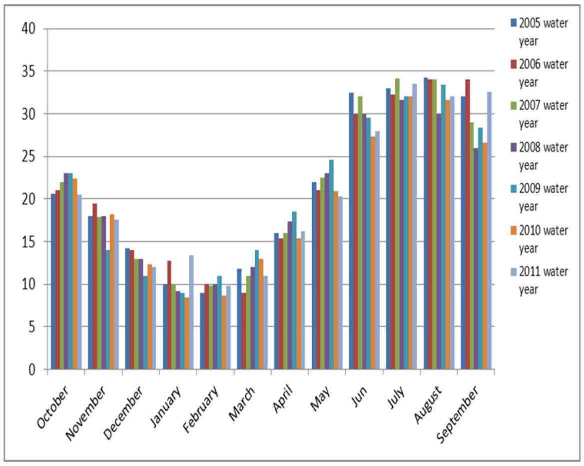

Figure 7. *Long-term temperature data in Southeast of Turkey*

5. Precaution for agricultural production

The impacts of drought, climate change, insufficient rainfall and water shortage can be economic, environmental and social in the vicinity of Şanlıurfa in the Southeast Anatolia Region, Turkey. 70% of renewable water resources are used for irrigation. Irrigation reduces by 10% the amount of water used; the use of water for homes around the world provides more than twice the required water. The economic and appropriate methods used to practically increase the efficiency of irrigation vary from region to region. However, in almost every case, 10-50% of farmers' water consumption can be reduced. For this purpose, farmers must select varieties of low water usage plants, and a pipe system, rather than a surface irrigation methods (drip irrigation) and limited irrigation systems in practice are to be preferred in the agricultural area. In addition, the breeding of drought-resistant plant varieties should be preferred in terms of cultivation.

Conclusion

The reduction of surface and groundwater flows should be carried out for the feeding of soil moisture. Appropriate techniques and equipment must be used in soil cultivation. Cultivation techniques must develop in relation to the appropriate agricultural mechanization techniques. Soil organic matter content applications should be increased, and instead of chemical fertilizers, organic fertilizers should be used. Flood and flood management techniques need to be learned by farmers. Efforts to reduce greenhouse gas emissions and use alternatives such as fossil fuels, and an effort should be made in bio-energy production. Despite the increase in precipitation the runoff decreases on average in all seasons as a result of enhanced evapotranspiration due to temperature rise in the research area. Attention to water management and water harvesting practices should be given more attention in times of drought.

This research study revealed that the climatic variation with regard to the occurrence of drought has a significant impact on the production of rain-fed crops. The small and medium rain-fed farms are highly vulnerable to climate change and to a larger extent the small and medium rain-fed farms have adopted more coping mechanisms for climate change compared to large farms. There are already signs of change as farmers are adjusting to the changes in the climate by both adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. This study suggests that as the impact of climate change is intensifying daily, it should be addressed through policy changes as soon as possible in order to avoid short term effects such as yield and income loss, and long-term effects such as the abandonment of farming as a profession.

Since drought management has gained much attention in the last decade, the uncertainty in drought assessment under climate change conditions definitely requires further research (Tsakiris and Spiliotis, 2011; Estrela and Vargas, 2012).The differences in the changes of drought characteristics are much more considerable. As a result, irrigated agriculture should be studied carefully in relation to losses in yield due to climate change and drought.

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