Effects of Global Climate Change on Agriculture and Water Resources

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Abstract

It is accepted that one of the most important environmental problems of the present century will be climate change. This will most likely result in the changes in weather patterns, and an increase in the frequency and severity of extreme events, such as floods and droughts. In Turkey as in the rest of the world, global climate change will be cause an increase in the severity and frequency of heat waves, sea level rise, and extreme rainfall and flood events in some regions, but increased drought in others, in a way that will directly affect living conditions.

In a study of 87 countries by the WMO, Turkey was one of 74 the countries affected by drought. According to various climate models, the East Mediterranean Basin and the subtropical zone including Turkey will be experienced a reduction in rainfall especially in winter, but with changes in the duration and severity of rainfall, both flooding and drought are likely. On the other hand, studies on water resources have shown that many catchment areas of the country will be experienced serious water shortages. Turkey is not a water rich country. Available water amount is 1500m^3 per capita. It is expected to decline to 1000 m^3 in 2050 as aresult of population growth and impact of climate change. As the largest user of water, the agricultural sector is expected to be affected by global climate change more than the other sectors. In this study global climate change and its impact on Turkey's agriculture and water resources are evaluated.

Keywords: *climate change, agriculture, water resources, Turkey.*

Introduction

During the recent decades, global climate change has been at the centre of many scientific studies. Global climate change, caused by natural processes as well as anthropogenic factors, is likely the major and the most important environmental issue that will affect the world during the 21st century.

Climate is averaged conditions on weather during long period. Climate system is comprised by complicated interactions among the atmosphere, the ocean, the cryosphere, the surface lithosphere and the biosphere. Energy from the sun drives the earth's weather and climate, and heats the earth's surface; in turn, radiates energy back into space. The earth's climate has exhibited marked natural variations and changes, with time scales varying from millions of years, down to a few years. Over periods of 1 or 2 years, fluctuations in global surface temperatures of a few tenths of a degree have been recorded. Some of these are related to the El Niño-Southern Oscillation (ENSO) phenomenon. Major volcanic eruptions have also had some impacts. Atmospheric greenhouse gases trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse. The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the build up of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide (Solcomhouse, 2007).

The concentration of greenhouse gases in the atmosphere continues to increase (Figure 1). Atmospheric CO_2 has increased from a pre-industrial concentration of about 280 ppm to about 385 ppm at present. CO_2 concentration data before 1958 are attained from ice core measurements in Antarctica and 1958 onwards are from the Mauna Loa measurement site. It is evident that the rapid increase in CO_2 concentrations has been occurring since the onset of industrialization. The increase has closely related to the increased use of fossil fuels (UNEP/GRID, 2007).

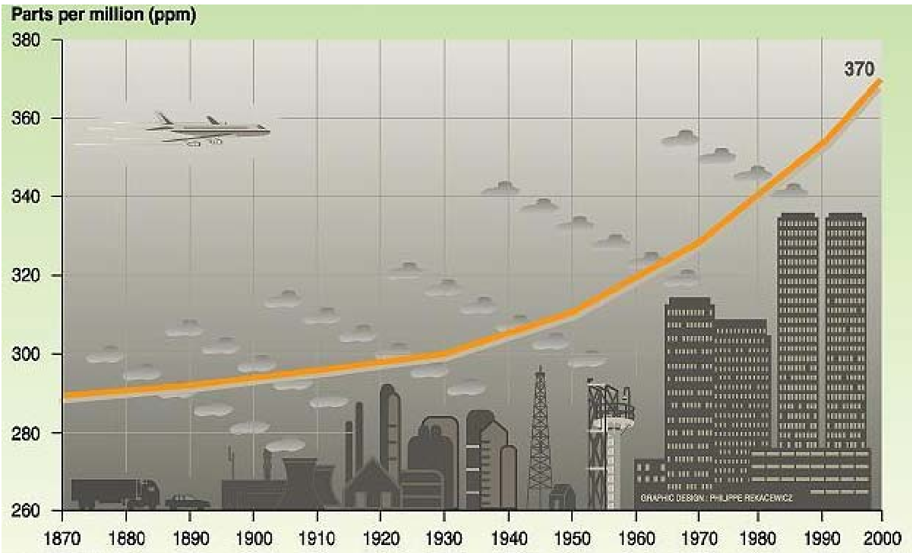

Figure 1. Global atmospheric concentration of CO_2 (UNEP/GRID, 2007).

The potential rise of mean global temperatures and the increase in weather disturbances due to the rapid increase of greenhouse gases in the atmosphere are well documented by the Intergovernmental Panel on Climate Change in 2001. Until recently, it was believed that major climate change took place over thousands of years. For example, a cooling trend of 0.2°C had been observed from 1000 to 1900 A.D. However, during the last century, the global temperature has increased by about 0.6°C when calculated as a linear trend. The last decade was the warmest since the inception of consistent temperature observations in 1880 and 2005 was the warmest year on record (Stein, 2005; Desjardins et al. 2007).

Changes in temperature, precipitation, and atmospheric carbon dioxide (CO_2) levels that affect the profitability of agricultural enterprises could lead to changes in the amounts and locations of cropland and pasture land, the types of crops and livestock produced, and technologies and management practices for individual crops and livestock (Abler et al. 2001).

On the other hand, global climate change will not affect all places on Earth the same way. Climate models predict that warming will be greatest in the Arctic and over land. Models also give a range of temperature predictions based on different emission scenarios (Figure 2). If humans limit greenhouse gas emissions (low growth), then the temperature change over the next century will be smaller than the change predicted if humans do not limit emissions (high growth) (IPCC, 2007)

Most climate change scenarios project that greenhouse gas concentrations will increase through 2100 with a continued increase in average global temperatures (IPCC, 2007). How much and how quickly the Earth's temperature will increase remains unknown given the uncertainty of future greenhouse gas, aerosol emissions and the Earth's response to changing conditions. In addition, natural influences, such as changes in the sun and volcanic activity, may affect future temperature, although the extent is unknown because the timing and intensity of natural influences cannot be predicted.

Advancements in model simulations, combined with more data on observed changes in climate, have led to increased confidence in projections of future temperature changes. In its 2007 assessment, IPCC for the first time was able to provide best estimates and likely ranges for global average warming under each of its emissions scenarios. Based on plausible emission scenarios, the IPCC estimates that average surface temperatures could rise between 2°C and 6°C by the end of the 21st century.

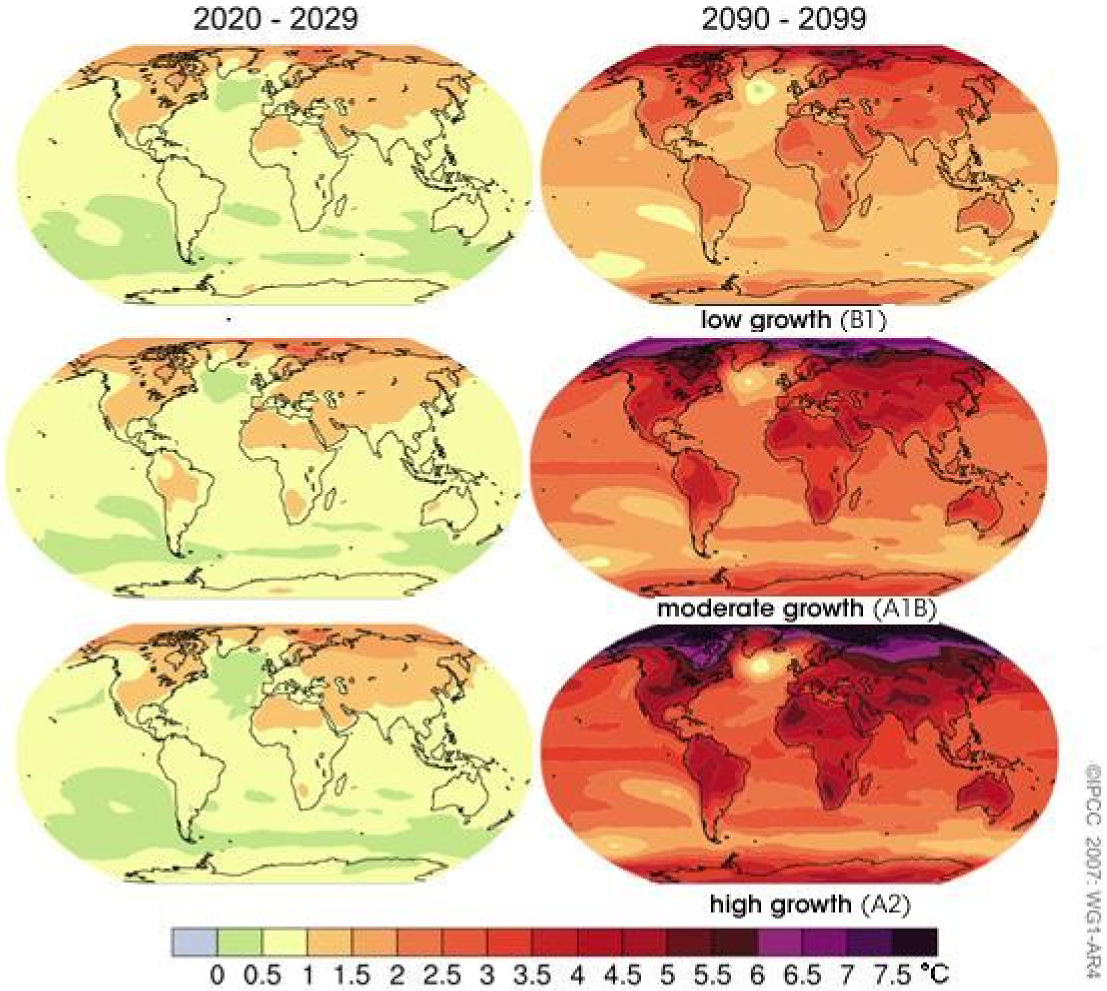

Figure 2. Projected future regional patterns of warming based on three emissions scenarios (low, medium, and high growth) (IPCC, 2007).

According to scenarios, relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999 can be seen from Figure 3. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. Both winter and summer months in Turkey there will be more than 20% decrease in precipitation.

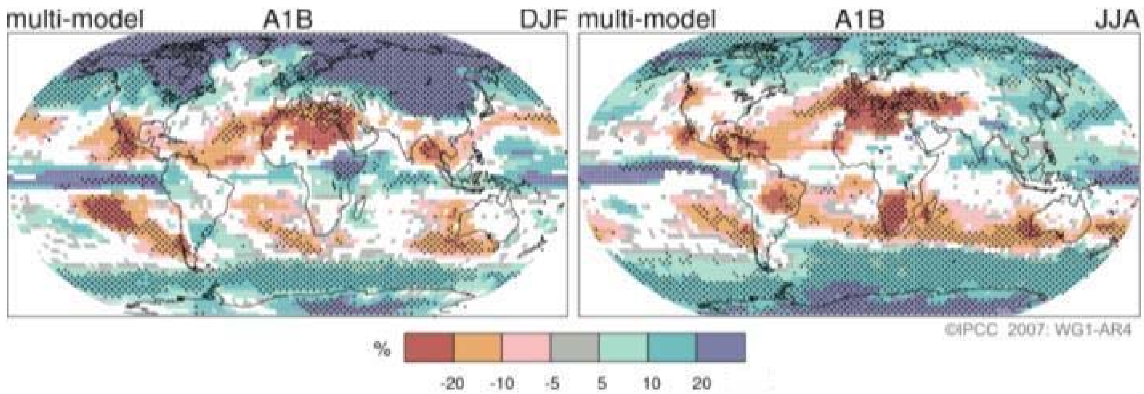

Figure 3. Projected changes in precipitation (IPCC, 2007)

Potential climate changes impact

Scientists expect that the average global surface temperature could rise 0.7-2.5°C in the next fifty years, and 1.4-5.8°C in the next century, with significant regional variation. Evaporation will increase as the climate warms, which will increase average global precipitation especially northern Europe and Canada. Soil moisture is likely to decline in many regions like Mediterranean and tropics, and intense rainstorms are likely to become more frequent. Sea level will likely to rise in many coastal areas. Climate change magnifies existing health, environment and social problems (Figure 4).

Effect of global climate change on agriculture

Global climate change will affect all economic sectors to some degree, but the agricultural sector is perhaps the most sensitive and vulnerable. Possible benefits and drawbacks of global climate change on agriculture are shown Figure 5. World agriculture, whether in developing or developed countries, remains very dependent on climate resources. The impact of climate variability and change on agricultural production is important at local, regional, national, as well as global scales. Crop yields are not only affected by variations in climatic factors such as air temperature and precipitation, but also the frequency and severity of extreme events like droughts, floods, hurricanes, windstorms, and hail (Alexandrov and Hoogenboom, 2000).

A number of indirect impacts may also be experienced such as changes in distribution, frequency and severity of pests, fire frequency, weed infestations, disease and soil conditions. Higher levels of carbon dioxide may stimulate plant growth by increasing the efficiency of water use, although the magnitudes of these effects under field experiment conditions varies from species to species. The impact of global warming on crop productivity and crop yields will depend greatly on the combination of secondary effects. In areas that may receive more precipitation in the future, and can adapt to enhanced CO_2 conditions, greater productivity may be possible, as growing seasons will potentially be extended. In areas where water will become a limiting factor, productivity could potentially be reduced due to the added stress of heat and salinisation.

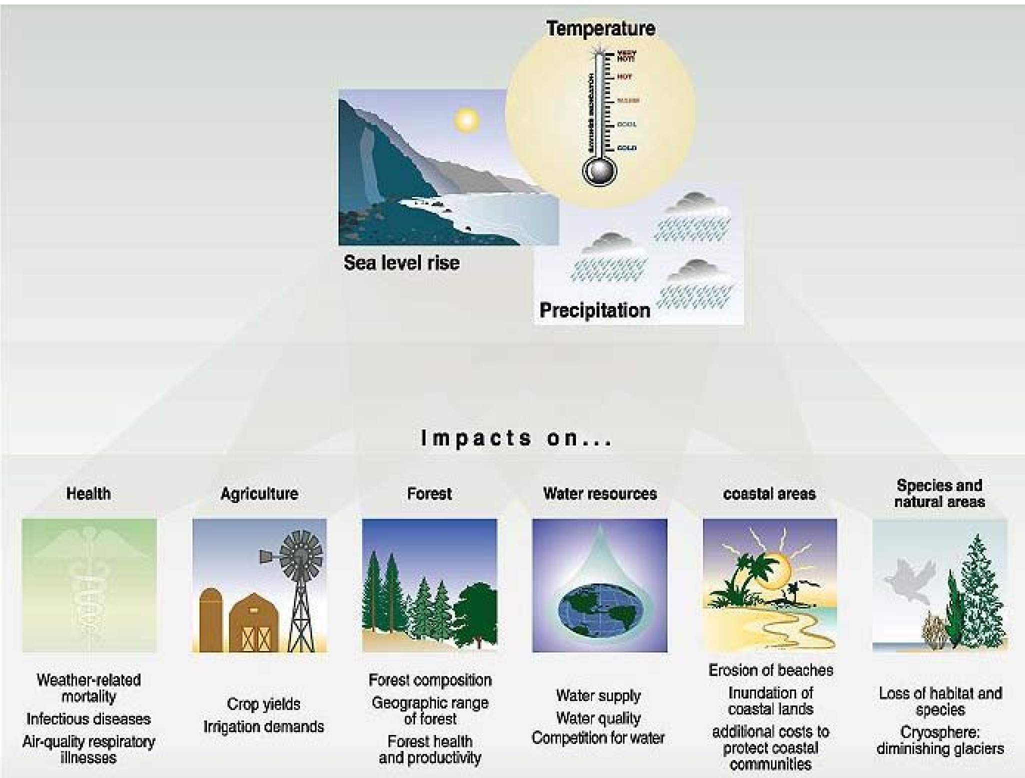

Figure 4. Potential climate change impact (UNEP/GRID, 2008)

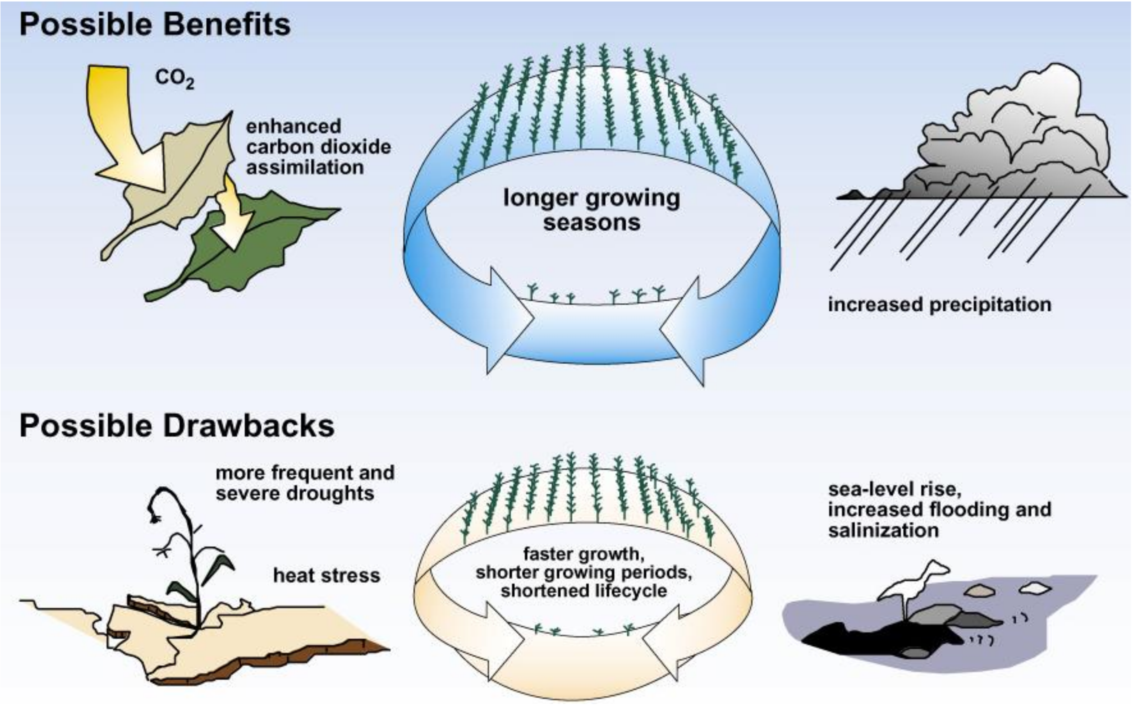

Figure 5. Possible benefits and drawbacks of climate change on agriculture (Crimp, 2000).

Salinisation occurs when soils become inundated with mineral salts from the lower soil profile. As salt is water soluble it can move through the soil profile in solution. During period of extreme heat the water is removed from the soil through evaporation, leaving the salt behind in the upper soil layers. If this process continues long enough, the concentration of salt becomes too high for most of the plants and they may die. On the other hand, plants that require the process of photosynthesis to grow need to assimilate CO_2. If the availability of CO_2 increases some plants are adapted to utilize this increase in order to enhance growth. Not all plant species will be able to utilize the enhanced levels of CO_2 and will thus not enhance their growth potential.

According to computer-modelled study conducted by the researchers at the NASA Goddard Institute for Space Studies, 2°C increase in temperature will have positive effect on cereal yield, but 4°C increase will affect the yields negatively (Figure 6). Downing et al. (2000) reported that increased CO_2 concentration will increase wheat yields due to the enhanced CO_2 assimilation (Figure 7).This figure shows a mean yield increase of 28% for doubling of current CO_2 concentrations (Olesen and Bindi, 2002).

Impacts of Climate Change on Turkey’s Agriculture and Water Resources

Water is the most critical resource for Turkey’s agricultural ecosystem. Average annual precipitation in Turkey is 643mm, and total available water has been determined as 112 billion m^3/year, of which 98 billion m^3 is surface water and 14 billion m^3 is underground water.

In order to be classified as a water-rich country, annual available water should exceed 8000-10000 m^3 per capita. In Turkey, per capita available water is 1500 m^3 and will decrease to around 1000 m^3 by the year 2050. Considering these figures, it can be seen that by the year 2050 or 2100, a serious water crisis will impact the production systems of Turkey (DSI, 2008a).

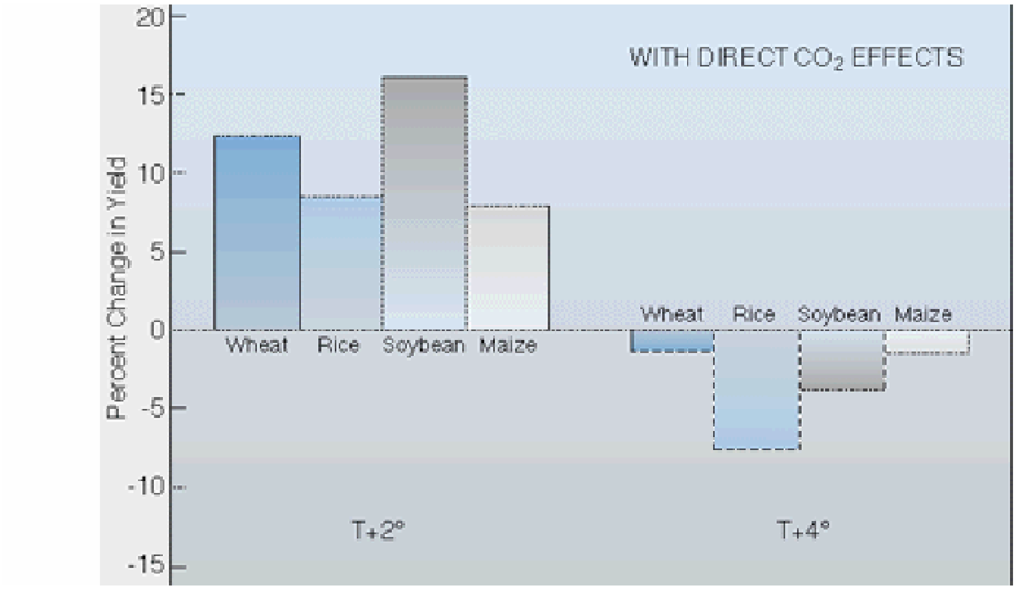

Figure 6. Calculated change in world- averaged crop yields of four cereal grains as a result of increases of 2 and 4°C in average global surface temperature, with direct effects of CO_2 on plant growth and water use (Rosenzweigh and Hillel, 1995).

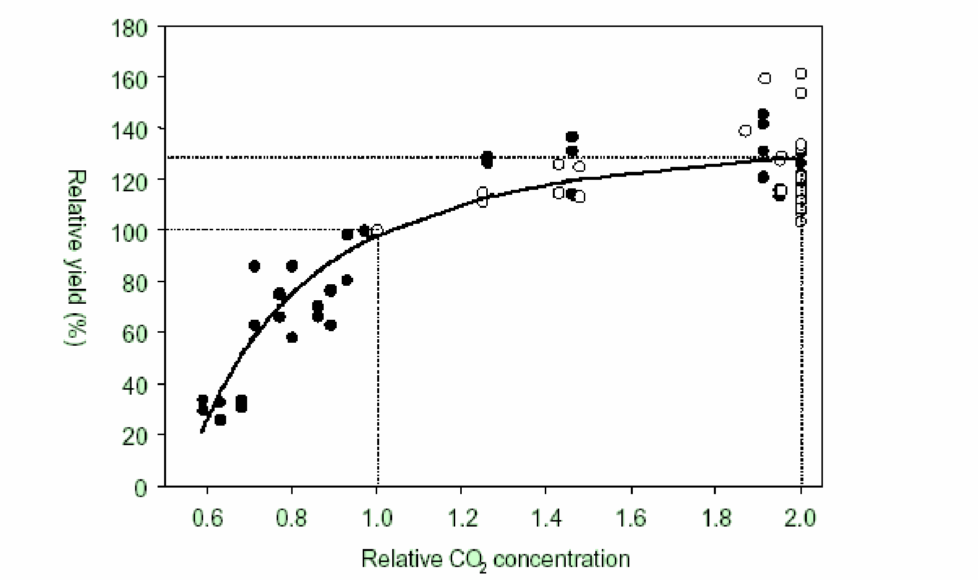

Figure 7. Wheat yields with increased CO_2 concentration

There are 26 major river basins in Turkey (Figure 8). When total water potentials are considered, 17 river basins out of 26 have no water stress problems. But Meriç, Ergene, Sakarya and Kızılırmak river basins are experiencing chronic water stress, and the Küçük Menderes basin is close to the absolute water stress level (Onder and Onder, 2007).

Figure 8. Water Stress Level on the River Basins of Turkey (Onder and Onder, 2007).

Irrigation has a vital role in increasing and stabilizing agricultural production in Turkey because of the scarcity and unreliability of precipitation during the growing season in most of the country (Kanber and Unlu, 2004). If all irrigable lands were opened to irrigation, roughly 200 km^3 of water deficit could be expected. Thus, water is a constraint on agricultural productivity in comparison to the extent of existing irrigable land resources, especially in the Mediterranean, Central and Southeast Anatolia regions. Turkey has approximately 26 Mha of irrigable land and the water resources allocated for irrigation are not enough to irrigate all of this area. It is estimated that an area of no more than 8.5 Mha could be economically irrigated with present water resources (Onder and Onder, 2007).

Agriculture, with a 74% share, is the biggest water user in Turkey, followed by domestic (15%) and industry sectors (11%) (DSI, 2007). Agricultural irrigation is applied by surface irrigation methods with 94%, sprinkler irrigation and drip irrigation with 6% (DSI, 2008b). An important reason for future water shortage prospects relating to the resource of available water is the widespread use of inefficient irrigation methods. However, in recent years great importance has been placed on improving irrigation efficiency, and there have been considerable improvements on the application more efficient irrigation methods.

At the same time however, the most marked effect of global climate change on the Mediterranean Basin is expected as more drought conditions. Precipitation in the Mediterranean Basin as a whole has decreased by 20% in the last 25 years. It is also expected that decreasing trend will be continued and a serious drop in precipitation is predicted in Turkey's semi-arid Mediterranean, Aegean and Central Anatolian regions.

In addition, sea levels in the Mediterranean are expected to rise by 20-40 cm by 2050, and this will affect river deltas, particularly in Turkey and Algeria (WWF, 2007).

It is estimated that summer temperatures in Turkey will rise by 3°C, and winter temperatures by 1-2°C. According to results from the General Circulation Model (GCM), winter precipitation in southern areas will considerably decrease (Kitoh et al. 2004). Similarly, according to Kondo (2005), summer temperatures in many parts of Turkey will rise by 3-5°C, and while spring precipitation may increase by 5-50 mm, summer precipitation may decrease by 5-20 mm. A project concerned with the effects on agricultural production of climate changes in arid areas (ICCAP) predicted that winter precipitation in Turkey would fall by 42-46% by the 2070s, but that crop requirements would rise by 5-10% (Nagona et al. 2007).

Growing Season Length (GSL) is the count between first span of at least 6 days with T>5°C. GSL has increasing over Turkey except for coastal regions (Figure 9). Projected average increase is 35 days in 100 years. This will have a positive effect on agricultural products. However orchard crops will be negatively affected, since they require certain period of cool conditions during winter known as vernalization (Sensoy et al, 2007).

Global climate studies examining the larger geographical areas of the East Mediterranean and the Middle East predict that, along with an expected increase in air temperature of 1-3°C, rainfall will replace snow in winter, annual precipitation will show a significant decrease, the annual flow of rivers will decrease, evaporation losses will increase, the water levels of reservoirs will fall, flood damage will increase because of the rapid melting of mountain snow, and the rapid depletion of this natural reservoir will mean that it will not be able to feed water sources for long periods. If measures are not taken to counter these adverse effects of climate change on the water supply, the country will face serious problems of water security and consequently food security (Önder et al., 2005).

It is estimated that Turkey as a whole will experience serious losses in agricultural production as a result of global climate change. More recent studies have supported these findings (Şaylan and Çaldağ, 2007; Kapur et al. 2007).

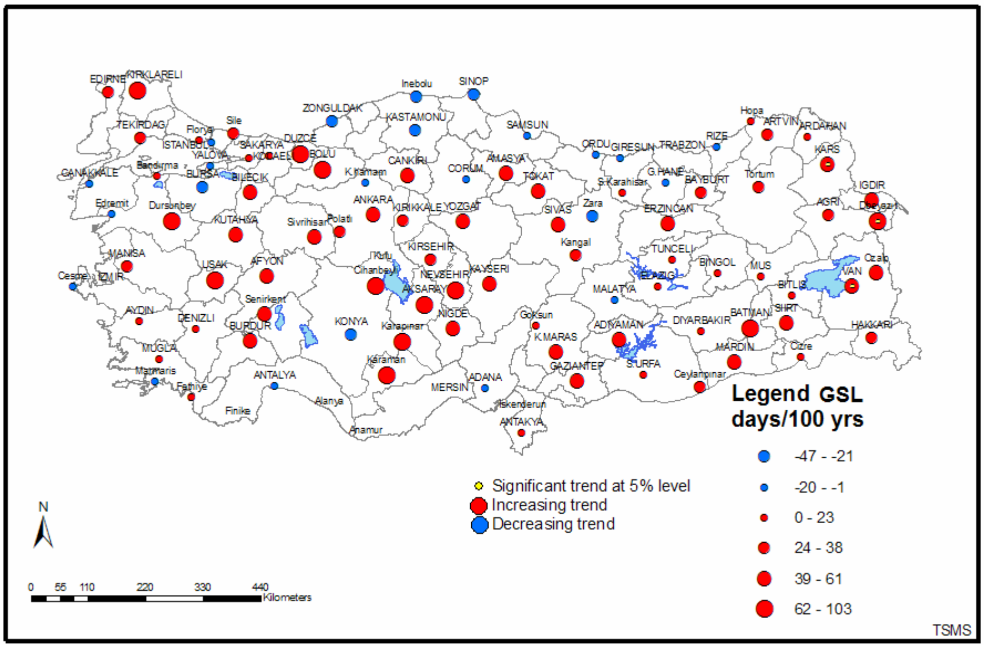

Figure 9. Trend in growing season length in Turkey from 1971 to 2004.

Turkey and Mediterranean Basin experienced a very drought year in 2007. The cost of drought to Turkey's agricultural sector was estimated as $ 4.2 billion. Production losses have been determined as 20% for wheat and seedless raisins, 24% for watermelons, 25% for tomatoes, and 17% for sunflowers (TZOB, 2008).

Conclusion

The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the build up of greenhouse gases. It is accepted that one of the most important environmental problems of the present century will be climate change. This will give rise to changes in weather patterns, and an increase in the frequency and severity of extreme events such as floods and droughts. In Turkey as in the rest of the world, global climate change will be cause an increase in the severity and frequency of heat waves, sea level rise, and extreme rainfall and flood events in some regions but increased drought in others, in a way that will directly affect living conditions and production systems.

The impact of climate change on agriculture will be translated through changes in temperature, water balance, atmospheric carbon dioxide composition and extreme events (floods/droughts). The impact of global warming on crop productivity and crop yields will depend greatly on the combination of secondary effects. In areas that may receive more precipitation in the future, and can adapt to enhanced CO_2 conditions, greater productivity could be possible, as growing seasons would potentially be extended. In areas where water will become a limiting factor, productivity could potentially be reduced due to the added stress of heat and salinisation. According to the three different GCM scenarios, only developed countries could convert negative climate effect to positive with their adaptation capacity.

In Turkey, legal arrangements related water sources management and development is available. Environmental dimensions of water developing projects must be evaluated seriously, water management based on water supply should be changed as water management based on water demand.

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