Climate Change In Seyhan Watershed of Turkey: Current Signals and Adaptation Measures

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1. Introduction

Seyhan watershed is located in the east of the Mediterranean Region of the southern Turkey. It consists of some parts of Adana, Kayseri, Niğde, Mersin, Sivas and Kahramanmaraş cities (Fig. 1). The total area of the watershed is 21.741 km^2 and total population is 2.4 million (Anonymous, 2009). 74.8% of population lives in cities and 25.2% lives in rural areas (Anonymous, 2009).

Being the second largest river basin after the Nile in the Eastern Mediterranean, the Seyhan river basin, in agricultural terms, is one of the most important regions in Turkey and in Europe (Anonymous, 2009). The river basin, in regards to biologic diversity, is also one of the richest regions in the world: dry farming, irrigated farming, animal husbandry and a variety of impending agricultural opportunities for local are all present. Main agricultural crops are wheat, corn, barley, oat, cotton, some fruits and vegetables (Anonymous, 2009). People's livelihoods in the watershed mainly rely agricultural activities: 28% make their living from farming, 11% from livestock breeding, and 9,8% from service sector of government. Jobless rate is 18.4% for women and 31.7% for men in the watershed area (Anonymous, 2009).

In terms of geographical structure, the Seyhan River Basin consists of high steppes, mountainous areas, transition zones, low planes and the Cukurova Delta. Due to the altitude variations; various climates are dominant in the Seyhan River Basin. While winters are warm and rainy and summers are arid and hot in the lower parts of the basin; continental climate with cold winters and hot summers and with low rates of precipitation is observed in the upper parts of the basin (Anonymous, 2009).

Vegetation cover differs in great extend in south-north direction according to climate and biogeographic regions (Fig. 2). Natural areas of the southern in most part of the Basin are dominated by maquis formation. Aladağlar Mountains is dominated by coniferous forests. Northern parts are mainly dry steppe with scattered patches of oak shrublands (Zeydanlı & Ulgen, 2009). The watershed can be divided into four subecoregions according to a study done by DKM (Zeydanlı & Ülgen, 2009). These subecoregions are:

Çukurova:

It covers 514.306 hectares of area. It is an alluvial plain under the influence of coastal Mediterranean Climate. Agricultural activities are extensive and most of the subecoregion is converted into agricultural field (circa 261.337 ha).

Aladağlar:

It is covered by the Taurus Mountains and is host to one of the highest peaks of Turkey Medetsiz (3524 m). 254.475 out of 799.915 hectares of this subecoregion is covered with forests. This subecoregion has typical Mediterranean climate but is cooler due to high altitude. Animal keeping is a historical and extensive economical activity in the area.

Tahtalı Mountains:

It is a highly mountainous sub-ecoregion in the southwest of the basin. It has continental climate and is much drier in comparison to Aladağlar. Although it is much similar to Eastern Anatolia with its mountainous features it also bears species of the Central Anatolia low mountain steppe. These mountains are in the transition zone between eastern and western part of Turkey. From a total area of 663.337 hectares, 219.464 hectares are steppe and 24.872 hectares forest.

Binboğa Mountains:

This sub-ecoregion is situated in the northeast of the basin and it is highly mountainous. It has a continental climate. These mountains are much more similar to eastern Anatolia in its biological features and they show transition features like Tahtalı Mountains. With 3011 hectares of forest and 39.61 hectares of steppe, the ecoregions totals 59.470 hectares.

Fig. 1. Map of the Seyhan Watershed.

2. Current signs of climate change in the watershed

There are several climate related indicators that show a gradual change in the climate of the watershed. Table 1 shows the highest temperatures reported in each month from the years 1970-2011. This data reveal that 9 out of 12 of these highest recorded temperatures were observed in last 20 years. On the other hand, mean annual temperatures in Adana meteorological station shows a gradual uptrend during the last 40 years period (Fig. 2), while annual precipitation data show a decreasing downtrend in the same period (Fig. 3). Annual discharge data of the Seyhan river also indicates a decrease in river flow during the last decades (Fig. 4). The largest decrease in monthly flow was observed in February. In addition, the total number of forest fires occurred Adana Forest Regional District in each year has shown an increase in last years, too (Fig. 5).

Increasing temperatures and decreasing precipitations has raised the demand for additional water for irrigation. Increasing forest fires forced Forest Service to take extra measures to fight with fires. Forest Service has rented helicopters to efficiently fight with fire. As a result, the area of forest burned in each year in Adana has decreased recently (Personal Communication). Intensive insect outbreaks were observed during the period between 1995 and 2005. Recently these outbreaks have decreased (Personal Communication).

Table 1. The highest daily temperatures measured in Adana Meteorological Station between the years 1971-2011 (Data from General Directorate of Meteorology).

Jan.	Feb.	March	April	May	June	July	August	Sept.	October	Nov.	Dec.
26.5	25.0	32.0	37.5	40.6	41.3	44.0	43.8	43.2	39.4	33.3	30.8
1971	1979	2008	2008	1990	2002	1978	1998	1994	1994	1992	2010

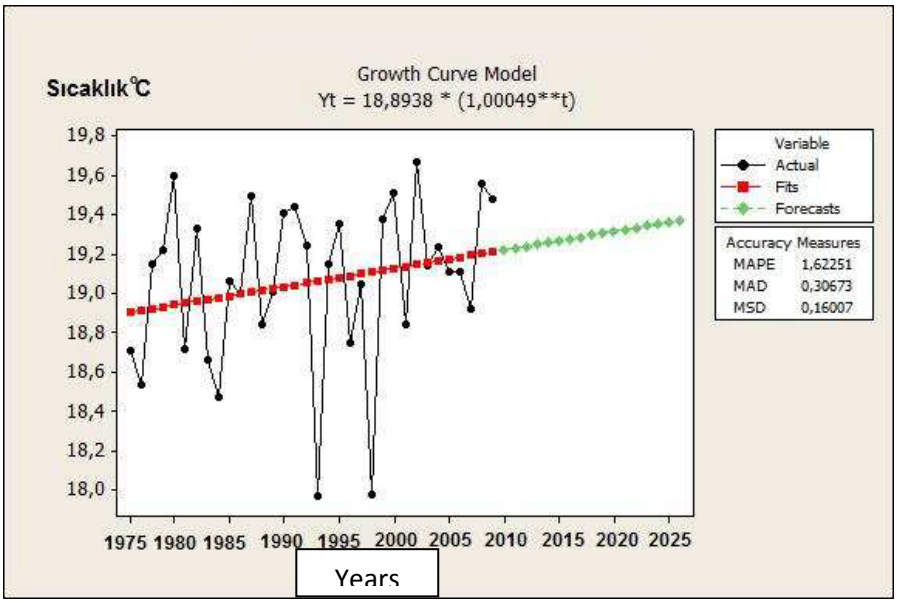

Fig. 2. Mean annual temperatures in Adana from 1970 to 2011(Bahadır, 2011)

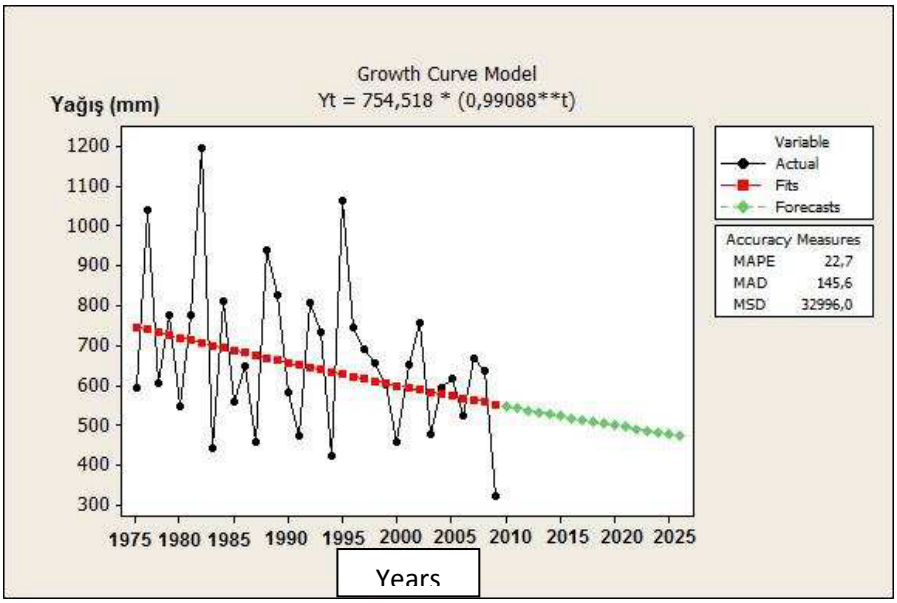

Fig. 3. Total annual precipitation in Adana from 1970 to 2011 (Bahadır 2011).

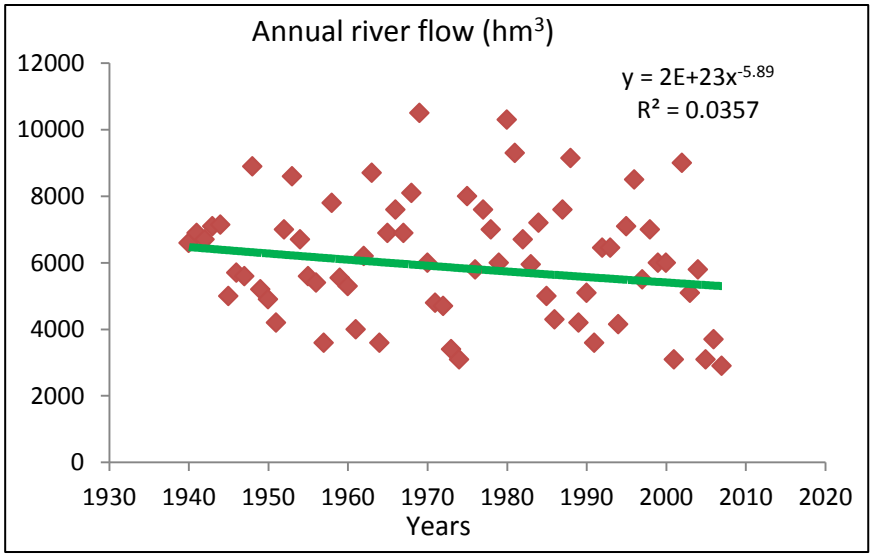

Fig. 4. Total annual discharges in Seyhan river from 1940 to 2009 (Data From SHW(DSI)).

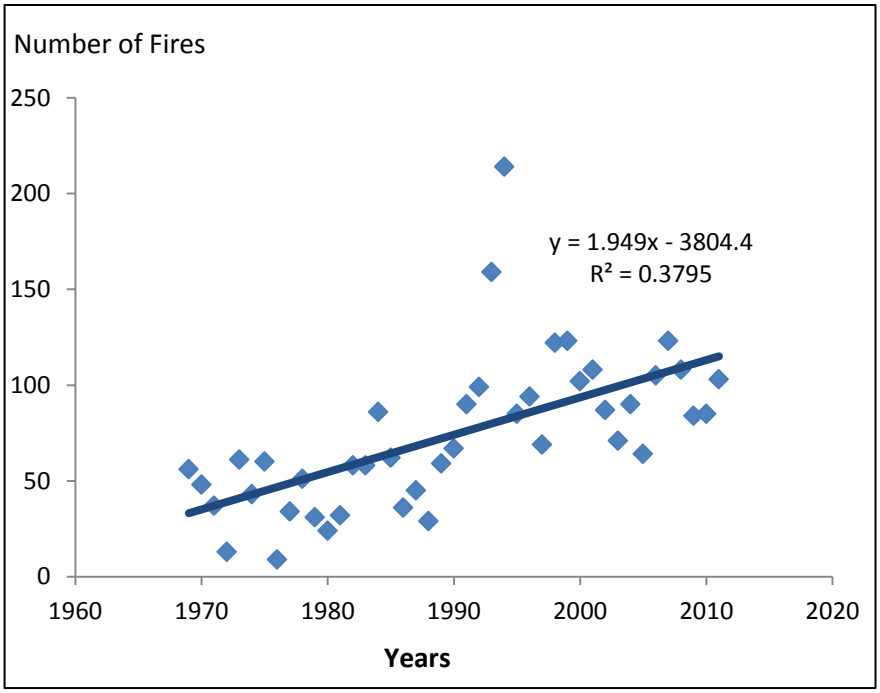

Fig. 5. Total number of fires in Adana Forest Area in each year (Data from Adana Forest Regional Directorate, Personal Communication).

3. Climate change projections and expected impacts of Climate Change for the watershed

According to the climate projections for Seyhan watershed for the year 2070[1] the air temperature is expected to rise by 2-3.5 °C, precipitation is expected to decrease by 25-35%, mountain snow pacts

[1] These projections were developed by Research Institute for Humanities and Nature (RIHN, Japan), the Scientific and Technological Research Council of Turkey (TUBITAK) and the Cukurova University.

are expected to melt earlier, irrigation water is expected to decrease, agricultural product patterns are expected to be forced to change, dry and irrigated farming regions are expected to be affected, demand for the use of groundwater is expected to increase and thus a risk of pollution is expected, and finally it is also expected that in coastal regions salt water from the sea will mix with inland ground water up to 10 km inshore (Ref.: http://www.iklim.mdgf-tr.org).

In addition, according to the preliminary studies performed by the International Panel on Climate Change, the Seyhan River Basin has been identified as the most sensitive and vulnerable region to climate change within the Mediterranean region (Ref. : http://www.iklim.mdgf-tr.org).

When we look at impacts of Climate Change for each sector, agriculture, forestry, environment, and water, are the major sectors that will be influenced by Climate Change more than the other sectors.

For the **forest sector**; effects like more insect outbreaks and pest damage, decrease in biomass growth, upward movements in plant belts, and increase in forest fires are expected (Table 2). According to a modeling study done by DKM (Zeydanlı and Ulgen) (2009), significant changes in distribution of Taurus cedar (*Cedrus libani*), brutian pine (*Pinus brutia*), black pine (*Pinus nigra*), and Taurus fir (*Abies cilicica*) are expected in Seyhan Watershed.

The results of the study showed that 93.1% of the forest area of Taurus cedar, 56.2% of the forest area of brutian pine, 68.5% of the forest area of black pine and 85.7% of the forest area of Taurus fir will not be suitable for the growth of related species in year 2050. But it should be kept in mind that the study only used distribution data of the each species in Seyhan Watershed to model and predict the future distributions of them. For example distribution of brutian pine starts from Egypt and extends to North upto Blacksea coast. Therefore, the results of the study need to be interpreted carefully.

For the **agriculture sector**, effects like decrease in agricultural production and soil quality, severe droughts, water scarcity, shifts in crops, more insect outbreaks and pest damage, land use change and depletion in ground water level are expected (Table 2).

Water will be the most effected sector in the Seyhan watershed. Agriculture, energy and public sectors are strongly depending on water in the watershed. Expected decrease in precipitation and increase in evapotranspiration will make water less available for the future. Also, increases in the prices of drinking and irrigation water are expected in the future. This will create additional economical pressure for the people in the watershed. Expected climate change impacts on the sector are listed in Table 2.

One of the main impact that **environment sector** might have is the decrease of biodiversity in the watershed. Decrease in precipitation, increase in temperature, land use change, shifts in plant belts and overexploitation of natural resources might cause significant decrease in biodiversity in the watershed.

A summary of climate change impacts, their sensitivities and related adaptive capacities are provided in Table 2. The sensitivities and adaptive capacities are gathered from existing studies and field examinations in the watershed. Current adaptive capacities that each sector has; are not enough to overcome negative effects of climate change in the watershed. But, it needs to build on them and strengthen them to eliminate the challenges created by climate change.

Table 2. Some important climate change impacts and their vulnerabilities for the sectors in the watershed

CC Signals	Sector	Impacts (biophysical and socio-economic)	Sensitivity	Adaptive Capacity
Decrease in annual precipitation and increase in average temperatures and CO_2 concentration	**Agriculture**	-Decrease in yield	➢ Lack of enough training for CC ➢ (dependence on one crop in some areas) ➢ Lack of integrated watershed management ➢ Low income of farmers ➢ Decrease in size of land each farmers has	-Existence of Universities and Research Stations to do research regarding impact of CC -Existence of Irrigation Unions -There are agricultural extension service offices in local areas
		-More insect outbreaks and damage in croplands	➢ Lack of enough extension works ➢ Lack of enough info and awareness regarding pest damage ➢ Lack of diversity in some areas	-well experienced technical staff
		-Water scarcity and decrease in soil moisture	➢ Lack of drip irrigation system ➢ Lack of drought action plan ➢ Lack of scientific info regarding how each crop resistant to drought ➢ Lack of enough water for irrigation ➢ Low organic matter ratio in soils of upper watershed(low water holding capacity)	-Existence of Universities and Research Stations to do research regarding impact of CC -Existence of Irrigation Unions -There are agricultural extension service offices in local areas
		-Rise in water prices	➢ Lack of enough water for irrigation ➢ Increase in demand of water for irrigation	-Existence of well organized and experienced departments of DSI
		-Change in land use	➢ Lack of good monitoring system for land use change	-Availability of info and technical equipments and staff to follow land use change
		-Shifts in main crops	➢ Lack of crop diversity in some areas	-Existence of Universities and Research Stations to do research -There are agricultural extension service offices in local areas
		-Depletion in ground water level	➢ Lack of drought action plan ➢ Lack of enough water for irrigation in some areas ➢ Lack of drip irrigation system in some areas ➢ Lack of crop diversity in some areas (dependence on one crop in some areas) ➢ Lack of alternative water resources in some areas ➢ Fewer intersectoral cooperation ➢ Lack of integrated watershed management	- Existence of Universities and Research Stations to do research related to drought - Existence of well organized State Hydraulic Works (SWH) Regional Directorate to cope with problems -existence of alternative water resources

	Water	-Increased demand for water	➢ Lack of training regarding water saving techniques ➢ Lack of drip irrigation system ➢ Lack of enough water ➢ Poverty of farmers to pay for water ➢ Lack of enough training regarding CC impacts on water resources	- Existence of Universities to do research related to CC -Existence of well organized State Hydraulic Works (SWH)Regional Directorate to cope with problems -Increase in the area of forest in the region
		-Increase in water pollution	➢ Lack of enough waste water treatment ➢ Pollution in ground and surface water resources due to over fertilization and pest control ➢ High sediment concentrations in stream waters ➢ High erosion rate in some areas	-Existence of well organized State Hydraulic Works (SWH)Regional Directorate to cope with problems - Existence of Universities to do research related to CC -Experience of SHW's staff in erosion control and streambank stabilization works -Increase in erosion control studies
		-Decrease in availability of water for hydropower	➢ Limited availability of alternative energy sources ➢ High energy prices	-Increasing investment in alternative energy sources
	Environment	-Decrease in biodiversity	➢ Existence of refuge areas in the watershed that does not have legal protection ➢ Lack of scientific info regarding how endemic and endangered plant and animal species will react to CC impacts	-Existence of NGO's that care about environment - Existence of Universities to do research related to CC
		-Increase in environmental pollution	➢ Pollution in ground and surface water resources due to over fertilization and pest control	Existence of NGO's that care about environment - Existence of Universities to do research related to CC
	Forestry	-Decrease in annual biomass growth	➢ Lack of drought action plan ➢ Lack of scientific info regarding how much each species resistant to drought ➢ Lack of enough water for irrigation ➢ Lack of drip irrigation system ➢ Lack of crop diversity in some areas (dependence on one crop in some areas) ➢ Lack of old-growth forests ➢ No protection of climatic refuge system ➢ Fewer intersectoral cooperation ➢ Lack of integrated watershed management	-Existence of Universities and Research Stations to do research related to CC - Experience of GDF's staff in erosion control and afforestation studies - Existence of well organized Regional Directorate of Forestry to cope with problems
		-Upward movement in plant belts	➢ Lack of good monitoring system for land use change ➢ Lack of scientific info regarding how species will react to CC ➢ Gap in regulations controlling conversion of lands	-Existence of Universities and Research Stations to do research related to CC -Existence of well organized Regional Directorate of Forestry to cope with problems

			from forests to grasslands and from grasslands to forests	
		- Increase in forest fires	➢ Lack of forest diversity (structural and species wise) ➢ Lack of enough maintenance ➢ Lack of training regarding fire fighting	-Existence of good capacity to fight fire in Forest Service (Existence of fire helicopters etc.) -Existence of fire breaks in forests -Existence of well-known researchers working on forest fires in universities
		-More insect outbreaks and pest damage	➢ Lack of enough info and awareness regarding pest damage ➢ Lack of diversity in some areas ➢ Lack of enough maintenance	-well experienced technical staff
	Social and economic sectors-	-Reduced income	➢ Low income rate ➢ Low education level especially in rural areas ➢ Limited income diversity ➢ High energy prices	-Good performance of overall economy
		-Migration to big cities	➢ Unplanned city development ➢ Limited infrastructure in big cities	-Good performance of overall economy
Increased weather anomalies	**Environment**	-Increased floods and landslides	➢ Intensive settlement in alluvial plains and riparian areas ➢ Lack of early flood warning system ➢ Destruction of riparian forests ➢ Channelization of streams (destruction of meanders) (Increases carrying capacity and speed of water causing more damage)	-Existence of well organized State Hydraulic Works (SWH) Regional Directorate in Adana to cope with problems
	Agriculture	-Reduced crop yield due to frost and overheat damages	➢ Limited alternative income sources of farmers	-Existence of farmers extension services
	Forestry	-Increased tree mortality due to heat waves	➢ Increased stress in trees due to low maintenance in stands	-Existence of experienced technical staff

4. Socio-economical Consequences of Climate Change Impacts on Forest Goods and Services (FGS)

Forests provide lots of services to other sectors that are called ecosystem services. These services are inter-alia: erosion control, oxygen production, carbon sequestration, protection of biodiversity, stabilization of water flow, soil protection, food for livestock, and additional income for villagers through ecotourism, non-wood forest products and honey forest establishments etc. Non-wood forest products that provide important source of income for forest service and villagers are peanuts of umbrella pine, laurel (bay leaves), resin production and rosemary production. Detailed explanations of each of these products are given in section 1.5.

Continuity of services provided by forest ecosystems depends on the health of forest ecosystems against biotic and abiotic stresses. Climate change is one of the main stress factors for the forest ecosystems in Seyhan Watershed. Possible socio-economical consequences of climate change impacts on FGS are summarized in Table 3. Climate change will negatively affect forest goods and services and it will reduce the magnitude of benefits they provide to the other sectors in the watershed.

Climate change will significantly reduce timber production, carbon sequestration, water quality, soil stabilization, erosion control, recreation, ecotourism, non-wood forest products and biodiversity functions of forests of Seyhan watershed. To overcome these negative effects of climate change, adaptation measures that listed in Table 3 need to be carefully implemented in the watershed.

Table 3. Climate change impacts and their socio-economical consequences on FGS

Impacts of CC	Vulnerability	Adaptation Options	Socio-Economic Impacts of Climate Change on FGS
Increase in forest fires	➢ Lack of forest diversity (structural and species wise) ➢ Lack of enough maintenance ➢ Lack of training regarding fire fighting	➢ Mix of stands (age and species) ➢ Protection of mix of diversity ➢ Try to sustain diversity ➢ Up-date Forest Management Plans (UNDP pilot site: Poz, option for coop.) ➢ Prevention: awareness of school children to prevent forest fires ➢ Consideration of controlled fire ➢ Maintenance in stands to decrease fire load ➢ Introduce other species resilient to forest fires ➢ Training of public for forest fire fighting	-Reduced income -Migration to big cities -Lost of property -Lost of crop -Lost of soil due to increased erosion -Lost of livelihood -Reduced timber production -reduced recreation and ecotourism -decrease in carbon sequestration -more floods
Decrease in annual precipitation and increase in average temperatures and CO_2 concentration	➢ Lack of drought action plan ➢ Lack of scientific info regarding how each species resistant to drought ➢ Lack of enough water for irrigation ➢ Lack of drip irrigation system ➢ Lack of crop diversity in	➢ Change/mix species to drought tolerant types on sensitive sites. ➢ More thinning to reduce moisture demand in open stands. ➢ Increase public awareness and vigilence. ➢ More research on finding drought resistant ecotypes of species ➢ Establishing drought action plan ➢ Widespreading drip irrigation system	- Reduced income - Migration to big cities - Shift in crop type - More investment on irrigation systems - Decrease in livestock -Lost of biodiversity -reduced timber production -reduced carbon sequestration

	some areas (dependence on one crop in some areas) ➢ Lack of old-growth forests ➢ No protection of climatic refuge system ➢ Fewer intersectoral cooperation ➢ Lack of integrated watershed management	➢ Promoting alternative crops ➢ Protecting old-growth forests ➢ Protection of climatic refuge system ➢ Shift to less water-consuming crops ➢ Enhance intersectoral cooperation ➢ Establish integrated watershed management plans	-increased erosion and floods -decrease in quality of water
More insect outbreaks and pest damage	➢ Lack of info and awareness regarding pest damage ➢ Lack of diversity in some areas ➢ Lack of enough maintenance	➢ Enhanced pest and disease monitoring and intervention where appropriate ➢ Increase species diversity ➢ Improved maintenance ➢ Establishment of early warning system	-Reduced income -Lost of crop -reduced timber production and carbon sequestration -reduced recreation and ecotourism -increased erosion
Depletion in ground water level	➢ Lack of drought action plan ➢ Lack of enough water for irrigation in some areas ➢ Lack of drip irrigation system in some areas ➢ Lack of crop diversity in some areas (dependence on one crop in some areas) ➢ Lack of alternative water resources in some areas ➢ Fewer intersectoral cooperation ➢ Lack of integrated watershed management	➢ Effective water management system ➢ Protection of existing wetlands ➢ Protecting forests ➢ Shift to less water-consuming crops ➢ Establishment and protection of riparian forests ➢ Support use of drip irrigation system ➢ Enhance intersectoral cooperation ➢ Establish integrated watershed management plans	-Reduced income -Shift in crop type -Lost of crop -Lost of biodiversity -reduced recreation and ecotourism -reduced timber production and carbon sequestration
Sea level rise	➢ Lack of awareness regarding effect of sea level rise ➢ Regulation controlling inhabitance in riparian areas and sea shores does not consider CC ➢ Lack enough scientific info regarding salt tolerance of existing species	➢ Increase public awareness ➢ Effective coastal and riparian management system ➢ More research on salt tolerance of species ➢ Protect wetlands and eucalyptus forests ➢ Establish dikes to protect lands and settlement areas ➢ Establish sand dune control system	-Lost of property -Migration to uplands -Reduced production -Lost of biodiversity -decrease in forest area -decrease in timber production and carbon sequestration
Upward movement in plant belts	➢ Lack of good monitoring system for land use change ➢ Lack of scientific info regarding how species will react to CC ➢	➢ Establish more seed stand on low elevations ➢ Monitor land use change closely ➢ Select planting stock with an origin up to 300m lower elevation of site	-Land use change -Reduced livestock due to conversion of some of the alpine grassland into forests
Increased floods and landslides	➢ Intensive settlement in alluvial plains and riparian areas ➢ Lack of early flood warning system	➢ Protect riparian areas from settlement ➢ Establish riparian forests in the areas where existing forests have been destroyed ➢ Land use classification	-Lost of property -Lost of livelihood -damage of riparian forests

5. Conclusions

Climate change is a significant threat for the Seyhan Watershed as it is for the other parts of the Mediterranean Region. Precipitation, mean annual temperatures, maximum monthly temperatures, river flow and forest fire data of the watershed show signs of changing climate in the watershed.

To overcome challenges that climate change brings to watershed, sector's vulnerabilities should be reduced and sector's adaptive capacities should be strengthened. Also, research related to adaptation of major ecosystems, forest tree species and agricultural crops to climate change need to be done as early as possible by the universities and research institutions in the region. There are also changes that need to be done in policy level to strengthen cooperation among sectors. In addition to these measures, training of NGO's, staff and managers is necessary to have a good adaptation progress in the watershed.

Forest ecosystems provide important goods and services that the other sectors benefit. These goods and services also contribute other sectors strength to overcome negative impacts of climate change and improve their adaptive capacity to cope with climate change. In addition, they generate additional income for villagers. Forest ecosystems of the Seyhan watershed have similar functions, too.

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