

CLIMATE CHANGE AND ORIENTAL SPRUCE (*PICEA ORIENTALIS*) ECOSYSTEMS IN EASTERN BLACKSEA REGION OF TURKEY

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Abstract: Climate change has been getting more attention from scientific community recently. Eastern Black Sea Region of Turkey will get significant influences from the climate change according to regional climate model (RegCM3). Oriental spruce (*Picea orientalis* L.) is an important tree species of Turkey and it only grows in the Eastern Black Sea Region of Turkey. With the increase in global warming, spruce forests started to have serious bark beetle problems. More than 200 000 trees died in the region recently due to bark beetle attack. We used existing literature related to oriental spruce and future climate of the region and field observations done in the different times to assess current status of the spruce stands. Future climate of the region has been predicted using RegCM3 regional climate model. Climate change could significantly influence distribution, diversity, structure and stability of the oriental spruce ecosystems. According to RegCM3 regional climate model, the temperatures will increase 2-4 °C in the region in the next century. Future climate scenarios predict 200-300 mm increases in precipitation in the eastern part of the region while the western part won't have any increase in precipitation in the next century. Temperature increases in the western part of the region can cause more stress on spruce trees and would probably increase bark beetle attacks. Also, fire could become an important threat in the western part of the region. It is possible to observe 400-800 m upward shift in the spruce belt in the western part. Treeline of spruce stands would probably move upward both in western and eastern part of the North-eastern Blacksea Region.

Anahtar Kelimeler: İklim değişimi, Doğu ladini, İklim tahmini, Böcek salgını

DOĞU KARADENİZ BÖLGESİ'NDE İKLİM DEĞİŞİMİ VE DOĞU LADİNİ (*PICEA ORIENTALIS*) EKOSİSTEMLERİ

Özet: İklim değişimi son zamanlarda bilim insanlarının dikkatini önemli ölçüde üzerine çekmektedir. Bölgesel İklim Modeline (RegCM3) göre Doğu Karadeniz Bölgesi iklim değişiminden önemli ölçüde etkilenecektir. Doğu ladini ülkemizin önemli bir orman ağacı olup sadece Doğu Karadeniz bölgesinde yayılış göstermektedir. Küresel ısınmanın artması ile doğu ladini ormanları önemli düzeyde kabuk böceği problemi ile karşı karşıya kalmışlardır. Bölgede 200.000 den fazla ladin ağacı kabuk böceklerinin zararından kurumuştur. Bu çalışmada mevcut literatürlerin ve arazi gözlemlerinin ışığında, iklim değişiminin ladin ormanlarına etkisi irdelenmiştir. Bölgenin gelecekteki iklimi RegCM3 modeli kullanılarak tahmin edilmiştir. İklim değişimi, ladin ekosistemlerinin çeşitlilik, yapı ve stabilitesini önemli ölçüde etkileyebilecektir. RegCM3 modeline göre bölgenin sıcaklıkları 2-4 °C artabilecektir. Ayrıca Doğu Karadeniz Bölgesinin batı kısmında yağış artışı beklenmezken, doğu kısmında (Rize ve Artvin) 200-300 mm yağış artışı tahmin edilmektedir. Bölgenin batısındaki sıcaklık artışı ladin ekosistemlerinin daha fazla strese maruz kalmasına neden olacak ve kabuk böceği salgınlarını arttırabilecektir. Ayrıca, bölgenin batısındaki ladin ekosistemlerinde yangın önemli bir problem olabilecektir.

Bölgenin batısında ladin kuşağı muhtemelen 400-800 m yukarı kayacaktır. Ağaç sınır Doğu Karadeniz Bölgesinin hem batı hem de doğusunda muhtemelen yukarı yöne kayacaktır.

Key word: climate change, oriental spruce, climate prediction, bark beetle attack,

INTRODUCTION

Global warming has been getting more attention both from public and scientific community in Turkey, as well as in other countries, recently. Weather anomalies, extreme temperatures, frequent flooding events, sea level rises, and ice melting are some of the events that scientific community strongly believe that warming related.

Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850). Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise (Anonymous, 2007).

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture (Anonymous, 2007).

The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth-rate was larger during the last 10 years (1995 – 2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates (Anonymous, 2007).

All of the above mentioned events are important signs that warming is real and fossil fuel use is the main reason of it. However, there are few studies in Turkey on how global warming will influence climate and main ecosystems of the country. Analyzing meteorological data from 1951 to 2004, Dalfes et al. (2007) found that winter precipitation in the western provinces of Turkey has decreased significantly throughout the last five decades. Fall precipitation, on the other hand, has increased at stations that lie mostly in the northern parts of central Anatolia. They stated that the most prominent feature that one can observe is the widespread increase in summer temperatures. For the future climate of the Turkey, using RegCM3 climate model, Dalfes et al. (2007) predicted 4-6 °C of temperature increases in the western part and 2-4 °C in the eastern part of the Turkey.. For the precipitation, in general, they predicted precipitation decreases along the Aegean and Mediterranean coasts and increases along the Black Sea coast of Turkey.

Oriental spruce (*Picea orientalis* L.) is one of the important tree species that grows naturally in the eastern Black Sea region of Turkey. Normally, spruce genus is the dominant tree species of boreal regions that cold winters and cool summers are typical. Therefore, it wouldn't be wrong to assume that these spruce ecosystems will be the first to

show signs of climate change impact. We used current literature and field observations to find reasonable answer to this.

SPRUCE ECOSYSTEMS IN TURKEY

Spruce has 35 species in northern hemisphere that only one species, *Picea orientalis*, naturally grows in the North-eastern Blacksea region of Turkey. Spruce forests cover 297 396 ha of forest areas in Turkey (Anonymous, 2006).. It prefers humid climate, areas with summer fogs and northern slopes where there is not enough precipitation. It establishes mixed stands mainly with *Pinus sylvestris*, *Abies nordmanniana*, *Fagus sylvestris* and *Quercus sp.* It becomes dominant species in the mixture in the elevations around 1000 m. and keeps that up to 2400 m. It also establishes pure stands between these elevations (Anonymous, 2001).

Mean annual temperatures in these areas ranges between 5-10 °C. However, winter temperatures can be as low as -20 °C and summer temperatures can be as high as 30 °C in these areas. Mean growing season temperatures changes between 10-20 °C (Tüfekçioğlu, 2008). Mean annual precipitation in spruce growing areas varies between 700-3000 mm.

Fog precipitation plays an important role in the distribution and survival of the spruce ecosystems in these warm temperate regions. However, there is no scientific study in the region that calculated the amount of water contributed by the fogs to the spruce ecosystems. Elsewhere, an 18-week study in a sitka spruce/western hemlock stand in Oregon recorded 290 mm of fog drip while precipitation was recorded as 640 mm (Kimmins, 1997). Also, fog provides shade from direct sun light and fog drip cools the surfaces of needles. We believe that these are the main factors that contribute survival of spruce ecosystems in this humid temperate region.

CLIMATE CHANGE AND SPRUCE ECOSYSTEMS IN THE WORLD

Spruce ecosystems mainly exist in the boreal zone of the World. The climate of the zone is characterized by short, moist, and moderately warm summers and long, cold, and dry winters. It has mean annual temperatures that range from -5 to 3°C (Perry, 1994). The boreal forest covers in excess of 1.2 billion hectares, spanning North America and Eurasia and is the largest terrestrial reservoir of global terrestrial carbon (30-35%), primarily held in the organic soils of the forest floor (Soja et al., 2007). Spruce forests also extend into temperate regions high elevation areas too.

It is generally accepted that mean global temperatures are increasing and that the largest temperature increases from climate change are currently found in the Northern Hemisphere upper latitudes and elevations, where the spruce forest mainly resides (Soja et al., 2007; Tüfekçioğlu, 2008). Predicted initial ecological indicators of climate change in these areas are: (1) an overall increase in fire regimes (frequency, severity, area burned, extent and longer fire seasons); (2) an increase in infestation (frequency, duration and extent); (3) an altered treeline; and (4) stand- and landscape-scale alteration of the mosaic composition of forests (age, structure and species composition) (Soja et al., 2007).

Fire is the main ecological factor that influences structure, age and species composition of spruce forests. Fire is especially important in the maintaining biodiversity of these forests. Studies done both in Canada-Alaska and Russia showed that fire frequency has been increased and this increase will be fastened by the climate change in the future (Soja et al., 2007).

Bark beetle attack has become an important threat to spruce ecosystems recently. Increase in bark beetle attacks have been linked to climate change (Berg et al., 2006).

Warm weather conditions provide enough time to insects to complete their life cycles in one, rather than two year, suddenly shifting the balance between insects and tree defense in favor of the insect. In Germany, 3700 ha of spruce forests have been destroyed by the bark beetle attacks in Bavyera National Park. It was postulated that increased air temperatures, windbreaks and drought were the main reasons of the damage (Weissbacher, 1999).

Climate change-induced treeline shifts have been observed in different parts of the world (Soja et al., 2007). Upper treeline shifts have been registered (description from west to east) in the southern Urals, in the Altai, in the Sayans and in the Kuznetsky Alatau (Soja et al. 2007). In southern Urals, the treeline of stocked forests moved 20–40 m upwards and decreased the adjacent tundra by a factor of two.

Climate change-altered growth responses have been observed in spruce forests. However, increased treeline productivity due to warmer temperatures at Northern latitudes may not be as straightforward as had been thought. For instance, Lloyd and Fastie (2002) investigated the response of trees growing at the cold margins of the boreal forest to climate variation in the 20th century. By comparing tree growth (measured tree ring-widths) to historic climate data they found regional variability in response to climate variation. After 1950, warmer temperatures were associated with decreased tree growth in all but the wettest regions. Consequently, the Lloyd and Fastie's investigation showed that growth declines were most common in the warmer and drier sites, and thus supports the hypothesis that drought-stress may accompany increased warming in the boreal forest (Soja et al., 2007).

Additionally, Barber et al. (2000) documented a negative growth response in Alaskan white spruce to drought. In tree ring studies near Fairbanks, Barber et al. (2000, 2004) used a combination of analysis of late wood rings and the $\delta^{13}\text{C}$ isotope ratios to investigate the effects of historical runs of warmer-than-usual decades on white spruce. Barber and her colleagues found evidence of the same moisture-stress-mediated effect predicted by the earlier gap model study.

CLIMATE CHANGE AND SPRUCE ECOSYSTEMS IN TURKEY

It is expected that Turkey is one of the countries that will be significantly influenced by the climate change. Analyzing the data from evenly distributed 18 meteorology stations between 1939 and 1989, Kadioğlu found a 0.63 °C increase in mean annual temperatures in Turkey (Asan, 1995). Analyzing the meteorological data belong to stations located in the Eastern Black Sea Region (1951-2004), Dalfes et al. (2007) observed increases in winter and spring precipitations in Artvin, decrease in spring precipitation in Trabzon and decrease in mean annual temperature in Artvin. In the same report, future climate of the region has been predicted using RegCM3 regional climate model.

According to RegCM3 regional climate model, mean temperatures would increase 2-4 °C in the region in the next century. Future climate scenarios predict 200-300 mm increases in precipitation in the eastern part of the region while the western part wouldn't have any increase in precipitation in the next century.

As a result of the predicted changes, it is possible to observe 400-800 m upward shift in the spruce belt in the western part. The eastern part could probably observe only upward movement of treeline. There wouldn't be any changes in lower boundary of spruce belt in eastern part because of precipitation increase. The area that spruce forests cover may decrease in the eastern part while it may increase in the eastern part.

Temperature increases in the region would cause more stress on spruce trees and could probably increase the bark beetle attacks. Around 100 000 spruce trees have been killed by the bark beetle attacks in Hatilla National Park, Artvin (Tüfekçioğlu et al., 2005). Tüfekçioğlu et al. (2005) have collected 200 tree ring samples from dead (100) and live (100) trees. Analyzing tree diameter growth revealed that dead trees had greater mean annual diameter increment compared to live trees in last twenty years. This indicates that these good growth performer trees have been under strong stresses in last 10 years.

Fire could become an important threat in the western part of the region with the predicted climate change in the region. Currently, fire is not a problem in oriental spruce ecosystems. Spruce ecosystems in our country have a humid climate in summer season. Therefore, it is unusual to see fire in them. However, fire is an important factor in maintaining structure, diversity and health of boreal spruce ecosystems.

Climate change could trigger drought-induced tree mortalities and decrease in annual tree growth in oriental spruce ecosystems. Drought-induced negative growth responses were observed in Alaska triggered by the climate change. Similarly, tree mortality cases were observed in low elevation spruce and pine forests during dry years in the Black Sea Region.

Climate change could also influence structure, stability and diversity of oriental spruce ecosystems. It could be possible to see fire-induced secondary succession taken place in the western part of the region. Similarly, insect attacks regulated secondary succession would be more common. This might increase species diversity in the region due to replacement of an shade tolerant species (oriental spruce) with an shade intolerant species. Stands of shade intolerant species have more plant species in understory compared to shade tolerant stands. Also, replacement of alpine grasslands by the spruce forest may cause decrease in plant species diversity.

CONCLUSIONS

Climate change could significantly influence distribution, diversity, structure and stability of the oriental spruce ecosystems. According to RegCM3 regional climate model, the temperatures would increase 2-4 °C in the region in the next century. Future climate scenarios predict 200-300 mm increases in precipitation in the eastern part of the region while the western part may not have any increase in precipitation in the next century. Temperature increases in the western part of the region would put more stress on spruce trees and could probably increase bark beetle attacks. Also, fire could become an important threat in the western part of the region. It is possible to observe 400-800 m upward shift in the spruce belt in the western part. Treeline of spruce stands might move upward both in western and eastern part of the region.

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