Biology 281 Essay

The Effects of Climate Change on Soil Seed Banks

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Climate change plays a powerful and diverse role in ecosystems all over the world. Wet areas are becoming dry, dry areas are experiencing more rainfall, and CO_2 is increasing at an alarming rate. These changes are not only visible in vegetation growth and distribution, they are also affecting the seed banks. A seed bank is the collection of seeds in the soil. These seeds are dormant and can stay in the bank with the potential to germinate for up to hundreds of years. Populations of indigenous seeds are decreasing, the emergence of seeds is fluctuating, fungal pathogens have better conditions to reproduce, and restoration of original seed populations is becoming increasingly difficult. This paper focuses on the life of a seed and changes to that life cycle due to climate changes in wetlands, glacial recession moraines, and frequent fire areas.

The life of a seed includes movement and climate conditions. Biotic and abiotic factors affect seed movement after a seed leaves its parent. Movements of seeds occur in two phases. Phase I is the movement from parent to a surface, while Phase II is classified as the succeeding horizontal and vertical movements. Phase II studies are less common but are more likely to account for the patterning of plants in communities and ecosystems. This is also the phase responsible for seed bank deposits (Chambers 1994).

Seed banks are an important part of every ecosystem. According to Leishman, Masters, Clarke, and Brown, "the presence of a reserve of dormant seeds in the soil can stabilize population dynamics by spreading risk and diminishing large fluctuations in response to short-term environmental perturbations" (Leishman et al. 2000). Seed banks are responsible for the repopulation of ecosystems after a disturbance and allow the coexistence of species in temporally varying environments. Long-lived seed banks conserve genetic diversity and limit change to the environment due to seed immigration into the area, thus allowing the species in the environment to remain intact. Warming of winters and increased summer rains, however, are reducing the number of viable seeds in seed banks worldwide (Leishman et al. 2000).

Seed bank deposits and the emergence of vegetation have varied greatly due to climate change. Wind-blown seeds have taken over some seed banks so the natural vegetation is inhibited from being expressed. Climate change has also allowed repressed seeds in the seed bank to grow due to the change in optimal growing conditions. These changes include variances in the hydrologic cycle, glacial recession, wildfires, and the amount of CO_2 in the atmosphere.

Brigitta Erschbamer evaluated the winners and losers of climate change. With an expected rise in temperatures from 1.4-5.8 degrees Kelvin by 2100, her study was conducted in the Central Alps, evaluating the effects of glacial recession. This region has experienced a 1 degree C change in temperature in the last 40 years (Erschbamer 2007).

Data from an 1858 glacier study was used as a basis for evaluating the newly exposed substrate from the receding glacier. Several other glacial studies in the same area revealed that plant species colonizing during different successional stages in the forelands of the glacier differ in functional traits. They may also differ in response to climate change. Glacial recession due to climate change will affect vegetative and reproductive growth at the species level, This study investigated three hypotheses related to this claim:

1. Species will exhibit significant vegetative and generative growth increase in response to warming,
2. Fast-Growing species will respond more to experimental warming than slow-growth species, and
3. Asexually and sexually reproducing forms of *Poa alpine* will react differently (Erschbamer 237).

Several species were evaluated via vegetative mapping in 1858, 1970, and 1991 in conjunction with this study, which harvested vegetation at three, four, and five year intervals. Differences in soil in two moraines were noted and studied as well as the species *Artemisia genipi*, *Trifolium pallescens*, *Anthyllis vulneraria* ssp.*alpestris*, *Poa alpine*, and *Poa alpine* ssp. *Vivipara* that were planted in a controlled environment. *A. genipi* and *P. alpine* both showed little change while *T. pallescens* and *A. vulneraria* had higher dry weights and enhanced reproduction (Erschbamer 2007).

Negative effects, however, have been noted in the tropics. Global climate change will have negative effects on the amount of precipitation in clouds that will water tropical trees and other vegetation. This will create a negative effect in seed bank accumulation, productivity and longevity of trees, as well as an emergence of previously suppressed seed banks (Nadkarni 2002).

The hydrologic cycle was also the focus of study for the removal of seeds from the seed banks of the Badlands slopes in Spain. Precipitation was thought to be the primary reason for the low concentration of seeds in the seed bank. Garcia, Recatala, Cerda, and Calvo studied the effects of erosion due to rainfall on seed banks on the Badlands slopes of Southern Spain. The study was prompted by a literature review that showed erosion is not the primary reason for seed removal from seed banks. The review, however, did not look into seed banks on badlands slopes. The hypothesis of this study states erosion is the main factor for seed removal from seeds on badlands slopes, and it was tested over a two-year period in a physical location. Seed loss was low in all experiments, including both natural and simulated rainfall (Garcia et al. 1995).

One problem that is positively affected by rainfall is the growth of fungal pathogens which can attack dormant seeds in the seed banks. Fungal pathogens are an increasing problem in areas that are usually dry but have experienced an increase in precipitation. Three types of fungi affect seeds. They are surface-contaminating fungi, which affect seeds "either directly through necrotic action or indirectly through the production of metabolic wastes" (Leishman et al. 2000), internally born fungi that also increase the metabolic activity of seeds, and soil born fungi which lack extensive study. The third is most responsible for the increased rate of seed mortality. All three can be reduced by applying a fungicide to seeds. Leishman and colleagues found that fungal pathogens, like most mutualisms, are species-specific, and the application of a fungicide treatment can have a negative impact on the vitality of some seeds (Leishman et al. 2000).

Fire and drought can also induce both positive and negative effects on seed banks. Wildfires are becoming a more prominent feature in ecosystems due to increases in temperature. One study examined the effects of ash cover and heat on the emergence of seeding plants. While the authors- Izhaki, Henig-Sever, and Ne'Eman- do acknowledge the existence and importance of predation, survival, and competition as important factors that limit seed emergence, they chose to focus on fires because they are common in the region studied (Izhaki et al. 2000).

Three microhabitats were examined and tested to determine the effects on the seed banks. They are pine-dominated shrub areas, shrub-dominated areas, and herbaceous-dominated areas. Their studies proved conclusive: germination levels were reduced, but heat exposure and ash cover also create "conditions that facilitate the establishment of pine seedlings from the canopy stored seed bank" (Izhaki et al.).

The changes in seed banks as a result of climate change also influence land management and productivity, which shape the food and textile industries. Virginia Dale examines the effects climate change will have on land use production and management strategies. Her literature review also evaluates the human factor by examining the socioeconomic and biological aspects of land use. There are three clear conclusions of the articles she reviewed:

1. In recent centuries, land use change has had much greater effects on ecological variables than it has on climate change.
2. The vast majority of land use changes have little to do with climate change, and
3. Humans will change land use, and especially land management, to adjust to climate change, and these adaptations will have some ecological effects (Dale 753).

Dale then makes a broad conclusion. She explains that to understand climate change, one must examine the socioeconomic and political conditions surrounding land use to produce efficient practices on a global scale (Dale 1997).

The LINGRA-CC study seemingly applied Dale's notion for the connectedness of climate use to the socioeconomic farming industry. A two year study reviewed how sink-source grasslands primarily used for food production would be affected by climate change. Lingra-CC is a study that examined the effects of increased CO_2 levels on grasslands used as food for grazing cattle. This study is modeled off the original two-year Lingra study, which began in 1993 in the Netherlands, designed for the purposes of predicting grassland productivity and studying the impact of management strategies under present and increased CO_2 emissions. Both the Lingra and Lingra-CC models express the source-sink habitat for the grass *Lolium perenne* and measure growth for the production of *L. perenne* grasslands due to productivity due to carbon partitioning to storage, roots, and shoots (Rodriguez et al. 1999).

The differences between Lingra and Lingra-CC however, are how productivity is calculated mathematically and the dependency of root growth on carbohydrate usability by the shoots according to the excess carbohydrates hypothesis. Root growth directly depends on "the quantity of carbohydrate the shoot is unable to utilize; under conditions of high photosynthetic rate or sink limitation a relatively large root system would be produced, tending to balance the metabolic activities of the root and shoot systems" (Rodriguez et al. 360).

Lingra-CC found that controlling carbon in both ambient and doubled amounts caused a decrease in the maximum biomass produced. The maximum biomass was measured with cuttings of leaf area index of >1 with cutting intervals of 20d for ambient and 17d for increased CO2. Doubled CO_2 produced a maximum yield that was 15% shorter than at ambient CO_2. The gain in harvested biomass when the cutting interval was reduced by 3d was negligible (Rodriguez et al. 1999).

This study is important to the region because "[i]n temperate Western Europe, ryegrasses are the main component of lowland pasture production, and future climate change is expected to affect their production" (Rodriguez et al. 359). As a result, farmers will have to change the amount of nutrients they feed the grass. If farmers are unable to match current rate of growth of grasses, they will be less likely to maintain their current livestock count. This could have widespread effects across the country (Rodriguez et al. 1999).

The United States will face its own unique changes. While the U.S. is not a member of the Kyoto treaty, several U.S. cities have agreed to meet the terms and standards of the treaty. One study focuses exclusively on the carbon budget allowances specified in the Kyoto Protocol to examine vegetation distribution under historical conditions and across a wide gradient of future temperature changes. It also looks for consistencies and trends among the many future scenarios, time-dependent changes in vegetation distribution and their associated carbon pools to illustrate the possible trajectories of vegetation change near the high and low ends of the temperature gradient, and the extent of the U.S. area supporting a negative carbon-supporting balance (Bachelet et al. 2001).

While there were both positive and negative feedbacks to the issues studied, a study of the Carolina Bays, having experienced a severe drought, did show significant changes to the land. Hydrologic conditions are a main force of plant species composition in wetland areas. After the 1997 El Nino, the normal cyclical weather patterns were severely disrupted in the region. Mulhouse, Burbage, and Sharitz studied the changes in the soil seed bank of four Carolina bays over a three year period after hypothesizing the correspondence between seed bank and vegetation was low (Mulhouse et al. 2005).

After the 1997-1998 El Nino, normal weather patterns subsided, and the region went into extreme drought. The bays studied were all dry by fall 2001. Since the soil in depressional wetlands in the southeastern United States is nutrient poor, the regions relied heavily on flooding to maintain species richness. The most common plants before the drought were perennial grasses and aquatic herbs. After the drought, woody species, non-aquatic herbs, and non-grass graminoids took over the region. These are all seeds that disperse via the wind that have taken over the seed bank. Unfortunately, it will be extremely difficult to restore this land (Mulhouse et al. 2005).

Climate change caused by increasing CO_2 emissions since the industrial age has had a steady impact on the environment, which in turn impacts our lives. Seed banks may seem inconsequential when solely observed in their ecosystems, far away from the hustle and bustle of our concrete environments. The truth is that we are related to the environment; the carbon dioxide we put forth into the environment has a direct, accelerated, negative effect on the food we eat and the ability to restore ruined ecosystems.

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