Does Global Climate Change contribute to desertification in Lebanon?

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Introduction

Climate change and desertification are two sides of the same coin and must be tackled together. "These two issues are very intimately related in the way you can describe them as two halfs of a coin," according to Yvo de Boer, executive secretary of the UN Framework Convention on Climate Change (UNFCCC).

Desertification is caused by a combination of factors that change over time and vary by location. These include indirect factors such as population pressure, socioeconomic and policy factors, and international trade as well as direct factors such as land use patterns and practices and climate-related processes.

Desertification is taking place due to indirect factors driving unsustainable use of scarce natural resources by local land users. This situation may be further exacerbated by global climate change. Desertification is considered to be the result of management approaches adopted by land users, who are unable to respond adequately to indirect factors like population pressure and globalization and who increase the pressure on the land in unsustainable ways. Desertification in Lebanon, is mainly caused by the exploitation and mismanagement of natural resources, overgrazing by herders, and deforestation, as well natural phenomena such as climatic variations, wind erosion and floods that degrade the fertile top soil, turning fertile land into useless desert. The role of global climate change goes side by side with desertification in Lebanon especially in the forest ecosystems and the outbreak of insect and disease pests associated with these ecosystems.

Effects of global warming on the distribution and abundance of insects

The effects of global warming on living organisms have now been recognized from the level of individual species to communities, most notably in the form of temperature-related range shifts (Walther et al. 2002, Root et al. 2003). As the number of insects per unit area is inversely related to latitude and elevation (Speight et al. 1999), we may assume that the increase of temperature would allow the spreading of insect species northward and upward, especially for those species that have wide ranges, as many forest pests have. This assumption is supported by fossil data related to the forest insect response to climatic changes of the past. Higher damage and insect diversity was recorded during the global warming which occurred during the Paleocene - Eocene transition, relative to other periods (Wilf & Labandeira 1999).

With mean global temperatures increasing over the past 100 years by about 0.8C and projected to continue (Houghton et al. 2001, Luterbacher et al. 2004), widespread climate-related changes in the biosphere can be expected. There are various ways by which the insects may react to climate change (Williams & Liebhold 1995, Ayres & Lombardero 2000, Harrington et al. 2001, Bale et al. 2002), and it seems reasonable to assume that an increase of temperature within the vital limits of a species implies a faster development. The species ready to expand are those characterized by high growth potential, multivoltinism and absence of diapause, whereas those that could be restricted show slow development rate and long cycles. The reduction of the period of time spent as a larva or pupa may improve survival, as these are the stages more subjected to predation and other mortality factors (Bernays 1997). The increase in population density may in turn promote a further expansion of the range. Some species would be simply limited in their survival at the southern edge of their range and would shift the range northward. Switching to new hosts may occur among non-specialist herbivores, and can be the first consequence of the strong selection on colonizers (Harrington et al. 2001).

Those insects developing without winter diapause, which are active during this season and are protected from the low temperature, are the best candidates for range expansion if the winter temperature maintain the current increasing trend (Sinclair et al. 2003). A good example concerning a forest pest is the case of the pine processionary moth *Thaumetopoea wilkinsoni* which has been observed during the last decade to be increasing in number and has expanded to higher altitudes (up to 1600 asl).

However, most forest insects of temperate regions have a winter diapause, which in some cases can last several years. Temperature plays a major role in the induction and maintenance of this diapause. An increase of the temperature would modify the induction and maintenance of the diapause, involving changes, which could affect the development of the insect, making predictions about population dynamics quite unreliable. In Lebanon and as early as the 1990s an example on how high temperature during the larval development has caused lower diapause rate and higher damage is illustrated by the cedar webspinning sawfly *Cephalcia tannourinensis*.

The change of temperature, which promotes the expansion of the insect's range, may also involve a new association between a herbivore and its host, as it has been shown by the pine processionary moth attacking the mountain stone pine (*Pinus pinea*) in the Shouf region. The large outbreaks observed in the expansion areas on the new hosts may be explained either by the high susceptibility of the hosts or by the inability of natural enemies to locate the moth larvae on an unusual hosts or environment (Benigni & Battisti 1999, Hodar et al. 2003). Thus the effect of global change on insect can be tremendous and lead to the dieback of trees within a forest and thus increase desertification.

The winter processionery moth thaumetopoea wilkinsoni

The winter pine processionary moth, Thaumetopoea wilkinsoni offers a possibility to test for the effects of global warming on an insect population over a wide area of the Mediterranean basin, where it is the most important pest of pine forests (*Pinus* spp.). Its geographic range lies within precise limits of elevation and latitude (Démolin 1969), primarily as a function of the average winter temperatures. The strict relationship between the insect range and the temperature was explored by Démolin (1969), who defined the potential range of the moth based on air temperature and solar radiation records. Because the larvae are oligophagous, potentially feeding on all *Pinus* spp., but also on *Cedrus* spp., host plant distribution does not restrict the present range of the insect; many usual or potential host species grow in areas where the insect is absent. Consequently, if the climatic conditions become favorable in higher latitudes or at higher elevations, the insect may expand its range to these areas, often coupled with host switching. This relative importance of temperature over biotic factors in defining the geographic distribution makes the moth a particularly suitable model to study the range shift in relation to global warming. An important forest pest in many areas, the moth has shown in the last decades a substantial expansion of the outbreak area both northward and upward (Huchon & Démolin 1971, Hellrigl 1995, Benigni & Battisti 1999, Goussard et al. 1999, Hodar et al. 2003), resulting in high attack rates in areas previously largely unaffected by the insect. The case deserves special interest for the implications it may have on the management of forests and plantations.

The cedar webspinning sawfly Cephalcia tannourinensis

The outbreaks of the spruce webspinning sawfly Cephalcia tannourinensis in the north of Lebanon particularly in Tannourine, Hadath EL jebbeh, Qnat, Kfour el Arabi and Niha cedar forest are a good example of what may happen when favorable climatic conditions interfere with the mechanism of the induction of extended diapause, allowing an exponential growth of the population and consequent damage to trees. This species, as many others in this genus, is monophagous on *Cedrus* and endemic to Lebanon, where outbreaks have been recorded (Nemer et al., 2005). *Cephalcia* species generally show low fecundity and spreading of the cohort over many years by mean of an extended diapause, which is induced by low temperature at pupation time (Battisti 1994). However, in the period 1992-2000 there was a sudden outbreak in the Cedars of Tannourine, Hadath EL jebbeh, Qnat, Kfour el Arabi and Niha, during which the populations developed an annual life cycle and grew exponentially, causing repeated defoliations, which ultimately threatened 70% of the forest over hundreds hectares (Nemer and

Nasr 2004). We hypothesized that favorable conditions promoted the survival and speeded up the development, making it possible to pupate when soil temperature was high enough to start pupation immediately, skipping in this way from the extended diapause. Later, an experiment showed that the soil threshold temperature for the induction of the extended diapause was about 12°C (Lahoud, 2007), well below the values recorded in the forest at the beginning of the outbreak.

Effects of global climate change on Biodiversity

Observed changes in climate have already adversely affected biodiversity at the species and ecosystem level, and further changes in biodiversity are inevitable with further changes in climate.

Changes in the climate and in atmospheric CO_2 levels have already had observed impacts on natural ecosystems and species. Some species and ecosystems are demonstrating some capacity for natural adaptation, but others are already showing negative impacts under current levels of climate change (an increase of 0.75°C in global mean surface temperature relative to pre-industrial levels), which is modest compared to future projected changes (2.0-7.5°C by 2100 without aggressive mitigation actions).

Aquatic freshwater habitats and wetlands, mangroves, coral reefs, Arctic and alpine ecosystems, and cloud forests are particularly vulnerable to the impacts of climate change. Montane species and endemic species have been identified as being particularly vulnerable because of narrow geographic and climatic ranges, limited dispersal opportunities, and the degree of other pressures.

Information in Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) suggests that approximately 10% of species assessed so far will be at an increasingly high risk of extinction for every 1°C rise in global mean temperature, within the range of future scenarios modelled in impacts assessments (typically <5°C global temperature rise).

Continued climate change will have predominantly adverse and often irreversible impacts on many ecosystems and their services, with significant negative social, cultural and economic consequences. However, there is still uncertainty about the extent and speed at which climate change will impact biodiversity and ecosystem services, and the thresholds of climate change above which ecosystems are irreversibly changed and no longer function in their current form.

Observed signs of natural adaptation and negative impacts include:

Geographic distributions: The geographic ranges of species are shifting towards higher latitudes and elevations. While this can be interpreted as natural adaptation, caution is advised, as the ecological effects of related community compositional change, the net effect of such range shifts on range area (i.e. the balance between range contraction and expansion for any given species), and related species extinction risk, is difficult to project; and there are geographic and dispersal rate limits, physical barriers, and anthropogenic barriers to species range expansion. Range shifts have mostly been studied in temperate zones, due to the availability of long data records; changes at tropical and sub-tropical latitudes will be more difficult to detect and attribute due to a lack of time series data and variability of precipitation. Nevertheless, biodiversity losses have already been reported in some tropical areas.

***Timing of life cycles (phenology)*:** changes to the timing of natural events have now been documented in many hundreds of studies and may signal natural adaptation by individual species. Changes include advances in spring events (e.g. leaf unfolding, flowering, and reproduction) and delays in autumn events.

Interactions between species: evidence of the disruption of biotic interactions is emerging. For example, differential changes in timing are leading to mismatches between the peak of resource demands by reproducing animals and the peak of resource availability. This is causing population declines in many species, including increasing the herbivory rates by insects as a result of warmer temperatures, and may indicate limits to natural adaptation.

Photosynthetic rates, carbon uptake and productivity in response to CO2 "fertilization" and nitrogen deposition: models and some observations suggest that global gross primary production (GPP) has increased. Regional modelling efforts project ongoing increases in GPP for some regions, but possible declines in others. Furthermore, in some areas, CO2 fertilization is favouring fast growing species over slower growing ones and changing the composition of natural communities while not appreciably changing the GPP.

Community composition and ecosystem changes**:** observed structural and functional changes in ecosystems are resulting in substantial changes in species abundance and composition. These have impacts on livelihoods and traditional knowledge including, for example, changing the timing of hunting and fishing and traditional sustainable use activities, as well as impacting upon traditional migration routes for people.

If we project these information and the prediction in Lebanon we will observe the following:

- By 2020: 300m upward shift of vegetation
- By 2050: 486m upward shift of vegetation
- By 2080: 700m upward shift of vegetation (Horsh Ehden & Arz El Shouf treeline would shift to around 2500m)
- Distribution or replacement of certain vegetation associations
- Protected zones, natural habitats and sand dunes are very vulnerable
- Ammiq wetland: reduction in total area of marshes and shorten the duration of marshes for bird migration

- Tyre sandy beach: High vulnerability to erosion and sea level rise leading to disappearance of its indigenous fauna and flora
- The palm islands nature reserve: inundation of the three islets
- Vulnerable species: endangered, endemic & at the edge of their geographical distribution

Thus in summary Global climate change will have a negative impact on the biodiversity as a whole and will probably lead to increase desertification in Lebanon.

The effect of global climate change on the productivity of selected plant species in Lebanon

The expected climate influence scenario on the productivity of three plant species is be based on the following hypothesis:

Since the temperature degrees will increase between 1,5 and 3 °C, the region of 300 to 400m above sea level will have a climate similar to the coastal plain area. This speculation is based on a climatic scenario known as the altitudinal zonation which indicates that the temperature degrees decrease of half °C with each 100m elevation above sea level.

Impact on citrus plantation

Based upon this hypothesis, the current area of citrus fruits plantations, will be replaced by the mounds area which is located on an elevation varying between 300 and 600m above sea level. It will also be possible to expand in establishing olive gardens until and elevation of 1100m above sea level, while in these days its maximum height is 800m and apples fields till an elevation of 1700m.

However, the substitute areas that can be reserved for planting citrus fruits differ from the current areas and may cause establishment problems related to soil types and other. The thermal difference between the current and the expected agricultural areas will not be a limiting factor for the citrus fruits growth. But the decrease in rain average according to the GCM scenario of

4.5%, 5.8% and 12.6% for the years 2020, 2050 and 2080 respectively, will have a direct impact on the water that feed the groundwater. The only source for these new gardens is from the wells. As for the increase of the dioxide of carbon, it has a positive impact on the chlorophyll assimilation and the growth of the citrus fruits tree, and that of course, from an agricultural point of view.

Impact on olive plantation

It is well known that the olive tree subsists with low rainfall not exceeding 200 mm as is the case in North Africa countries (Tunis, Algeria,…). Moreover, it tolerates temperatures as high as 40 °C. On the other hand, snowfall on olive tree's twigs results in its breaking.

The intensive tropical agriculture (citrus, banana, avocado) in the areas surrounding the coastal line of Lebanon and on elevations approximately equal will surely lead to a move in live plantations to more elevated areas. However, the current prices for olives and its byproducts, in addition to the competition of other Lebanese oils (sunflower, soya, corn), do not encourage the establishment of new olive plantations which demand a high establishment cost in terms of land reclamation and terracing when the annual production does not exceed 1.1-1.3 tons/ha for a non irrigated crop. Adding to this is the labor cost for olive fruits picking in the mountain areas where no machinery can be used as is the case of most Mediterranean countries.

All these facts lead to adopt a basis of comparison according to the following hypothesis:

As for the areas reserved for olive agriculture, its stretching due to the construction expansion on the coastal line may not be compensated with new plantation areas establishment due to the high land reclamation and rehabilitation cost. However, the high demand on olive and its byproducts in the industrial Mediterranean countries due to its nutritional and medicinal components may play a positive role in the rehabilitation of old-abandoned olive plantation, as it is happening now in France, with a small expansion of the areas towards higher elevations.

The climatic factors (temperature, humidity, CO_2) present in the current olive plantation areas (0-800 m) will not be different from the new predicted areas (i.e. between 300-1100 m according to the weather change scenario GCM for the years 2020, 2050 and 2080). Thus, the gradual move of olive agriculture towards more elevated areas will be the best solution to escape the negative impact of the expected higher annual temperature averages in the coastal area. For example, the maximum temperature averages recorded for the past 30 years (1978-2008) in Zgharta olive plantation coastal area at an elevation of 110 m was 18.6 during the month of February and this maximum temperature average in the same area are going to be 20.3, 21.3 and 22.8 in the year 2020, 2050 and 2080, respectively. This thermal increase happens at the flowering time resulting in a drop in the number of flower formation. But the temperature is going to be 17 and 19 degrees at the Ghazir station located in the same area at an elevation of 425 m in the year 2020 And 2080.

On the other hand, the increase in the relative humidity will contribute to the development of fungal diseases on olive such as *Cycloconium oleaginum* Cast and *Verticillium dahlia* Kalla. Consequently, the expansion of olive agriculture towards higher altitudes where the relative humidity drops gradually will be a positive factor on the product quality.

The expected low rainfall will negatively affect the non-irrigated olive plantation during the months of October and November that is at the end of the dry season, whenever the tree is in extreme need for supplemental irrigation to increase its fruit size.

In all cases the use of appropriate agriculture technologies, especially the pruning designs corresponding to low rainfall will decrease the negative impact of the climatic change. The significant increase in the temperature and the decrease in the average relative humidity necessitate the allocation of the humid northern slopes and not the arid hot southern zones for olive plantation in order to keep a good level of olive production.

The expected results of the climatic impact on the olive tree, is not totally negative or in other words, it will not negatively affect the total production and the quality of produce. The reason is that the olive tree successfully adapts to any level of annual rainfall whether low (<200 mm as in North Africa) or high (>1000 mm as in Sicily in Italy).

In summary the global climate change has negative impact on the distribution of plant species in Lebanon and the shift in the distribution in a non adaptive soil or in construction areas will lead automatically to the increase of desertification.

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