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Research Paper

AGRO ECOLOGICAL IMPACT OF CLIMATE CHANGE

Mr. N. Sukumaran[1]

[1]*Assistant Professor of Sociology, Annamalai University, Annamalainagar – 608002, Tamil Nadu, India*

ABSTRACT

This paper deals with agroecological impact of climate change. It outlines the impact of elevated atmospheric CO2 level on crop yield, interaction of elevated CO2 with temperature and precipitation and soil nutrients. This paper makes a special note on impact of climate change on weeds insects pests disease, animal production and health. This paper concludes with some interesting findings.

KEYWORDS: *climate change, temperature, precipitation, agriculture, disease*

INTRODUCTION

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provides a number of important considerations on the overall impacts of higher temperatures on crop responses. It could be noted that at the plot level, and without considering changes in the frequency of extreme events, moderate warming with respect to what may happen in the first half of this century may benefit crop and pasture yields in temperate regions, while it would decrease yields in semiarid and tropical regions. Modeling studies indicate small beneficial effects on crop yields in temperate regions corresponding to local mean temperature increases of 1–3°C and associated CO2 increase and rainfall changes. By contrast, in tropical regions, models indicate negative yield impacts for the major crops even with moderate temperature increases (1–2°C).

Climate change affects agriculture and forestry systems through a number of critical factors:

1. Rising temperatures, can lead to negative impacts such as added heat stress, especially in areas at low-to-mid latitudes already at risk today. However, they can also lead to positive impacts, such as an extension of the growing season in high-latitude regions that are currently limited by cold temperatures.
2. Elevated atmospheric CO2 concentrations, which tend to increase lant growth and yield, and may improve water use efficiency, particularly in so-called C3 carbon fixation plants such as wheat, rice, soybean, and potato. The impact on so-called C4 carbon fixation plants, such as maize, sugarcane, and many tropical pasture grasses, is not as pronounced due to different photosynthetic pathways. How much agricultural plants in fields and trees in plantation forests benefit from elevated CO2, given a number of limiting factors such as pests, soil and water quality, crop-weed competition, remains an open question.
3. Changes in precipitation patterns, especially when considering likely changes in the frequency of extremes, with both droughts and flooding events projected to increase in coming decades, leading to possible negative consequences for land-production systems. At the same time, a critical factor affecting plant productivity will be linked to simultaneous temperature and precipitation changes that influence soil water status and the ratio of evaporative demands to precipitation.

All these factors, and their key interactions, must be considered together, across crops in different regions, in order to fully understand the impact that climate change will have on agriculture.

Importantly, the experimental measurements of crop and pasture responses to changes in climate variables are still limited to small-scale plots, so that results are difficult to extrapolate to the field and farm level. As a consequence, current computer models of plant production, although quite advanced in their handling of soil-plant-atmospheric dynamics as well as crop management, lack realistic descriptions of key limiting factors to real fields and farm operations. Therefore, the potential for negative surprises under climate change is not fully explored by current regional and global projections. Key interactions that are currently poorly described by crop and pasture models include:

(i) Nonlinearity and threshold effects in response to increases in the frequency of extreme events under climate change; (ii) modification of weed, pest, and disease incidence, including weed-crop competition;
(iii) Large-scale field response of crops to elevated CO2 concentration; and
(iv) interactions of climate and management variables, including effects of elevated CO2 levels.

Regardless of these uncertainties, there is no doubt that plant development, growth, yield, and ultimately the production of crop and pasture species will be impacted by, and will respond to, increases in atmospheric CO2 concentration, higher temperatures, altered precipitation and evapo-transpiration regimes, increased frequency of extreme temperature and precipitation events, as well as weed, pest and pathogen pressures [3,8]. Recent research has helped to better quantify the potential outcome of these key interactions.

ELEVATED ATMOSPHERIC CO_2 LEVELS

Hundreds of studies conducted over the last 30 years have confirmed that plant biomass and yield tend to increase significantly as CO2 concentrations increase above current levels. Such results are found to be robust across a variety of experimental settings—such as controlled environment closed chambers, greenhouses, open and closed field top chambers, as well as Free-Air Carbon dioxide Enrichment experiments. Elevated CO2 concentrations stimulate photosynthesis, leading to increased plant productivity and modified water and nutrient cycles. Experiments under optimal conditions show that doubling the atmospheric CO2 concentration increases leaf photosynthesis by 30–50 percent in C3 plant species and by 10–25 percent in C4 species, despite feedbacks that reduce the response of leaf photosynthesis by elevated atmospheric CO2 concentrations.

However, crop yield increase is lower than the photosynthetic response. On average, across several species and under unstressed conditions, compared to current atmospheric CO2 concentrations of almost 380 parts per million (ppm), crop yields increase at 550 ppm CO2 is in the range of 10–20 percent for C3 crops and 0–10 percent for C4 crops. Increases in above-ground biomass at 550 ppm CO2 for trees are up to 30 percent, with the higher values observed in young trees and a minimal response observed in the few experiments conducted to date in mature natural forests. Observed increases of above-ground production in C3 pasture grasses and legumes are about 10 and 20 percent, respectively.

INTERACTIONS OF ELEVATED CO_2 WITH TEMPERATURE AND PRECIPITATION

Climate changes projected for future decades will modify and May often limit the direct CO2 effects on crop and pasture plant species that were discussed above. It could be noted that high temperature during the critical flowering period of a crop may lower otherwise positive CO2 effects on yield by reducing grain number, size, and quality. Increased temperatures during the growing period may also reduce CO2 effects indirectly, by increasing water demand. For example, yield of rain fed wheat grown at 450 ppm CO2 was found to increase up to 0.8°C warming, then declined beyond 1.5°C warming; additional irrigation was needed to counterbalance these negative effects. In pastures, elevated CO2 together with increases in temperature, precipitation, and N deposition resulted in increased primary production, with changes in species distribution and litter composition. Future CO2 levels may favour C3 plants over C4; yet the opposite is expected under associated temperature increases. The net effects remain uncertain.

Because of the key role of water in plant growth, climate impacts on crops significantly depend on the precipitation scenario considered. Because more than 80 percent of total agricultural land and close to 100 percent pastureland is rain fed, Global Climate Model (GCM)-projected changes in precipitation will often shape both the direction and magnitude of the overall impacts. In general, changes in precipitation, and more specifically in evapo-transpiration to precipitation ratios, modify ecosystem productivity and function, particularly in marginal areas; higher water-use efficiency as a result of stomatal closure and greater root densities under elevated CO2 may in some cases alleviate or even counterbalance drought pressures. Although the latter dynamics are fairly well understood at the single plant level, large-scale implications for whole ecosystems are not well understood.

INTERACTIONS OF ELEVATED CO_2 WITH SOIL NUTRIENTS

In fertile grasslands, legumes benefit more from elevated atmospheric CO2 concentrations when compared to species that do not fix nitrogen. Therefore, to capitalize on the benefits of elevated CO2 levels, declines in the availability of nitrogen may be prevented by biological N2-fixation. However, other nutrients, such as phosphorus, an important nutrient for biological N-fixation, may act as a limiting factor and restrict legume growth response to higher atmospheric CO2 concentrations.

INCREASED FREQUENCY OF EXTREME EVENTS

The impacts of increased climate variability on plant production are likely to increase production losses beyond those estimated from changes in mean variables alone. Yield damaging climate thresholds spanning just a few days in the case of certain cereals and fruit trees include absolute temperature levels linked to particular developmental stages that condition the formation of reproductive organs, such as seeds and fruits. This means that models of yield damage need to include detailed phenology as well as above-optimal temperature effects on crops. Short-term natural extremes such as storms and floods, interannual and decadal climate variations, as well as large-scale circulation changes such as the El Niño Southern Oscillation (ENSO) all have important effects on crop, pasture, and forest production. For example, El Niño–like conditions can increase the probability of farm incomes falling below their long-term median by 75 percent across cropping regions, with estimated impacts on GDP ranging from 0.75 to 1.6 percent. Europe experienced a particularly extreme climate event during the summer of 2003, with temperatures up to 6°C above long-term means, and precipitation deficits of up to 300 millimeters. During this period, a record crop yield reduction of 36 percent occurred in Italy, in the case of corn crops in the Po valley, where extremely high temperatures prevailed. The uninsured economic losses for the agriculture sector in the European Union were estimated at 13 billion Euros. Likewise, in dry regions, severe soil and vegetation degradation may lead to significant reductions in the productivity of pastoral areas and farmlands. Understanding links between increased frequency of extreme climate events and ecosystem disturbances—fires, pest outbreaks, and so on—is particularly important to better quantify impacts. Only a few analyses have started to incorporate effects of increased climate variability on plant production.

IMPACTS ON WEED AND INSECT PESTS, DISEASES AND ANIMAL PRODUCTION AND HEALTH

The impacts of climate change and increases in CO2 concentrations on weeds, insects and diseases is understood qualitatively, but quantitative knowledge is lacking, despite data from experiments that can be relatively easily manipulated and controllable climate and management variables. However, recent research has attempted to highlight the competition between C3 crop and C4 weed species under different climate and CO2 concentrations.

CO2 and temperature interactions are recognized as a key factor determining plant damage from pests in future decades; CO2 and precipitation interactions will be likewise important. But most studies continue to investigate pest damage as a separate function of either CO2 or of higher temperatures. For instance, some have discovered that the recent warming trends in the United States and Canada have led to earlier insect activity in spring and proliferation of some species, such as the mountain pine beetle, with major damages to forest resources.

Importantly, increased climate extremes may promote plant disease and pest outbreaks. Studies focusing on the spread of animal diseases and pests from low to mid-latitudes as a result of warming have shown that significant changes are already under way. For instance, models have projected that bluetongue, a disease affecting mostly sheep, and occasionally goat and deer, will spread from the tropics to mid-latitudes. This may already be happening, with the first ever incidence of bluetongue detected in Northern Europe in 2006, followed by major outbreaks in the subsequent years and a sustained presence in the region. Likewise, simulated climate change has increased the vulnerability of the Australian beef industry to the cattle tick (Boophilus microplus). Most assessment studies do not explicitly consider either pest-plant dynamics or impacts on livestock health as a function of CO2 and climate combined.

The lack of prior conditioning to extreme weather events can result in catastrophic losses in confined cattle feedlots. For example, in Africa, droughts (1981–1999) have been shown to induce mortality rates of 20 to 60 percent in national herds. Moreover, new models of animal nutrition have shown that high temperatures can put a ceiling to dairy milk yield from feed intake. In the tropics, this ceiling occurs at one third to one half of the potential of the modern Friesians cow breeds. The energy deficit of this genotype will exceed that normally associated with the start of lactation, and decrease cow fertility, fitness, and longevity. Likewise, increases in air temperature and humidity have the potential to affect conception rates of domestic animals not adapted to those conditions. This is particularly the case for cattle, in which the primary breeding season occurs in the spring and summer months.

Interactions with air pollutants Tropospheric ozone has significant adverse effects on crop yields, pasture and forest growth, and species composition. Although emissions of ozone precursors, chiefly mono-nitrogen oxides (NOx) compounds, may be decreasing in North America and Europe due to pollution control measures, they are increasing in other regions of the world especially Asia. Additionally, as global ozone exposures increase over this century, direct and indirect interactions with climate change and elevated CO2 levels will further modify plant dynamics. Although several studies confirm previous findings that elevated CO2 concentrations may ameliorate otherwise negative impacts from ozone, it is important to note that increasing ozone concentrations in the future, with or without climate change, will negatively impact plant production and possibly increase exposure to pest damage. Current risk assessment tools do not sufficiently consider these key interactions. Improved modeling approaches linking the effects of ozone, climate change, nutrient and water availability on individual plants, species interactions, and ecosystem functions are needed, and some efforts are under way. Although Ultra Violet (UV)-B exposure is in general harmful to plant growth, knowledge on the interactions between UV-B exposure and elevated CO2 is still incomplete, with some experimental findings suggesting that elevated CO2 levels ameliorate the negative effects of UV-B on plant growth, while others show no effect.

VULNERABILITY OF CARBON POOLS

Impacts of climate change on the land that is under human management for food and livestock have the potential to significantly affect the global terrestrial carbon sink and to further perturb atmospheric CO2 concentrations. Furthermore, the vulnerability of organic carbon pools to climate change has important repercussions for land sustainability and climate mitigation actions. Future changes in carbon stocks and net fluxes would critically depend on land use planning—policies, afforestation/reforestation, and so on—and management practices such as nitrogen fertilization, irrigation, and tillage, in addition to plant response to elevated CO2. Recent experimental research confirms that carbon storage in soil organic matter pools is often increased under elevated CO2, at least in the short term; yet the total soil carbon sink may become saturated at elevated CO2 concentrations, especially when nutrient inputs are low.

AREAS OF NEW KNOWLEDGE

Increases in the frequency of climate extremes may lower crop yields beyond the impacts of mean climate change. More frequent extreme events may lower long-term yields by directly damaging crops at specific developmental stages, such as by surpassing temperature thresholds during flowering, or by making the timing of field applications more difficult, thereby reducing the efficiency of farm inputs. A number of simulation studies have investigated specific aspects of increased climate variability within climate change scenarios. For example, it has been assessed that, under scenarios of increased heavy precipitation, production losses as a result of excessive soil moisture—already significant today—would double in the United States to $3 billion per year in 2030. Other scenarios have focused on the consequences of higher temperatures on the frequency of heat stress during growing seasons, as well on the frequency of frost occurrence during critical growth stages.

The impacts of climate change on irrigation water requirement may be large. A few new studies have further quantified the impacts of climate change on regional and global irrigation requirements, irrespective of the positive effects of elevated CO2 on crop water use efficiency. Considering the direct impacts of climate change on crop evaporative demand, in the absence of any CO2 effects, an increase of net crop irrigation requirements is estimated, that is, net of transpiration losses, of 5 to 8 percent globally by 2070, and larger regional signals, for example, 15 percent in southeast Asia. In another study, that included the positive CO_2 effects on crop water use efficiency, increases in global net irrigation requirements of 20 percent by 2080 were projected, with larger impacts in developed regions, due to increased evaporative demands and longer growing seasons under climate change. New studies have also projected increases in water stress—the ratio of irrigation withdrawals to renewable water resources—in the

Middle East and Southeast Asia. Furthermore, recent regional studies have likewise underlined critical climate change and water dynamics in key irrigated areas, such as increased irrigation requirements in North Africa and decreased requirements in China.

The stabilization of CO2 concentrations reduces damage to crop production in the long term. Recent work has further investigated the effects of mitigation on regional and global crop production, specifically, in the case of stabilized atmospheric CO2. Compared to business as usual scenarios—under which the overall impacts were already small—by 2100, the impacts of climate change on global crop production are predicted to be only slightly under 750 ppm CO2 stabilization. This is significantly reduced (–70 to –100 percent), if lower risks of hunger are considered (–60 to –85 percent), under 550 ppm CO2 stabilization. These same studies suggest that climate mitigation might alter the regional and temporal mix of winners and losers with respect to business as usual scenarios, but that specific projections are highly uncertain. In particular, in the first decades of this century and possibly up to 2050, some regions may be worse off with mitigation efforts than without, as a result of lower CO2 levels—and therefore reduced stimulation of crop yields—but the same magnitude of climate change, compared to unmitigated scenarios. Finally, a growing body of work has started to analyze the potential synergies as well as the incompatibilities between mitigation and adaptation strategies.

CONCLUSION

It could be seen clearly from the above discussion that agro ecological impact of climate changes an important phenomenon. The elevated atmospheric CO2 level to some extent enhances the crop yield in some regions and declines the crop yield in some regions. This increase in temperature can reduce the crop yield. The elevated CO2 may decline nitrogen content in the soil. Hence, there is a need to practice proper climate change mitigation measures in safeguarding the cropping system

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