Biodiversity Journal, 2015, 6 (2): 633–636

Effects of climate changes on agriculture

Parinesa Moshefi[1] & Ata Bahojb-Almasi[2*]

[1]Department of Geology, Maragheh branch, Islamic Azad University, Maragheh, Iran; e-mail: parinesa.moshefi@yahoo.com
[2]Master of Agronomy, University of Tabriz, Iran; e-mail: Ataalmasi@yahoo.com
[*]Corresponding author

ABSTRACT This paper reviews literature concerning a wide range of processes through which climate change could potentially impact agriculture. Agriculture is strongly influenced by weather and climate and, at present, the aggregate impacts of climate change on global-scale agricultural productivity cannot be reliably quantified.

KEY WORDS agriculture; climate; climate change.

Received 19.05.2015; accepted 20.06.2015; printed 30.06.2015

INTRODUCTION

Climate change has many elements, affecting biological and human systems in different ways. Global average temperature increases mask considerable differences in temperature rise between land and sea and between high latitudes and low; precipitation increases are very likely in high latitudes, while decreases are likely in most of the tropics and subtropical land regions (IPCC, 2007).

Climate change is inevitably resulting in changes in climate variability and in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events (IPCC, 2012). Changes in climate variability and extremes can be visualized in relation to changes in probability distributions, shown in figure 1 (IPCC, 2012). Current observations and climate projections suggest that one of the most significant impacts of climate change is likely to be on the hydrological system, and hence on river flows and regional water resources (Strzepek & McCluskey, 2007; Bates et al., 2008).

Principal climate variables affecting water availability are precipitation, temperature and potential evaporation. Precipitation is the source of all freshwater resources and determines the level of soil moisture, which is essential in the formation of runoff and hence river flow. Soil moisture is determined not only by the volume and timing of precipitation, but also by a complex interaction and feedbacks with evaporation and temperature (IPCC, 2001). Consequently, the likely impacts of climate change on the agricultural sector have prompted concern over the magnitude of future global food production (Bindi & Olesen, 2000).

DISCUSSION

Effects of increased temperatures

Temperature often determines the potential length of the growing seasons for different crops, and generally has a strong effect on the timing of the development processes and on the efficiency with which solar radiation is used to make plant biomass (Monteith, 1981). Recent increases in climate variability may have affected crop yields in countries across Europe since around the mid-1980s (Porter & Semenov, 2005) causing higher interannual variability in wheat yields. Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of development. Only a few days of extreme temperature at the flowering stage of many crops can drastically reduce yield (Wheeler et al., 2000).

Bryant et al. (2008) report the change of Corn Heat Units under climate change scenarios in their analysis on the economic impacts of climate change on cash crop farms in Québec. Wollenweber et al., (2003) found that the plants experience warming periods as independent events and that critical temperatures of 358 °C for a short-period around anthesis had severe yield reducing effects. However, high temperatures during the vegetative stage did not seem to have significant effects on growth and development.

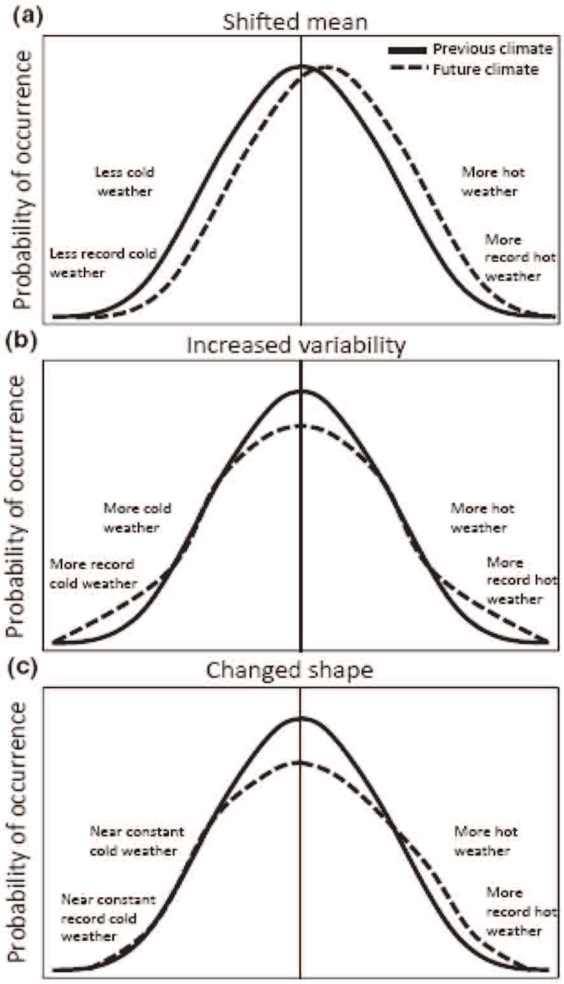

Figure 1 The effect of changes in temperature distribution on extremes. Different changes of temperature distributions between present and future climate and their effects on extreme values of the distributions: (a) Effects of a simple shift of the entire distribution towards a warmer climate; (b) effects of an increase in temperature variability with no shift of the mean; (c) effects of an altered shape of the distribution, in this example a change in asymmetry towards the hotter part of the distribution. From IPCC (2012).

In general, the conclusion is that increased mean annual temperatures in mid- to high-latitude regions, if limited to one to three degrees, across a range of CO_2 concentrations and rainfall changes can have a small beneficial effect on the main cereal crops, notwithstanding that such simulations are highly uncertain (IPCC, 2007).

Effects of rainfall

Climate changes remote from production areas may also be critical. Irrigated agricultural land comprises less than one-fifth of all cropped area but produces between 40 and 45 per cent of the world's food (Döll & Siebert, 2002), and water for irrigation is often extracted from rivers which depend upon distant climatic conditions.

With no change in precipitation (or radiation), slight warming (+1°C) might reduce average yields by about 5-4%; and a 2°C warming might reduce average yields by about 10-7%. In addition, reduced precipitation could also decrease yields of wheat and maize in these breadbasket regions. A combination of increased temperatures (+2°C) and reduced precipitation could lower average yields by over a fifth (Warrick et al., 1986). In a study looking at the impacts of current climate variability, Kettlewell et al. (1999) showed that heavy rainfall in August was linked to lower grain quality which leads to sprouting of the grain in the ear and fungal disease infections of the grain.

Effects of CO_2 fertilisation

Increases in CO_2 concentration would increase the rate of plant growth. A doubling of CO_2 may increase the photosynthetic rate by 30 to 100%, depending on other environmental conditions such as temperature and available moisture (Pearch & Bjorkman, 1983).

As well as influencing climate through radiative forcing, increasing atmospheric CO_2 concentrations can also directly affect plant physiological processes of photosynthesis and transpiration (Field et al., 1995). Therefore any assessment of the impacts of CO_2-induced climate change on crop productivity should account for the modification of the climate impact by the CO_2 physiological impact. Many studies suggest yield rises owing to this CO_2-fertilization effect and these results are consistent across a range of experimental approaches including controlled environment closed chambers, greenhouse, open and closed field top chambers, and free-aircarbon dioxide enrichment experiments (Tubiello, 2007). Despite the potential positive effects on yield quantities, elevated CO_2 may, however, be detrimental to yield quality of certain crops. For example, elevated CO_2 is detrimental to wheat flour quality through reductions in protein content (Sinclair et al., 2000). There are, however, important differences between the photosynthetic mechanisms of different crops and hence in their response to increasing levels of CO_2.

Effects on pest and diseases

Studies suggest that temperature increases may extend the geographic range of some pests currently limited by temperature. In cool temperate regions, where insect pests and diseases are not serious at present, damage is likely to increase under warmer conditions. Fungal and bacterial pathogens are also likely to become more severe in areas where precipitation increases (Zhou et al., 1995).

Indications suggest that pests, such as aphids and weevil larvae (Staley & Johnson, 2008), respond positively to elevated CO_2. Increased temperatures also reduced the overwintering mortality of aphids enabling earlier and potentially more widespread dispersion (Zhou et al., 1995). Over the next 10–20 years, disease affecting oilseed rape could increase in severity within its existing range as well as spread to more northern regions where at present it is not observed (Evans et al., 2008).

Adaptation to climate change

Smith (1997) distinguishes between anticipatory and reactive adaptation, in which anticipatory adaptation forecasts climate change and acts before it unfolds, while reactive adaptation changes behaviour only after climate change has taken place. According to Mendelsohn (2010), efficient adaptation results in the actual net damages (damages minus the cost of adaptation) being less than the potential damages from climate change. Thus, if farmers adapt their behaviour to new climatic conditions, then the net impact to the farm and the sector can be lessened. Adaptation through cropping pattern change can in some cases ease the exposure of plants to critical higher temperatures; for example by introducing winter types that may benefit from, or are less susceptible to, higher temperatures (Peltonen-Sainio et al., 2011). As regards precipitation changes and water shortage, farmers can adjust by improving soil water-holding capacity by adding crop residues or manure, or by adopting conservation tillage such as reduced tillage or no-till (Smith & Olesen, 2010).

CONCLUSIONS

An increase in mean temperature can be confidently expected, but the impacts on productivity may depend more on the magnitude and timing of extreme temperatures. Agricultural impacts in some regions may arise from climate changes in other regions, owing to the dependency on rivers fed by precipitation, snowmelt and glaciers some distance away. Few studies have assessed the response of crop yields to CO_2 fertilization under actual growing conditions, and consequently model projections are poorly constrained.

All these results are subject to significant uncertainties under the most likely climate change. A strong incidence of extreme events could increase the variability of production in a way that is not captured by the standard estimations in the literature. Farmers may significantly adapt farming practices, or different degrees of adaptation to climate change could be observed.

REFERENCES

Bates B.C., Kundzewicz Z.W., Wu S. & Palutikof J.P., 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Bindi M. & Olesen J.E., 2000. “Agriculture”. In: M.L. Parry (Ed.), Assessment of Potential Effects and Adaptations for Climate Change in Europe: The Europe ACACIA Project. Norwich, United Kingdom: Jackson Environment Institute, University of East Anglia.

Bryant C., Singh B., Thomassin P., Baker L., Desroches S., Savoie M., Delusca K., Doyon M. & Seyoum E., 2008. Evaluation of Agricultural Adaptation Processes and Adaptive Capacity to Climate Change and Variability: The Construction of New Adaptation Planning Tools and with Stakeholders and Farming Communities in the Saguenay-Lac-Saint-Jean and Montérégie Regions, Project number A1332 submitted to Natural Resources Canada, Climate Change Impacts and Adaptation Program, Université de Montréal and McGill University Research Team, June 2008.

Döll P. & Siebert S., 2002. Global modeling of irrigation water requirements.Water Resources Research, 38: 8.1-8.10. DOI:10.1029/ 2001WR000355

Evans N., Baierl A., Semenov M.A., Gladders P. & Fitt B.D.L., 2008. Range and severity of a plant disease increased by global warming. Journal of Royal Society, 5: 525–531. DOI:10.1098/rsif.2007.1136

Field C., Jackson R. & Mooney H., 1995. Stomatal responses to increased CO_2: implications from the plant to the global scale. Plant, Cell and Environment, 18: 1214-1255.DOI:10.1111/j.1365-3040.1995. tb00630.x

IPCC., 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IPCC. J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, J. van der Linden, X. Dai, K. Maskell and, C.A. Johnson (Eds.). Cambridge University Press, UK., 944 pp.

IPCC., 2007. Climate Change 2007: impacts, adaptation and vulnerability. summary for policy makers. Available at: www.ipcc.cg/SPM13apr07.

IPCC., 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. In: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Field C.B., Barros V., Stocker T.F. et al. (Eds.), Cambridge University Press, Cambridge, NY, USA.

Kettlewell P.S., Sothern R. & Koukkari W.L., 1999. UK wheat quality and economic value are dependent on the North Atlantic oscillation. Journal of Cereal Science, 29: 205–209. DOI:10.1006/jcrs.1999.0258

Mendelsohn R., 2010. Agriculture and economic adaptation to agriculture, COM/TAD/CA/ENV/EPOC (2010)40/FINAL, OECD, Paris.

Monteith J.L., 1981. Climatic Variation and the Growth of Crops. Quarterly Journal of the Royal Meteorological Society, 107: 749–774.

Pearch R.W. & Bjorkman O., 1983. Physiological Effects. In: Lemon E.R. (Ed.), Cdeg.2 and Plants: The Response of Plants to Rising Levels of Atmospheric Cdeg.2, Westview Press, Boulder, Colorado, 65–105.

Peltonen-Sainio P., Hakala K. & Jauhiainen L., 2011. Climate Induced Overwintering Challenges for Wheat and Rye in Northern Agriculture. Acta Agriculturae Scandinavica, Section B, Soil and Plant Sciences, 61: 75–83.

Porter J.R. & Semenov M.A., 2005. Crop responses to climatic variation. Philosophical Transactions of the Royal Society, 360: 2021–2035. DOI:10.1098/rstb. 2005.1752

Sinclair T.R., Pinter P.J. Jr., Kimball B.A., Adamsen F.J., La Morte R.L., Wall G.W., Hunsaker D.J., Adam N., Brooks T.J., Garcia R.L., Thompson T., Leavitt S. & Matthias A., 2000. Leaf nitrogen concentration of wheat subjected to elevated (CO_2) and either water or N deficits. Agriculture, Ecosystems and Environment, 79: 53–60. DOI:10. 1016/S0167-8809(99) 00146-2

Smith J.B., 1997. Setting Priorities for Adapting to Climate Change. Global Environmental Change, 7: 251–264.

Smith P. & Olesen J.E., 2010. Synergies Between the Mitigation of, and Adaptation to, Climate Change in Agriculture. Journal of Agricultural Science Cambridge, 148: 543–552.

Staley J.T. & Johnson S.N., 2008. Climate change impacts on root herbivores. In: S.N. Johnson & P.J. Murray (Eds.), Root Feeders: an ecosystem perspective. Wallingford, UK: CABI.

Strzepek K. & McCluskey A., 2007. The Impacts of Climate Change on Regional Water Resources and Agriculture in Africa.Policy Research Working Paper 4290.World Bank, Washington, DC.

Tubiello F.N., 2007. Crop response to elevated CO_2 and world food supply-a comment on "Food for Thought" by Long et al. Science, 312: 1918–1921, 2006. European journal of agronomy, 26: 215–223. DOI:10.1016/j.eja.2006.10.002

Warrick R.A., Gifford R. & Parry M.L., 1986. CO_2, Climatic Change and Agriculture. In: Bolin B., Doos B.R., Jager J. & Warrick R.A. (Eds.), The Greenhouse Effect, Climatic Change and Ecosystems, SCOPE 29, John Wiley and Sons, Chichester, 393–473.

Wheeler T.R., Craufurd P.Q., Ellis R.H., Porter J.R. & Prasad P.V.V., 2000. Temperature variability and the yieldof annual crops. Agriculture, Ecosystems and Environment, 82: 159–167. DOI:10.1016/S0167-8809(00)00224-3)

Wollenweber B., Porter J.R. & Schellberg J., 2003. Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. Journal of Agronomy and Crop Science, 189: 142–150. DOI:10.1046/j.1439-037X.2003.00025.x

Zhou X.L., Harrington R., Woiwod I.P., Perry J.N., Bale J.S. & Clark S.J., 1995. Effects of temperature onaphid phenology. Global Change Biology, 1: 303–313. DOI:10.1111/j.1365-2486.1995.tb00029.x