# ANTICIPATED IMPACTS ON FOOD PRODUCTION

## How significant is the water variable?

The links between climate, water and food production may be complex, but the equation between temperature, water and plant physiology is essentially fixed. For any C3 or C4 plant, a fixed amount of evapotranspiration and carbon dioxide is required to assimilate carbon. Put simply, more food or fibre production requires more soil water – whether it is derived from rainfall or from surface and groundwater sources through irrigation. While ‘more crop per drop’ may be an objective for overall management of irrigation and delivery of water to the soil horizon, any increase in biomass can only be attained through increased water availability in the soil horizon. While climate already determines what can be grown at any particular location, it is the range of hydrological changes that are anticipated under the various emissions scenarios that gives cause for concern. Impacts on crop production systems can be anticipated, from failure of rainfed crops in highland areas to inundation of irrigated crops in coastal deltas.

From a water management perspective, the first question to ask is how any climate change impact will translate to higher or lower temperatures and more or less water availability in the root zones of the staple crops upon which humans and animals depend. If this can be established with an adequate degree of precision for specific farming systems, the second question to ask is whether water management can facilitate the adaptation of farming systems to mitigate climate risk or exploit climatic opportunities. The levels of confidence attributed to the modelling of climatic impacts under the SRES emission scenarios notwithstanding, at the global level it is not a simple case of agriculture systems coping with higher temperature and less water. Purely interms of climatic variables, the regional contrasts are significant. When super-imposed upon the mosaic of socio-economic development, the actual impact of climate on soil moisture availability and water supply to agriculture will be felt in terms of global food security as a second or third order effect. To the extent that water serves as the transmitter of climate changes to society, decisions over how water is allocated to meet basic human needs and the demands of productive sectors will constitute the primary adaptation measure.

Rainfed systems will be impacted by the first order effects of climate change – temperature, relative humidity and rainfall. Once soil moisture deficits in the root zone falls below the wilting point of staple crops, the assimilation of carbon and biomass is attenuated and yields fall off.

Zero rainfall or lower than expected rainfall equates to zero or reduced crop yields and cannot be negotiated. Improvements to soil structure and moisture holding capacities can be made by agricultural practice, but if soils do not reach field capacity in any year, production will be zero or sub-optimal. Because of these first order effects, the productivity of rainfed systems under climate change assumptions can be modelled interms of agro-ecological response , but this does not detract from the fact that production from rainfed systems will continue to be inherently volatile. Under climate change projections, amplification of this volatility is expected.

Irrigated systems of all kinds, from village gardens to the large irrigation schemes associated with river valleys and coastal deltas are designed to buffer soil moisture deficits and remove the agricultural production risk both in subsistence and commercial farming systems. In this sense they have already adapted to climates with no or limited annual replenishment of soil moisture and will be impacted by second order effects of climate change – runoff and groundwater recharge. High temperatures and high insolation encourage growth of key staples such as rice, and low relative humidity keeps down pests and disease. Unlike rainfed systems, irrigated agriculture cannot be analyzed in the same way as the rainfed systems under Agro Ecological Zones assumptions. Indeed AEZ modelling copes with irrigated areas as a ‘mask’.

Regions already struggling with complex food related challenges will clearly be more sensitive. The larger agricultural systems, such as the areas of continuous irrigation in Asia, may be more buffered in terms of runoff sources and recharge and the ability to apply technology, but basin-wide shifts in temperature, evapotranspiration and water availability would have greater impacts on global food supply. Assessing the scale impacts of climate change, hydrology and global food production is, therefore, a key challenge to modellers and statisticians. While there are a range of adaptation options already available, many of which are frequently used to cope with current climate variability, such options may only be suited to cope with moderate climate changes, but limited in dealing with more severe changes.

Thus, climate influences agriculture in various direct and indirect ways. Maximum, minimum and average temperatures set boundary conditions for crop growth, and changes in any of these parameters, therefore, have direct or indirect positive or negative effects on the food production potential of a specific crop and region. Temperature changes may eventually shift entire climate zones. Observations from many regions show that several natural systems are affected by regional climate changes, but it remains a challenge to isolate the climate signal from other drivers of change occurring simultaneously.

Direct effects from temperature changes on agriculture have been noted with' medium confidence' in Northern Europe but are harder to detect in other parts of the world. Less extreme cold temperatures but more Heat-waves are becoming increasingly likely.

There is strong consensus that continued greenhouse gas emissions will cause further warming. In the shorter term, a range of emission scenarios points toward a 0, 2 ˚C warming per decade. On longer time-scales , scenarios indicate an increase between 1.1 and 6.4 ˚C. Clearly, uncertainty remains high. As these are global averages, regional differences are likely to be substantial. Temperature increases are generally expected to be higher both at high latitudes and altitudes. For instance, the measured temperature increase at 3000 meters in the Himalayan region is three times higher than at sea-level over the last 100years.

As argued above, the direct climate impacts on the hydrological systems are essential to agriculture. According to IPCC and Bates et al.  climate change is in general expected to exacerbate water stress. This may have severe impacts, in particular in regions already under sever stress from population growth, rapid economic development, land-use changes, pollution and urbanization. The combined changes in both precipitation and temperature also affect groundwater recharge and runoff, and may therefore strengthen (warmer/less rain) or counteract (warmer/more rain) each other.

IPCC points out that there is a high level of confidence that the negative impacts from climate change on freshwater systems will outweigh the potential benefits. As there will also be an intensification of the hydrological cycle, there are increasing risks of more heavy rain-falls, increasing direct crop damage and/orca using flash-floods and floods.

The direct impacts on food production depends on region and time scale. Although crop productivity is projected to increase some at mid- to high latitudes when mean temperature increases 1–3 ˚C, it is expected to decrease as the temperature increase becomes higher. In the seasonally dry and tropical regions, sensitivity to even small shifts in temperature is higher, and it is expected that productivity will decrease. In total (global scale), food production is projected to first increase but later decrease following continuously higher average temperatures. It is also important to consider other effects. The effects of CO2 on plant growth present a good example. Although CO2 acts as a fertilizer, it is the combination with the temperature changes and availability of nutrients which will give a net effect. CO2 fertilization is, therefore, most profound in tropical wet climates and less so in cold climates. Other important aspects to consider are the changing patterns of weeds, pests and (pollinating) insects following changes in temperature and precipitation.

Although uncertain, IPCC also provides some disturbing examples of the effects that could be expected if not appropriately managed.

In Africa alone,75–250 million people are projected to be exposed to increased water stress, and yields from agriculture are expected to decrease as much as 50% in some countries. The area of semi-arid and arid land will increase. Land areas classified as very dry have already doubled since the 1970s .In Asia, freshwater availability in many large rivers may decrease and changes in water availability from glacier and snow melting will have extensive effects on water availability and thus indirectly on agriculture. In the Middle East, an increase in average temperature of 1 ˚C is likely to increase agricultural water demand by 10%. The costs can be significant and scenarios projecting a high significant temperature increase suggest costs equal to a 3,5% loss in GDP due to loss of arable land and threats to coastal cities. In Latin America, there could be gradual replacement of tropical forests by savannah and productivity of some important crops is projected to decrease. Lobell et al., points out that South Asia and Southern Africa are two regions with food production based on crops that are likely to be negatively affected by climate change. However, the effects are in the end strongly dependent upon changes in other socio-economic parameters and the projected range of increasing numbers of hungry people in the future is very wide.

Climate change impacts are not only confined to developing countries. Agriculture and forestry is expected to become increasingly difficult in eastern Australia as aridity intensifies.

In Europe, the already significant regional differences in water availability will increase and drought will be even more common in the Mediterranean region. North America will experience potential increases in rain-fed agriculture in the eastern and northern parts while decreasing snow and ice will reduce summer flows in already water scarce western regions. An article presenting potential hot-spots in North America represents uninteresting overview of such challenges. In addition, there could also be severe effects on water quality, which, in turn, could have adverse effects on agriculture.

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