ANTICIPATED IMPACTS OF CLIMATE CHANGE ON GLOBAL HYDROLOGY

Transmission of impacts to agriculture

The Fourth Intergovernmental Panel on Climate Change Assessment Report, published in 2007, presents the state of the art knowledge, including important references to the modelled climate change impacts on water resources. A more detailed technical paper on climate change and water has been prepared by the IPCC and provides a comprehensive synthesis. Since agriculture is practiced in most parts of the world, with the exception of interior deserts and the Polar Regions, all hydrological impacts are of significance to agricultural practice and production.

According to the IPCC AR4 “warming of the climate system is unequivocal” with considerable impacts on air and ocean temperatures, snow and glacier melting and a rising sea-level. Both IPCC and Bates et al. stress with high confidence that a number of hydrological systems have started to change following changes in climate, for example through increased runoff and earlier peak discharge in snow and glacier-fed river systems.

There is a globally increasing trend in precipitation over land areas of about 3.5 mm/year per decade but this is based on very short observational record. Regional scales are more important than global averages. Increasing precipitation trends are evident from the eastern part of the Americas, northern Europe, and northern and central Asia since the beginning of the last century. Decreases have been observed in the Sahel region, the Mediterranean, southern Africa and parts of southern Asia. Changes in precipitation and evaporation have more or less direct impacts on both river and groundwater systems. Already semi-arid areas are vulnerable to small changes, and many such areas are expected to see decreasing rainfall combined with increasing evaporation. Certainly, in terms of managing the shallow renewable groundwater circulation, the prospect of climate change should prompt a sharpened appreciation of recharge processes, storage changes and socio-economic response. In addition, for those aquifer systems decoupled from contemporary recharge, the planned depletion may need to be re-evaluated if those aquifers are going to become the lender of last resort. Ocean temperatures are an important factor to determine changes in precipitation. Events such as the El Niño and La Niña in the Pacific Ocean clearly

have strong impacts on regional climate, not least precipitation patterns. Recent decreases in precipitation over part of Africa have been attributed to the warming of the Indian Ocean sea-surface temperatures.

The understanding of the coupling of such events to atmospheric circulation (such as El Niño – Southern Oscillation (ENSO),the North Atlantic Oscillation (NAO), and climate change is essential. ENSO, as an example, and the associated cycles of drought and flooding events, could explain as much as 15–35% of global yield variations in wheat, oilseeds and coarse grains harvests.

Increased precipitation will augment the risks for floods, in particular in flood plains and other low-lying areas. Deltas are particularly vulnerable to changes. Increases in precipitation, with more intense run-off, in combination with higher sea-levels could cause increasing flood risks. Less precipitation could, also in combination with higher sea-levels, lead to more intense coastal erosion.

Most mountain glaciers are currently retreating, which at least partly explains changes in annual net flow as well as temporal changes in some rivers. In the Hindu Kush range, changes in the river ecosystem resulting from decline in the glaciers and perennial snow have already been observed. Historically, high-level discharge in these rivers lasted throughout the cropping season, from April–September. It has now shifted into shorter, more intense run off in April and May, leaving increasing periods of the cropping season relatively dry.

Although total river basin discharges will normally first increase through increased melting, the long term effect will be less run-off as increasingly smaller glaciers and reduced snow-pack reduce storage of precipitation as snow and ice. When a glacier eventually disappears, the effects on the seasonal availability of water in downstream regions can be dramatic. Such changes represent a serious challenge to the one-sixth of the global population that relies on melt-water from glaciers and permanent snow-packs for part of the year, notably in China and India for example.

Extreme events transmitted through the hydrological cycle, can have severe direct impacts on agriculture. From 1992 to 2001, nearly 90 percent of all natural disasters were of meteorological or hydrological origin. However, it is still difficult to detect trends in small-scale events such as dust storms, hail and tornados and there are no obvious long-term trends in relation to the annual number of tropical cyclones. Although a substantial increase is evident in the Atlantic since the early 1970s, periods of equally high number have occurred earlier in the 20th century.

However, measured effects from extreme events are dubious. In part, this is in because the interactions are complicated and not linear, but also because a range of non-climate factors governs the observed effects. Modified landscapes and infrastructure development as well as changes in hydrological systems strongly influence the effects of the climate signal.

Flooding may increase in one area, but it remains a challenge for a planner to determine how much of the increase is due to climate change exacerbating precipitation and run-off and how much results form non-climate factors such as land use changes, river modifications etc. A drought may appear more straight forward, but the effects can be amplified by factors such as poor land management, land use changes and increased water use.

Regional rainfall projections and runoff are particularly interesting. Possible changes in runoff over the 21st century, based on results from 12 rainfallrunoff models, were presented in a paper by Milly et al. They show that there is a strong agreement between models on increases in the high latitudes of North America and Eurasia, in the La Plata basin of South America, in eastern equatorial Africa and in some major islands of the equatorial eastern Pacific Ocean. Similarly, decreasing average annual runoff (typically 10–30%) could be expected in southern Europe, the Middle East, mid-latitude western North America, and southern Africa. In other regions, there is less agreement between the models. An interesting and more detailed case also showing such challenges is the effort to predict rainfall changes over the Amazons. Eleven models were used in the IPCC AR4 to predict rainfall. Out of these, five predicted an increase of annual rainfall, three predicted a decrease, and the other three models predicted no significant changes in rainfall.

This is the planning reality many policy makers and managers will have to work from.

Precipitation patterns may also be affected by other factors. In a recent article in Nature, Cox et al. focuses on the increasing risk of Amazonian drought due to decreasing aerosol pollution. The correlations between such factors in this region can be difficult, as drought is a recurring phenomenon during El Niño – Southern Oscillation (ENSO) events. However, the drought occurring in 2005 did not correspond to such an ENSO event and it was therefore possible to look at other potential parameters affecting precipitation. This serves as an illustration of how difficult it is to find straightforward correlations and cause-effects. If there has been a significant cooling effect from relatively high atmospheric aerosol content, future warming could actually become even higher if we are successful in reducing the atmospheric content of such particles.

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