Chapter D.1

Introduction

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The foregoing parts demonstrate that the dynamics and biophysical character of land-atmosphere interactions are intimately connected to the dynamics and biophysical character of the land-based water cycle. The hydrological cycle has been shown to play a central role in our analysis of climate change, the impacts of land-use and land-cover change, and vegetation dynamics.

There are additional, significant issues that must be considered to more completely define the full dimension of global change with respect to the hydrological cycle. These collectively define a central role for humans in shaping the character of the terrestrial water cycle, not only at local scales, but over regional and even global domains as well.

Humans exert an influence on the water cycle not only through the highly-publicised greenhouse effect but also through the forces of land-cover change, land-management practices, urbanisation, and the construction and operation of water engineering facilities. These factors all dramatically alter hydrological dynamics and form the key focal points of this section. These issues will be addressed in the context of our primary scientific question:

- Over a decades-to-century time frame, what are the relative impacts on the terrestrial hydrological cycle of (*a*) climatic variation and greenhouse warming, (*b*) land-cover change and land management, and (*c*) direct alterations due to water resource management?

The global change research community has arguably focused its attention on climate change and much less on these other factors. Is this the correct focal point for our collective efforts? An objective answer to this central question will colour the progress of our science over the next several years, and we contend it is a necessary starting point as we look toward the future.

It is clear that movement toward a global picture of hydrospheric change – one in which humans figure prominently – will require us to identify appropriate hydrological and socio-economic principles and to combine these within a common framework. A central goal of this chapter is to summarise recent findings and to explore their use in moving us toward a global synthesis. Our emphasis will be on the biogeophysical aspects of this question, but considering socio-economic issues as they become relevant.

Building on a long and rich history of small-scale catchment-scale studies dating back more than 100 years, there are exciting new opportunities in the water sciences as we move toward a global view of environmental change and its impact on the water cycle. More traditional hydrological research has uncovered the mechanics of the water cycle describing such processes as evapotranspiration, soil physics, groundwater dynamics and runoff generation. Process-based knowledge has also accumulated on the mobilisation and transport of constituents – including pollution – which are entrained in runoff and river flow. This work provides us with the fundamental principles necessary to detect and interpret the ongoing forces of environmental change. It thus merits an important place in this synthesis chapter and we treat it explicitly in several sections.

Early on, scientific hydrology was turned toward a pragmatic goal of providing sufficient understanding to predict, or at least better manage, catastrophic flooding, drought, erosion and sedimentation, and pollutant source areas and eutrophication. In fact, much of what prompted hydrological analysis was driven by the needs of hydrological engineers. Humans are thus hardly passive when it comes to hydrological events and we have done much to transform the terrestrial hydrosphere into a highly managed biogeochemical cycle (Fig. D.94). This is certainly true at the local scale, and we contend that these changes are now certainly of regional importance, and ultimately pandemic in extent. With population growth and economic development will come increasing pressures to control water supplies in service to humanity. It is thus important to articulate the role of humans and to prepare for the wise management of what are in many parts of the world increasingly scarce water resources. Integrated Water Resources Management (IWRM) will constitute a key emphasis in our discussion.

The community is poised for major progress toward global synthesis. This results from the wide availability, relatively recently, of state-of-the-art datasets and analysis tools including GIS (Geographic Information System) and remote sensing. Analogous to the paired catchment study which has served as the mainstay of hydrological research at the small scale, the conceptual framework of the drainage basin as a functioning hydrological unit permits us to analyse how the spatial organisation of whole river systems conditions continental runoff. This perspective will be critical to our success in progressing upwards in scale from the small catchment to the meso-scale catchment to continents, and ultimately the globe.

We have several specific goals for this section:

- to articulate the role of humans in the terrestrial water cycle by assessing the relative importance of different sources of anthropogenic impact: climate change, land-cover and land-use change, and water engineering;
- to define a strategy for moving across time and space scales;
- to summarise recent developments in the field over the last 10–20 years and explore how these might be used to move us toward a more synthetic view of a rapidly changing water cycle, ultimately to the global scale; and,
- to identify appropriate water management principles that could be applied in the face of these ongoing environmental changes.

This part is structured according to a scaling framework which permits us to place recent findings into a common context. Detailed sections on local to small-catchment scale processes are followed by a regional analysis. We turn next toward an analysis of emerging trends at the global scale. At each stage we re-visit our central hypothesis, assess its validity, and identify key areas for future progress. Several case studies of specific river basins are completing the part. A concluding section identifies key steps forward.