Chapter D.8

Conclusions: Scaling Relative Responses of Terrestrial Aquatic Systems to Global Changes

Michel Meybeck · Charles J. Vörösmarty · Roland E. Schulze · Alfred Becker

D.8.1 Terrestrial Aquatic Systems and Earth System under Pressure

From an even cursory reading of the material presented in this chapter, it should be quite apparent that terrestrial aquatic systems encompass a broad set of biogeophysical landscape features and complex processes. Terrestrial aquatic systems include water, waterborne material, sediment and biota in vegetation, the soil unsaturated zone, groundwaters, wetlands, rivers, lakes and artificial water bodies such as reservoirs, canals. The fundamental drivers of water circulation and related material fluxes (for nutrients, carbon, particulate matter, pollutants) are multiple and combine physical, chemical and biological processes including open water evaporation, precipitation, infiltration, water runoff generation, water routing, erosion, leaching, weathering, silting, evapotranspiration, biological uptake and bacterial degradation. Together with their associated coastal zones, terrestrial aquatic systems constitute what we define as continental aquatic systems (CAS) (Fig. D.94).

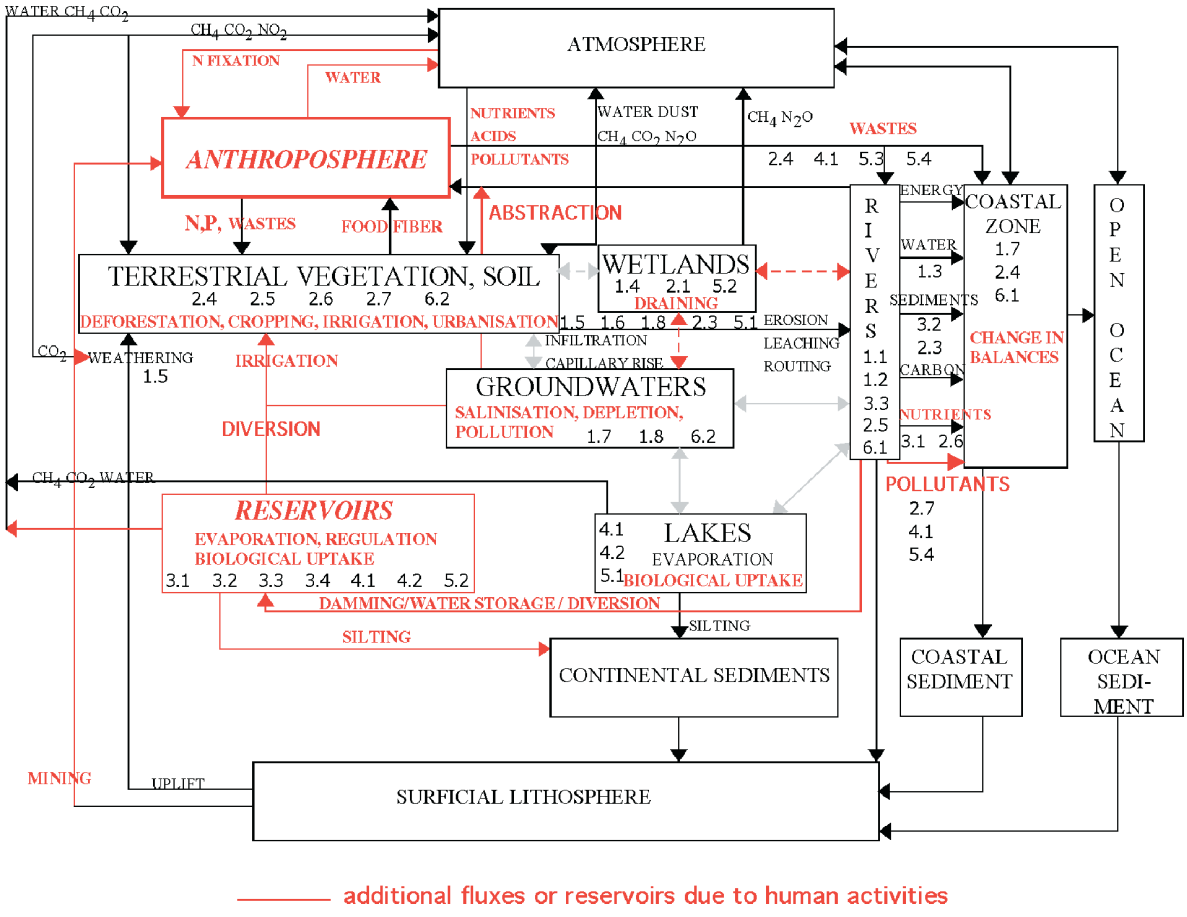

Fig. D.94. Continental aquatic systems (CAS) in the present-day Earth system (in *red*: major impacts of human activities; *grey*: water flux; *numbers* refer to Table D.30; Meybeck 2003)

Some CAS fluxes have very short cycles of only days to weeks, such as those associated with major atmospheric cycles, while others have very long cycling times that span geological time scales. The time domain of water transferred from headwaters to the receiving bodies ranges from a few days when routed through river channels (Vörösmarty et al. 2000b), to years and even a century if large lakes and/or groundwater pools are pres-ent. At the global scale, river waters continuously carry enormous fluxes of material to the oceans (40 000 $km^3\,yr^{-1}$ of water with 20×10^{15} g of suspended matter, 4×10^{15} g of dissolved salt as Ca^{2+}, SO_4^{2-}, dissolved inorganic carbon and 0.4×10^{15} g of organic carbon). They also provide the coastal zone with essential nutrients as nitrogen, phosphorus and silica as well as with $25 \pm 10 \times 10^{15}$ g of particulates that regulate coastal morphology.

Human activities have greatly modified the Earth system through climate change, land-cover and land-use changes, water engineering, and the release of wastes to aquatic systems. In the past 50 years, this anthropogenic influence has exceeded natural forcings in many parts of the world, or for some issues such as the nitrogen and phosphorus inputs to ocean, helping to define a new era, the *Anthropocene* (Crutzen and Stoermer

Table D.30. Major global pressures on Continental Aquatic Systems and the mapping of local-to-regional scale impacts to the global scale (also reported in Earth system dynamics, Fig. D.94, adapted from Meybeck 1998). *A*: human health, *B*: hydrological cycle balance, *C*: water quality, *D*: global carbon balance, *E*: fluvial morphology, *F*: aquatic biodiversity, *G*: coastal zone impacts. Only the major links between issues and impacts are listed here (POPs = Persistent Organic Pollutants)

Pressures	Local to regional changes of environmental states	Global impacts						
		A	B	C	D	E	F	G
1 Climate variability and climate change	1.1 Development of non-perennial rivers		•	•	•	•	•	•
	1.2 Segmentation of river networks					•	•	
	1.3 Changes in flow regimes		1		1	⇔	⇔	1
	1.3 Development of extreme flow events		•			•	•	•
	1.4 Changes in wetland distribution	•	•	•	•		•	•
	1.5 Changes in chemical weathering				•			•
	1.6 Changes in soil erosion				•	•		•
	1.7 Salt water intrusion in coastal groundwaters		•					
	1.8 Salinisation through evaporation		•	•			•	
2 Land use change	2.1 Wetland filling or draining			•	•		•	
	2.2 Changes in water passways		1	1				
	2.3 Change in sediment transport				•	•		•
	2.4 Urbanisation	•	•					•
	2.5 Alteration of first order streams					•	•	
	2.6 Nitrate and phosphate increase	•		•	•			•
	2.7 Pesticide increase	•		•				•
3 River damming and channelisation	3.1 Nutrient and carbon retention				•			•
	3.2 Retention of particulates				•	•		•
	3.3 Loss of longitudinal and lateral connectivity						•	
	3.4 Creation of new wetlands	•		•	•		•	
4 Industrialisation and mining	4.1 Increases in heavy metals and POPs	•		•				
	4.2 Acidification of surface waters			•			•	
	4.3 Salinisation	•		•			•	
	4.4 Sediment sources					•		•
5 Urban wastes	5.1 Nitrate and phosphate increase	•		•	•		•	•
	5.2 Enhancement of water-borne diseases	•						
	5.3 Organic pollution	•		•			•	
	5.4 Heavy metals and POPs increase	•		•				•
6 Irrigation/water transfer	6.1 Partial to complete decrease of river fluxes					•	•	•
	6.2 Salinisation (evaporation and percolation)		•	•				

A: Human health, *B:* hydrological cycle balance, *C:* water quality, *D:* global carbon balance, *E:* fluvial morphology, *F:* aquatic biodiversity, *G:* coastal zone impacts. Only the major links between issues and impacts are listed here (*POPs* = Persistent Organic Pollutants).