WETLANDS AND AGRICULTURE: ARE WE HEADING FOR CONFRONTATION OR CONSERVATION?

Brij Gopal[1]

Abstract—Wetlands and agriculture are closely linked. Historically, agriculture had its beginning in riparian wetland habitats and expanded into other wetlands. Later, large areas of riverine, palustrine, and coastal wetlands were converted into paddy fields or drained for agriculture. Agriculture has grown most at the expense of natural wetlands. Today, the intensive agriculture depends upon heavy inputs of water (irrigation) and agrochemicals. Thus, agriculture now threatens the remaining wetlands through alteration of hydrological regimes, siltation, and pollutants. Conservation of wetlands requires an integrated, balanced, and coordinated approach to the management of water resources whereby the impacts of agriculture on wetlands are minimized without compromising agricultural production.

INTRODUCTION

Wetlands and agriculture are closely linked together, dating back to the prehistoric period. Both wetlands and agriculture have greatly influenced humankind. Available evidence suggests that human settlements started in and around the wetlands (Williams 1990). Long before humans learned to grow food, they depended, at least partly, on wetlands for their sustenance. Agriculture had its beginning in the wetlands and grew at the expense of wetlands (and forests). Today, about 12 percent of the earth's land area is under agriculture. Wetlands occupy < 6 percent of the land area. Of this, rice culture accounts for about 15 percent and provides staple food for about 40 percent of the world's human population (Hook 1993).

The concern for wetlands is rather recent—only about three decades old. Until recently, wetlands were treated with contempt as wastelands, worthy of drainage and reclamation for agriculture and other land uses. Now that many functions and values of wetlands have been recognized (Mitsch and Gosselink 1993), efforts are made to conserve and restore them. Wetlands, which have been the victim of agriculture, are also projected today as protectors of water resources against the impacts of agriculture. In this paper, I try to trace the linkages between wetlands and agriculture through the millennia and show how agriculture continues to impact upon the wetlands. I conclude with a call for an appropriate policy to strike a balance between agriculture and wetland conservation.

AGRICULTURE IN WETLANDS

Agriculture is deeply rooted in wetlands. Since prehistoric times, agriculture has been practiced in and sustained by wetlands. Agriculture is known to have started in the Middle East where seasonally flooded wetlands—the riverine floodplains—provided the ideal environment. The crops required no subsidy of energy and nutrients. Seeds were sown after the floods receded exposing the wet soils enriched with fresh sediments, and the decaying terrestrial vegetation provided the nutrients. Such low-subsidy agriculture in floodplains continues today in many parts of the world. In India, the local communities raise a variety of crops, such as cucurbits, chillies, tomatoes, etc., not only in the riparian fringes, but even on the riverbed. The seasonal wetlands throughout the arid and semi-arid regions of the world are widely used for raising a variety of crops during the low water period; for example, dambos are valuable habitats for agriculture and grazing in Zimbabwe (Scoones and Cousins 1994). Such agriculture relies heavily on the timing, frequency, and intensity of flood events.

As the human societies depended increasingly more on agriculture and developed settlements around wetlands, agriculture was diversified greatly to exploit many kinds of wetlands. Humans also recognized the food value of many of the wetland plants, which were cultivated in the wetlands by excluding other competitors. Rice (including deep-water rice) and taro are well-known examples. *Trapa bispinosa, Nelumbo nucifera, Euryale ferox*, several sedges (*Cyperus esculentus*) and grasses (*Panicum, Echinochloa*, etc.) are cultivated extensively in seasonal wetlands of South and Southeast Asia for food.

At the same time, in several parts of the world, agriculture expanded further into the waterbodies. Deep-water rice, for example, is grown in India, Bangladesh, Myanmar, Thailand, Vietnam, Mali, and Niger in waters where depths may exceed 6 m (Vergara 1992). In shallow marshes and littorals of large lakes, rapid vegetative growth of certain macrophytes, such as *Vossia, Cyperus papyrus, Salvinia* spp., *Eichhornia crassipes*, *Echinochloa, Paspalum*, etc., produces huge biomass, which decays very slowly resulting in the accumulation of thick layers of detritus mixed with mineral matter. This decaying mass of organic matter becomes afloat with the rise in water level following the rains. These floating islands also become colonized with a variety of terrestrial and wetland plants and often grow in size with further accumulation of organic and mineral matter. Floating islands occur widely throughout the tropics and are known

[1] Associate Professor, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India.

Citation for proceedings: Holland, Marjorie M.; Warren, Melvin L.; Stanturf, John A., eds. 2002. Proceedings of a conference on sustainability of wetlands and water resources: how well can riverine wetlands continue to support society into the 21st century? Gen. Tech. Rep. SRS-50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 191 p.

variously as camalotes in Brazil, embalsados in Argentina, Batumes in Paraguay, sudds in Africa, and phumdis in eastern India (John 1986, Por 1995, Tombi Singh and Singh 1995). They are known also from outside the tropics; e.g., in the Mississippi River Delta in Louisiana (Sasser and others 1995) and in Lake Posta Fibreno in Italy (V. Chet, personal communication). Probably taking cue from these natural floating islands, and apparently as a response to the uncertainty of availability of water or to the threats from flood, and recognizing the freedom of moving them around at their will, humans started cultivating upon these floating islands. The chinampas (floating gardens) in Mexico are a well-known example (Coe 1964, West and Armillas 1950). In China, rice cultivation on artificial floating islands in lakes and rivers is known to have been practiced for more than 1,600 years (You Xiuling 1991). Some of the floating islands on the Yangtze River are reported to have been so large that several families lived on them together with their pets. The practice of creating floating islands from lake mud, decaying organic matter, and macrophytes and cultivating vegetables on them continues even today in several parts of South and Southeast Asia. Elaborate descriptions of these floating islands are available for Malaysia (Department of Agriculture 1939), New Guinea (Serpenti 1965), Myanmar (Annandale 1918), and Kashmir in India (Kaul and Zutshi 1966, Moorcroft and Trebeck 1841, Sahni 1927, Sturtevant 1970).

CONVERSION OF WETLANDS FOR AGRICULTURE

The most common form of agriculture in wetlands is, however, paddy cultivation. Evidence of rice culture dates back to the earliest age of humans (Hook 1993). Domestication of rice started in shallow swamps (Chang 1976, Harlan 1977), and probably independently in China, Thailand, and India (Gorman 1977, Ho 1977, Vishnu-Mittre 1977). With the growing demand for food, seasonal marshes throughout South and Southeast Asia and in China were modified into paddy fields as man-managed wetlands. It was only after the European colonization in the 18th and 19th centuries that the coastal swamps and mangroves were rapidly converted to paddy fields (Richards 1990). The conversion of extensive mangroves (Sunderbans) in the Ganga-Brahmaputra Delta started at the end of the 18th century by then the East India Company, which required the private landowners to clear and reclaim Sunderban forests and swamps for rice cultivation. By the 1870s, 2790 km^2 of mangroves had been converted to rice fields. The pace of conversion got further accelerated, and though enormous deposits of sediments transported by the two rivers had resulted in the expansion of Sunderbans, 2,750 km^2 of Sunderbans were reclaimed between 1880 and 1940 and another 5,230 km^2 in the next 40 years (Richards 1990). Similarly, the conversion of mangrove swamps in the Irrawady River Delta started after the British began colonizing Burma in 1852. During the period from 1880 to 1920, the area under rice grew from 3,979 km^2 to 12,059 km^2, and wetlands declined from 9,059 km^2 to 4,698 km^2. The story of conversion of wetlands including mangroves in the Chao Phraya Delta under the British colonial rule is also similar, though it required a great deal of water management and flow regulation. The independence of nations in the region in the middle of the 20th century did not help check the loss of wetlands, particularly the mangroves. The rapid growth of human population and the need for self-sufficiency in agricultural production led to expansion of cultivated land area and intensification of agriculture. This resulted in further decline of mangroves in the deltas of all major rivers in the Indian subcontinent. It is estimated that recent losses of mangroves have been 6 percent in Indonesia, 8 percent in Malaysia, 20 percent in Thailand, and 50 percent in the Philippines (Gosselink and Maltby 1990). Mangroves in the Mekong River Delta in Vietnam suffered extensive destruction (estimated 24 000 ha) by defoliants during the war, and, later, they have been rapidly converted to paddy fields and aquaculture (Khoa and Roth-Nelson 1994).

Other inland marshes and swamps have also been extensively converted to paddy fields and fishponds. In India, the fisheries department promoted conversion of marshes into fishponds throughout the Gangetic Plains (Jhingran 1992). A recent example is that of Lake Kolleru—a shallow lake covering 900 km^2 between the floodplains of River Krishna and Godavari. More than 90 percent of the lake has been converted into large fishponds—an activity promoted by the government to increase fish production (Gopal 1991).

Further losses of wetlands have occurred throughout the tropics for agriculture in the floodplains. The rivers have been regulated extensively by levees and dykes to isolate the floodplains. There are no published estimates of the loss of floodplain wetlands. However, it must be pointed out that the growing needs of water for irrigated agriculture have also resulted in an equally large area of man-made wetlands in the form of tens of thousands of irrigation tanks and reservoirs (Gopal and Krishnamurthy 1993). Vast areas of wetlands have also developed by waterlogging due to seepage (or rise in water table) from the irrigation network.

In the temperate regions, however, the wetlands have been extensively drained and converted into terrestrial systems. It is estimated that over 1.6 million km^2 of wetlands had been drained until 1985 (L'vovich and White 1990) of which three-fourths were drained in the temperate regions. Williams (1990) and Gosselink and Maltby (1990) have discussed in detail the wetland drainage for agriculture with detailed examples from U.S., Europe, and Australia. The extent and history of wetland reclamation in Holland is indeed impressive. People used coastal salt marshes as early as 500 B.C. Reclamation with polders proceeded with increasing pace until around the 14th century, and after 1500, agriculture fuelled the reclamation at a much faster rate. The limited land space motivated a larger plan in 1918 to reclaim Zuider Zee to add 2,050 km^2 of agricultural land. The drainage was accompanied by extensive peat mining and elimination of peat bogs. In the Netherlands alone, 20,000 km^2 (two-thirds of the present-day Netherlands) of wetlands have been reclaimed from the sea, freshwater lakes, low-lying riverine silts, and peat areas. Similar drainage of peatlands occurred in other parts of Europe much earlier.

Drainage has been far more extensive in the United States, though it started only in the mid-19th century. As early as 1921, the U.S. Department of Agriculture had identified about 37 million ha of wetlands that were "in need of drainage" in the eastern parts of the country. The wetlands in the presettlement United States are estimated to cover

74.87 million ha (OTA 1984) of which more than 50 percent had been lost until 1975. More than 80 percent of the total wetland loss has occurred due to conversion to agriculture. Extensive drainage has occurred in bottomland forests and wet prairie regions where a 13.7-percent wetland loss occurred between the 1950s and 1970s (Gosselink and Maltby 1990, Williams 1990). The riparian and coastal wetlands and peatlands have also been lost similarly though to a much lesser extent. Wetland loss to agriculture by conversion continues even today. Bernert and others (1999) report that in the Willamette Valley (Oregon) about 3800 ha (2.1 percent of the wetlands in the 1980s) of wetlands had been lost to uplands during 1980 to 1994, of which a 70-percent loss was associated with agriculture and only 6 percent was lost to urbanization.

IMPACTS OF WETLAND CONVERSION

Conversion of wetlands to agriculture means more than just a loss. The resulting land use changes as well as the agricultural practices in and around the remaining wetlands, which have many impacts upon the wetlands. Several recent studies have shown that the conversion of wetlands to agriculture or other land uses (including forestry) impacts upon the biodiversity though various taxonomic groups respond differently and at different spatial scales. Mensing and others (1998) have observed that in the riparian wetlands of the Northern temperate United States, shrub carr vegetation, amphibians, and birds are influenced by land use at relatively smaller scales (500 and 1000 m), whereas fish respond to land use at landscape level (2500 m or more). Diversity and richness of shrub carr vegetation, birds, and fish generally decrease with increasing cultivation in the landscape. A decrease in the proportion of open water to rangeland results in an increase of amphibian abundance but a decline of fish abundance. They also reported that wet meadow vegetation, aquatic macro-invertebrates, amphibians, and fish respond to local disturbances. Galatowitsch and others (1999) examined changes in floristic composition corresponding to land use differences at site to landscape levels in wet meadows associated with prairie glacial marshes in Minnesota. They observed that under the impact of agriculture, together with urbanization, the vegetation composition shifted from native graminoid and herbaceous perennial abundance to annuals or introduced perennials. Bethke and Nudds (1995), who analyzed data on duck abundance in Canadian prairie-parklands or the period 1975–89, observed that the recent decline in the number of breeding ducks, particularly in the West, have been partly due to loss of habitat to agriculture, in addition to loss to climatic change (drought). Agriculture can impact on aquatic invertebrates also in temporary wetlands. Based on a study of the resting eggs, shells, and cases remaining after wetlands dried in the prairie pothole region, Euliss and Mushet (1999) observed that the aquatic invertebrates were negatively impacted by intensive agriculture. There were more taxa and greater numbers of cladoceran resting eggs (ephippia), planorbid, and physid snail shells, and ostracod shells in wetlands within grasslands than in croplands.

The changes in agricultural wetlands, such as paddy fields, depend upon the agricultural practices involving removal of plants other than the crop, water management, and the use of agrochemicals. In less intensive paddy cultivation, the paddy fields support large biodiversity and their productivity, taking into account that the production of all consumable biota is substantially high (Heckman 1979). Under intensive cultivation, the biodiversity is greatly reduced. Aquaculture is another form of agricultural activity that has adversely impacted the coastal wetlands in many countries through loss of biodiversity and pollution.

The agricultural impacts on wetlands are far more complex. The requirements of water for irrigation directly impinge on the wetlands as water flows are regulated and diverted. Shallow and smaller wetlands in drier climates are more severely affected as their water is used for irrigation. In Greece, irrigation is reported to be the most important activity negatively influencing all functions and values of Ramsar wetlands (Gerakis and Kalburtji 1998). Diversion of water and reduced freshwater flows to estuarine areas have affected the mangroves worldwide by way of changes in species composition due to increased salinity. The fertilizers and pesticides applied in the field find their way through surface runoff and subsurface flow into adjacent wetlands. Furthermore, the agricultural activities enhance erosion resulting in increased input of sediments into the wetlands. Thus, changes in the hydrological regimes and an increase in the sediment and nutrient loading impact upon the biota and ecosystem processes in wetlands.

Zalidis and others (1997) identified the four most frequent factors that caused change in the ecological character of Greek wetlands. Of these, agricultural and municipal pollution, causing changes in water quality, accounted for 54 percent, construction of irrigation schemes and diversion of water courses, for 12 percent, and the expansion of agriculture and settlement for 32 percent of the damage to wetlands. Change in water regime affected 50 percent of the springs and 40 percent of the rivers; loss of wetland area affected 60 percent of the marshes and 52 percent of the estuaries, whereas all deltas and 75 percent of rivers had their water quality impacted. Wetlands in the Evros River Delta are also affected by pollutants transported by the river from agricultural area in the catchment lying in Bulgaria, Turkey, and Greece (Angelidis and Athanasiadis 1995).

In Southern Ontario (Canada), cumulative effects of agricultural land drainage (runoff, subsurface flow, and nutrient loss) have been estimated to account for the loss of 47 percent of wetlands from 1800 to 1990 (Spaling 1995). In northern prairie wetlands in North Dakota, Freeland and others (1999) observed higher sedimentation and fertilization rates in wetlands next to cultivated fields as indicated by higher phosphorus, organic matter, and nitrate-N concentrations in subsoils (15–60 cm) of wetlands surrounded by cultivated land than in those surrounded by grasslands.

In a study of Dives marshes (France), Granval and others (1993), however, observed that agricultural practices such as fertilizer use and grazing are beneficial to earthworms, and, therefore, to their various predators such as snipes (*Gallinago gallinago*). The biomass of earthworms in grazed meadows was more than 10 times higher than in the adjacent reedbed (*Arundo phragmites*).

Data on agricultural impacts on wetlands in the tropics are rare. Kassenga (1997) identified irrational use for agriculture and pollution to be responsible for the degradation and loss of wetlands in the basin of Lake Victoria (Tanzania). He also reported subsidence of wetlands due to excessive extraction of water. In India, practically all wetlands are affected by agriculture though there are no specific data. Pesticides in the fields surrounding the Keoladeo National Park (Bharatpur) are considered to be a major threat because the park depends entirely on water from outside (Vijayan 1995). In Kerala (South India), intensive use of fertilizers for rice cultivation has caused widespread eutrophication of backwaters.

WETLANDS AS REGULATORS OF NUTRIENT FLUX

Natural wetlands, which lie at the interface between agricultural uplands and the deep open waters, act as recipients of sediments and agrochemicals and are known to regulate their flux to the lakes and rivers. As pointed out above, the agrochemicals entering the wetlands are recognized to be among the factors causing degradation of wetlands. Yet, these very wetlands are valued for the same functions of intercepting nutrients and other substances, and, hence, for protecting the downstream waters (Lowrance and others 1984, Schlosser and Karr 1981, Weller and others 1994, Whigham and others 1988). Hillbricht-Ilkowska and Kostrzewska-Szlakowska (1993) have shown that the lake littorals are more efficient in removing nutrients (particularly nitrogen) than the riparian zones. However, there is growing realization that the natural wetlands will be quite limited in absorbing agricultural wastewater (Peterson 1998). Natural wetlands have in most places either been lost or are highly degraded. Furthermore, the natural wetlands in the tropics, e.g., in the Indian subcontinent, also appear to receive wastewaters and runoff from nonpoint sources (including agriculture) far beyond their buffering capacity. In this context, the constructed wetlands technology is being extended to intercept agricultural runoff and remove pollutants from it (Hammer 1992, Kern and Idler 1999, Peterson 1998, Rodgers and Dunn 1992). Thus, constructed wetlands may replace the natural wetlands and become partners with agriculture in integrated water and nutrient management.

CONCLUSION

The continuing loss of natural wetlands to agriculture and the increasing emphasis on intensive agriculture, which causes wetland degradation, raise doubts over the future of wetlands, including agricultural wetlands. Can the man-made wetlands replace the functions and values of natural wetlands? Can wetlands be really conserved without checking agricultural impacts? The sustainability of wetlands and agriculture is interlinked with that of the water resources. The sustainability of agro-ecosystems also depends upon wetlands because the latter provide, besides irrigation water, also crop pollinators, some frost protection, and predators of crop pests (Gerakis and Kalburtji 1998). The future scenario appears to be worse. Discussing the loss of wetlands to drainage in Eastern Europe, Hartig and others (1997) have pointed out that following climate change, higher temperatures and greater evapotranspiration may alter the hydrologic regime such that freshwater wetlands are further encroached upon by agricultural land use. Wetland conservation seemingly faces confrontation with agriculture. The problem lies in the national policies and their implementation. In recent years, several countries have adopted national wetland policies, but, only rarely, agriculture is recognized as a major sector competing with wetlands for water or agriculture leading to degradation of wetlands. There has been no effort to resolve the conflict with the agricultural policy. Within the United States, Nelson (1986a, 1990) had discussed various aspects of the agricultural policy in some detail. He points out the policy crisis results from contradictory incentives of central government to both drain and preserve wetlands. A similar situation exists also in the United Kingdom (Nelson 1986b).

In Greece, Zalidis and others (1997) pointed out the inefficacy of the agricultural policy, which could not protect small wetlands or deal with the loss of wetlands from intensified use of existing farmland. However, Pyrovetsi and Daoutopoulos (1998) observed that the wetland farmers had a more negative attitude toward the wetland resources and were more ignorant of conservation issues or the impact of their practices on the environment than plain farmers.

Most of the developing countries, with great population pressures, are compelled to focus on increasing agricultural production despite declining returns from the degraded land resources. In the process, there are ever-increasing demands on water resources, which have depleted and degraded rapidly. Both agriculture and wetlands are threatened. Therefore, the need for an integrated, balanced, and coordinated approach to water resource management is greater than ever before. We need an integrated policy, which takes care of both natural wetlands and agriculture so as to minimize the impacts of agriculture on wetlands without compromising agricultural production.

ACKNOWLEDGMENTS

I am grateful to Dr. Marjorie Holland and Dr. Charles M. Cooper for their invitation to the conference, and to the Croft Institute for International Studies at the University of Mississippi and the Society of Wetland Scientists for providing necessary financial support for my participation. I thank Professor D.P. Zutshi and Mr. V. Chet for valuable information on the cultivation of floating islands.

REFERENCES

Angelidis, M.O.; Athanasiadis, A.I. 1995. Pollution mechanisms. In: A Ramsar wetland—delta of the River Evros, Greece. Aquatic Sciences. 57(2): 161–171.

Annandale, N. 1918. Aquatic molluscs of the Inle Lake and connected water. Records of the Indian Museum. 14: 103–182.

Bernert, Joseph A.; Eilers, Joseph M.; Eilers, Benn J. [and others]. 1999. Recent wetlands trends (1981/82–1994) in the Willamette Valley, Oregon, U.S.A. Wetlands. 19(3): 545–559.

Bethke, R.W.; Nudds, T.D. 1995. Effects of climate change and land use on duck abundance in Canadian Prairie–Parklands. Ecological Applications. 5(3): 588–600.

Chang, T.T. 1976. Rice: *Oryza sativa* and *Oryza glaberrima* (Graminae: Oryzae). In: Simmonds, N.W., ed. Evolution of crop plants. London: Longman: 98–104.

Coe, Michael D. 1964. The chinampas of Mexico. Scientific American. 211 (1): 90–98.

Department of Agriculture (Economics Branch). 1939. Padi planting methods in Malaya. Malayan Agricultural Journal. 27(2): 40–59.

Euliss, Ned H., Jr.; Mushet, David M. 1999. Influence of agriculture on aquatic invertebrate communities of temporary wetlands in the prairie pothole region of North Dakota, U.S.A. Wetlands. 19(3): 578–583.

Freeland, John A.; Richardson, Jim L.; Foss, Lynn A. 1999. Soil indicators of agricultural impacts on northern prairie wetlands: Cottonwood Lake research area, North Dakota, U.S.A. Wetlands. 19(1): 56–64.

Galatowitsch, S.M.; Whited, D.C.; Lehtinen, R. [and others]. The vegetation of wet meadows in relation to their land use. Environmental Monitoring & Assessment. 60(2): 121–144.

Gerakis, Argyrios; Kalburtji, Kiriaki. 1998. Agricultural activities affecting the functions and values of Ramsar wetland sites of Greece. Agriculture Ecosystems & Environment. 70(2–3): 119–128.

Gopal, B. 1991. Wetland (mis)management by keeping people out: two examples from India. Landscape and Urban Planning. 20: 53–59.

Gopal, B.; Krishnamurthy, K. 1993. Wetlands of South Asia. In: Whigham, D.F.; Dykyjova, D.; Hejny, S., eds. Wetlands of the world. I. Inventory, ecology and management. Handbook of vegetation science. Dordrecht, Kluwer: 15/2: 345–414.

Gorman, C. 1977. A priori models and Thai prehistory: a reconsideration of the beginnings of agriculture in Southeastern Asia. In: Reed, C.A., ed. Origins of agriculture. The Hague: Mouton: 321–355.

Gosselink, J.G.; Maltby, E. 1990. Wetland losses and gains. In: Williams, M., ed. Wetlands: a threatened landscape. Oxford, U.K.: Blackwells: 296–322.

Granval, P.; Aliaga, R.; Soto, P. 1993. The impact of agricultural management on earthworms (*Lumbricidae*), common snipe (*Gallinago gallinago*), and the environmental value of grasslands in the Dives marshes (Calvados); Gibier Faune Sauvage. 10(March): 59–73. In French.

Hammer, D.A. 1992. Designing constructed wetland systems to treat agricultural nonpoint source pollution. Ecological Engineering. 1: 49–82.

Harlan, J.R. 1977. The origins of cereal agriculture in the Old World. In: Reed, C.A., ed. Origins of agriculture. The Hague: Mouton: 357–383.

Hartig, Ellen K.; Grozev, Ognyan; Rosenzweig, Cynthia. 1997. Climate change, agriculture, and wetlands in Eastern Europe: vulnerability, adaptation, and policy. Climatic Change. 36(1–2): 107–121.

Heckman, C.W. 1979. Rice field ecology in northeastern Thailand. The Hague: W. Junk, bv. 228 p.

Hillbricht-Ilkowska, A.; Kostrzewska-Szlakowska, I. 1993. Transport of dissolved forms of nitrogen derived from arable land along the river-lake system in a post-glacial landscape. In: Gopal, B.; Hillbricht-Ilkowska, A.; Wetzel, R.G., eds. Wetlands and ecotones: studies on land-water interactions. New Delhi: National Institute of Ecology and International Scientific Publications: 61–74.

Ho, P.T. 1977. The indigenous origins of Chinese agriculture. In: Reed, C.A., ed. Origins of agriculture. The Hague: Mouton: 413–484.

Hook, Donald. 1993. Wetlands: history, current status, and future. Environmental Toxicology & Chemistry. 12(12): 2157–2166.

Jhingran, V.G. 1992. Fish and fisheries of India. 3rd ed. New Delhi: Hindustan Publishing Corp.

John, D.M. 1986. The inland waters of tropical West Africa. Archiv fuer Hydrobiologie, Ergebnisse der Limnologie. 23: 1–244.

Kassenga G.R. 1997. A descriptive assessment of the wetlands of the Lake Victoria Basin in Tanzania. Resources Conservation & Recycling. 20(2): 127–141.

Kaul, V.; Zutshi, D.P. 1966. Some ecological consideration of floating islands in Srinagar lakes. Proceedings of the National Academy of Sciences of India; 36B: 273–281.

Kern, J.; Idler, C. 1999. Treatment of domestic and agricultural wastewater by reed bed systems. Ecological Engineering. 12: 13–25.

Khoa, L.V.; Roth-Nelson, W. 1994. Sustainable wetland use for agriculture in the Mekong River Delta of Vietnam. In: Mitsch, W.J., ed. Global wetlands: Old World and new. Amsterdam: Elsevier: 737–748.

L'Vovich, M.I.; White, G.F. 1990. Water. In: Burner, B.L., III; Clark, W.C.; Kates, R.W. [and others], eds. The earth as transformed by human action. New York: Cambridge University Press.

Lowrance, R.; Todd, R.; Fail, J. [and others]. 1984. Riparian forests as nutrient filters in agricultural watersheds. Bioscience. 34: 374–377.

Mensing, D.M.; Galatowitsch, S.M.; Tester, J.R. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. Journal of Environmental Management. 53(4): 349–377.

Mitsch, W.J.; Gosselink, J.G. 1993. Wetlands. 2nd ed. New York: Van Nostrand-Reinhold. 722 p.

Moorcroft, William; Trebeck, G. 1841. Travels in the Himalayan provinces of Hindustan and the Panjab; in Ladakh and Kashmir. London: John Murray.

Nelson, R.W. 1986a. Wetland management strategies balancing agriculture with conservation: a national survey of expert opinion. Environmental Professional. 8(1): 54–69.

Nelson, R.W. 1986b. Wetlands policy crisis U.S.A and U.K. Agriculture Ecosystems & Environment. 18(2): 95–122.

Nelson, R.W. 1990. Can experts agree on policy directions toward wetlands and agriculture. Environmental Professional. 12(2): 131–143.

OTA (Office of Technology Assessment). 1984. Wetlands: their use and regulation. Washington, DC: U.S. Government Printing Office.

Peterson, H.G. 1998. Use of constructed wetlands to process agricultural wastewater. Canadian Journal of Plant Science. 78(2): 199–210.

Por, F.D. 1995. The pantanal of Mato Grosso (Brazil): world's largest wetlands. Monographiae Biologicae 73. Dordrecht: Kluwer. 122 p.

Pyrovetsi, M.; Daoutopoulos, G. 1999. Farmers' needs for nature conservation education in Greece. Journal of Environmental Management. 56(2): 147–157.

Richards, J.F. 1990. Agricultural impacts in tropical wetlands: rice paddies for mangroves in South and Southeast Asia. In: Williams, M., ed. Wetlands: a threatened landscape. Oxford, U.K.: Blackwells: 217–233.

Rodgers, J.H., Jr.; Dunn, A. 1992. Developing design guidelines for constructed wetlands to remove pesticides from agricultural runoff. Ecological Engineering. 1: 83–95.

Sahni, B. 1927. A note on the floating islands and vegetation of Khajiar, near Chamba in the N.W. Himalayas. Journal of the Indian Botanical Society. 6: 1–7.

Sasser, C.E.; Gosselink, J.G.; Swanson, E.M.; Evers, D.E. 1995. Hydrologic, vegetation and substrate characteristics of floating marshes in sediment rich wetlands of the Mississippi River Delta Plain, Louisiana, U.S.A. Wetlands Ecology and Management. 3: 171–187.

Schlosser, I.J.; Karr, J.R. 1981. Riparian vegetation and channel morphology impact on spatial patterns of water quality in agricultural watersheds. Environmental Management. 5: 233–243.

Scoones, I.; Cousins, B. 1994. Struggle for control over wetland resources in Zimbabwe. Society & Natural Resources. 7(6): 579–594.

Serpenti, L.M. 1965. Cultivators in the swamps: social structure and horticulture in a New Guinea society (Frederik-Hendrik Island West New Guinea). Assen, Netherlands: Van Gorcum-Prakke.

Spaling, H. 1995. Analyzing cumulative environmental effects of agricultural land drainage in Southern Ontario, Canada. Agriculture Ecosystems & Environment. 53(3): 279–292.

Sturtevant, W.C. 1970. Agriculture on artificial islands in Burma and elsewhere. Eighth International Congress of Anthropological and Ethnological Sciences; Tokyo and Kyoto; 1968: 11–13. Vol. 3.

Tombi Singh, H.; Singh, R.K.S. 1995. Loktak Lake, Manipur. WWF-India, New Delhi. 69 p.

Vergara, B.S. 1992. Tropical wet rice systems. In: Pearson, C.J., ed. Field crop ecosystem. Amsterdam: Elsevier: 167–182.

Vijayan, L. 1995. Keoladeo National Park. WWF-India, New Delhi. 77 p.

Vishnu-Mittre. 1977. Changing economy in ancient India. In: Reed, C.A., ed. Origins of agriculture. The Hague: Mouton: 570–588.

Weller, D.E.; Correll, D.L.; Jordan, T.E. 1994. Denitrification in riparian forests receiving agricultural discharges. In: Mitsch, W.J., ed. Global wetlands: Old World and new. Amsterdam: Elsevier: 117–131.

West, Robert C.; Armillas, P. 1950. Las chinampas de México: Poesia y realidad de los "jardines flotantes." Cuadernos Americanos. Año 9, No. 2: 165–182. Vol. 50.

Whigham, D.F.; Chitterling, C.; Palmer, B. 1988. Impacts of freshwater wetlands on water quality: a landscape perspective. Environmental Management. 12: 663–671.

Williams, Michael, ed. 1990. Wetlands: a threatened landscape. Oxford, U.K.: Blackwells. 419 p.

You Xiuling. 1991. Rice planting on the water surface in ancient China. Chinese Journal of Rice Science. 5.2: 79–82. In Chinese.

Zalidis, George C.; Mantzavelas, Antonis L.; Gourvelou, Eleni. 1997. Environmental impacts on Greek wetlands. Wetlands. 17(3): 339–345.