SECTION 3.3

INTEGRATED LAND-WATER SYSTEMS AND THEIR POSSIBLE MODERN APPLICATION

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3.3.1. INTRODUCTION

Integrated land-water systems represent zones where interaction exists between terrestrial and aquatic components as represented, for example, by lake pastures where aquatic plants are grazed by cattle, horses and other livestock. Very often they are typical of the so-called ecotones which are the marginal zones of ecological units such as ecosystems and in this context very often for example the littoral zones of stagnant or running water. In a more sophisticated way they comprise the cycling of aquatic and terrestrial compounds as exemplified by the mulberry dike - carp pond resources systems in China.

Many of the integrated land-water systems have an old tradition and have developed along with irrigation, the culture of paddies (at least since 6,000 years B.C.) and marsh cultures like the most sophisticated one of the Marsh Arabs in the Shatt el Arab Region. Most recently many of the old integrated systems have increasingly attracted general interest and in addition new devices of integrated land-water systems have been established. In this section an overview of relevant activities will be given.

3.3.2 LAKE- AND MARSH-PASTURES AND THE MARSH ARABS

The use of aquatic plants for livestock has a long tradition in semi-arid and arid areas but has been given only little attention in recent times. A paradigmatic example of this kind is offered by the highly unstable Hamun Lake in the eastern Persian province of Seistan and expanding into Afghanistan. In this shallow lake, area of 4000km^2, and its catchment area, the culture of the "Gaw-dars" (cow-herdsmen) developed some thousand years ago. A variety of aquatic macrophytes, cattail (Typha sp.) presents the main source of nutrition for cattle (zebus). It is also used for the construction of huts, for thatching, rafts ("tutins"), mats etc. As fodder for livestock it is usually harvested and transported to villages by the rafts. On the other hand, the herds may at times be driven to the macrophyte stands (Loffler, 1956). In addition, fishery plays a major role in Hamun Lake with Schizothorax sp. being the main species (300 - 500 metric tons per year). At present the water budget of the lake is greatly affected by the use of water from its main inflow, the Hilmand-Rud, for irrigation.

Similarly the luxuriant submerged vegetation in the shallow lakes ("lagunas") of the Titicaca-area are an important pasture for cattle during the dry season when fodder resources are restricted to these aquatic sites (Loffler, 1968).

Most recently (Nörthcote et al., 1989) the socio-economic importance of the macrophytes in Lake Titicaca itself (Puno Bay and the shallow parts of Lago Pequeno) have been analyzed. The following section is an extract of the chapter on the socio-economic importance of macrophyte extraction in Puno Bay by Levieil et al. (in Northcote et al., 1989). Shore dwellers find the so-called "llachu" (mainly submerged macrophytes such as Elodea potamogeton, Myriophyllum elatinoides and Potamogeton strictus) most useful as livestock fodder and sometimes for handicrafts (e.g. mattress stuffing) or as fuel. Livestock may graze directly on "llachu" growing in water less than one meter deep from July to February (sometimes August to January) when there is no grazing left in the terrestrial pasture land.

Sometimes the "llachu" is harvested directly or from a boat. "Llachu" harvesting is open to all shore dwellers; however, the "llachu" beds are divided into zones and belong to different shore communities. Among "llachu", Elodea is considered the best fodder. Its dry matter contains 15-29% protein. Obviously the algae (periphyton) growing on them may contribute to its nutritive value. Apart from "llachu", the totora bulrush (Scirpus tatora) is used as "totora verde" for livestock fodder and harvested in much the same manner as "llachu" except that livestock are never allowed to enter the totora beds in order to avoid any damage by trampling. The exploitation of totora, unlike that of "llachu", is severely restricted and most totora plots are privately owned.

Transplanting and sowing of S. tatora takes place to a certain extent and may become intensified in the future. Due to its digestibility and protein content (9-15% of dry weight) totora verde is a good fodder which is easier to transport (e.g. as rafts) than "llachu". "Totora amarilla", the maturation stage of S. tatora, is used for the construction of boats ("balsas") similar to the "tutins" of Hamun Lake, for mattresses, mats and roofing. After its harvest and before its use it is left to dry in the sun for one or two weeks. Over the last decades, due possibly to the increased demand for "totora verde", "balsas" and mattresses it is increasingly difficult to find good quality "totora amarilla" in Puno Bay. In addition to totora verde and amarilla, the rhizomes of S. tatora ("sacca" and "siphi", young and tender and mature rhizomes respectively) as well as its stalk base serve as food resources for people at the end of the dry season. Finally, in dry years when the lake level is down, the exposed totora plots are tilled: the preparation of the rhizome areas for this procedure is usually done by pigs and the mixture of mud, rhizomes and decaying organic matter, called "kille", if dried, floats on the surface of the lake. Large chunks of "kille" are the raw material of the well known floating islands of the Uros. Otherwise "kille" serves as organic fertilizer.

Both "totora" and "llachu" contribute greatly to the productivity of Lake Titicaca. They provide a substrate and protection for eggs and young fish. Birds, particularly ducks, also consume several species of macrophytes and almost all feed on invertebrates that live in the "llachu" and "totora " beds. On the other hand, both fish and birds contribute to the economy and diet of shoreline communities, particularly that of the inhabitants of the Uros islands.

Aquatic pastures for terrestrial livestock of the kind described above exist in many regions but virtually nothing is known about their origin and traditional roots. Quite a few of them could have derived from Arab traditions (in the cases of Titicaca via the Spanish Conquistadors) but many probably came about accidentally. The Pulvar Lake marsh area in Southern Iran, a vast valley obviously dammed by a land-slide, may belong to the latter group. All these cases suggest that the improvement of existing technology at sites of this kind and the establishment of new aquatic pastures are highly desirable especially in semi-arid regions and at the same time, with respect to their construction, rather economic.

To some extent the large marshes of the lower Euphrates, Tigris and Shatt el Arab may also be considered as an aquatic river-lake pasture system used mainly for water buffaloes. In this region, however, it is the most sophisticated reed culture existing on our planet and created by the Marsh Arabs which dominates. With the design of different buildings such as the "raba", the "sarifa" and the "mudhif" built of reeds and matting (Thesiger, 1964) it is an example of an old and outstanding amphibic lifestyle.

Rice cultivation is believed to have originated in Southeast Asia 6,000- 8,000 years ago, dispersed independently in West Africa much later and only recently has developed in the temperate zones of Europe. At present the total area amounts to about 1.5 million km^2, and contributes to the cultivation of other aquatic plants, fish-ponds, ponds for recreation etc., as man-made wetlands. Obviously, from the earliest onset of these activities man took advantage of the animals which became abundant in these artificial ecosystems. These included certain insects (e.g. Dytiscus sp., Belostoma sp., etc.), shrimps, fish, amphibians, reptiles, birds and mammals. In particular, fishery (some thirty species are involved) in combination with rice cultivation was given increasing attention.

It is most likely that the so-called "Minipadi" system in Western Java has evolved to the highest level of such combined activities including dams for terrestrial cultivation (Ruddle, 1980). The concurrent cultivation of rice and fish results in two crops of rice and eight harvests of fish (mainly fry and fingerlings of carp (Cyprinus carpio) but also a few other species). This system is strongly linked with fish and pond production: six of the harvests resulting from rice field activities such as field preparation and flooding, including the repair of dikes and ditches for fish culture, serve for pool stocking whereas the last two harvests serve as table fish for both household consumption and sale. The latter fish harvests take place during the weeding processes and the first harvest of rice. The last fish yield amounts to about 80-100 kg-ha which corresponds roughly to US $ 80.

Another system in Indonesia, again in West Java, is the "Surjan". This system puts more importance on the dikes which here are wider, in order to support dryland crops such as beans, chili peppers, and cucurbits. In contrast to the minipadi, polycultural fish production is practiced in the surjan (Cyprinus carpio, Barbus goniotus, Oreochromus mossambicus, Clarias batrachus etc.) (Ruddle, 1980).

Ruddle (1980) claims that in addition to economic and dietary benefits to the farm household and the use of more available niches -- despite higher input costs -- the joint cultivation of rice and fish in paddies generally enhances both the yield of rice and fish.

The author also points out that there are certain aspects of rice technology which are inimical to fish raising, and vice versa some facets of fish cultivation that are detrimental to the rice crop. Among the risks for fish, pesticides of various kinds, high N application and the selection of fast-growing rice (105-125 instead of 160 days) may be mentioned. On the other hand, fish sometimes damage young rice plants though normally rice yields improve if fish are present and even more under polyculture of fish species (Ruddle, 1980). Among others, improved aeration and increased soil fertility enhanced by the decomposition of fish excrement contribute to increased rice yields.

At present, the principal constraints for fish cultivation in paddies are the toxic agricultural chemicals and of course -- very often so -- the provision of a regular water supply (Ruddle, 1980).

As a consequence of these constraints a decline in the area and productivity of rice field fisheries is observable throughout Southeast Asia. In response, and despite greater investment required, the importance of freshwater fishponds has been increasing although in many cases pond and paddy field culture of fish still play their complementary role (Ruddle, 1980). It is hoped therefore that in the future rice-fish-terrestrial plant systems will be given more adequate attention.

If the hydrological features of a river (low and high water levels) tend to be similar, the establishment of paddies within a floodplain is a common practice. A good example of this is the inner delta of the Niger where, before the impact of irrigation projects, the paddy yields amounted to 235 g/100 m3 of water (Drijver and Marchand, 1986). After upstream damming and increased irrigation, not only was the water volume available for flooding but also the timing and duration of floods profoundly changed. Although the paddy harvests went up to 5,000 g/100 m3 of water, other essential resources were lost. Cattle herds, which came from distances of more 200 km to survive on the former grassland available during the dry season in the floodplain, can no longer be supported there on a full scale. Likewise, the well-adapted floodplain agriculture no longer functions. Thus, for example, a special type of sorghum was planted at the end of the flooding: the fast-growing roots of this sorghum variety are able to follow the rapidly-receding water table down to 2.5m. The fishery suffered even more disturbance during the onset of the flooding and when the water was draining back. Fishing during these periods needed a minimum of effort and investment. Drijver and Marchand (1986) demonstrated impressively that, despite increased rice production, due to the loss of meat, milk (migrating cattle herds) and fish the net margin of profit per 100 m^3 was $0.49, but due to the costs of construction and interest this value was distinctly less (- $0.77). Moreover the increased paddy area attracted the immigration of people and therefore led to intolerable deforestation.

In 1953, a new type of integrated system was introduced in the area of Szarvas. In order to economically use the solontchak (salt-soil) plains, which were otherwise known for their high ecological value, large parts of them were flooded and stocked

with fish (Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys molitrix and a few Siluris glanis). The fingerlings are then put into ponds until fall when they are transferred to hibernation basins where they finally gain their selling weight of about 1 kg. In this way, 300-350 t/ha of fish can be produced annually. During the time when the ponds are stocked with fish, ducks and chickens are put into the ponds to attain their selling weight of 3kg after 48 days. The total amount of yield per year attains some 1,000 kg/ha.

After five years' use, the lakes are drained and the improved soil is now ready for an agricultural period of four years. During the first season it is used for corn, clover, etc., part of which is used for fish food and fertilizing. Afterwards three seasons serve for rice cultivation. The planting of young rice is performed under dry conditions during the middle of April. Afterwards the water level is kept at approximately 10 cm. After the drainage of the paddies, the harvest of rice is carried out at the beginning of September, and the yield may amount to 3 t/ha per year. After these agricultural activities another fish-duck season is introduced. Meanwhile this type of integrated system has also been successfully introduced in CSFR.

All of the integrated systems mentioned so far have been evolved in the Old World. There exists, however, a great variety of wetlands, one example of which is the tree swamp type in North America whose potential has not been fully used yet. Protein harvest, timber improvement of water quality as a consequence of slowly growing trees, and flood/storm absorption are only a few items which make those tree swamps extremely important sites (Odum, 1982; Day et al., 1982; Patten and Matis, 1982). Terrestrial and aquatic components abound in these systems, which in Europe have almost completely disappeared. However, the optimum strategy for ecological as well as economic design has not yet been achieved for most of these North American tree swamps, which present a valuable potential.

In contrast to the tree swamps of USA and Canada, the "Chinampa" system (derived from twigs, brushwood and faggots) was developed during the pre-Colombian time in Mexico, and not only still is in existence but has become one of the important MaB activities and is expanding at proper sites. The latter comprise mainly fens and generally minerotrophic wetlands very often in the neighbourhood of lakes and rivers. Small lots of land are confined by channels whose walls are consolidated with twigs, poles etc. The excavated material is to raise the level of the lots and at the same time fertilization is provided by the channel material. The channels provide for transportation and fishery whereas the chinampas serve for a variety of vegetables such as beans, spinach, corn and others. The yield of the different agricultural

products is generally high. Thus about 54 t/ha of celery could be harvested after 150 days. Some of the chinampas are located in wet tropical forests, which offer additional technologies; some others -- as already mentioned -- are close to the rivers which allows for additional irrigation. Obviously the chinampa system can be applied in any proper area within the tropics.

The last example is devoted to one of the most reknowned integrated systems, the mulberry dike - carp pond resource system of the Zhujiang (Pearl River) Delta in Southern China (Ruddle et al., 1983; Ruddle, 1985a; Ruddle, 1985b; Guangzhou Intst. Geogr., 1980; Chung Kung-Fu, 1979; Luo Kaifu et al., 1980).

In China different types of wetlands cover an area of approximately 100,000 km^2 (= 165 million mu) (Huang Xichou, 1980). Many of these wetlands still have their natural character, but quite a lot have been transformed into grazing land by means of drainage. In contrast to these simple types of reclamation the Zhujiang Delta of South China is an example of an old established and elaborated integrated system, which has evolved over the last two millennia and is operated on a geographic and economic scale unmatched elsewhere in the world (Ruddle, 1985). The system covers an area of approximately 1,600 km^2 and supports an estimated population of 1.3 million people. About 290 km^2 are occupied by fishponds and about 130 km^2 provide for plantations of mulberry trees, sugar cane, rice and others like vegetables and mushrooms. The fishpond system came into existence only shortly after the T'ang Dynasty whereas silk cultivation has existed at least since the Han Dynasty.

The size of the dams varies between 0.2 and 0.5 ha and their depth between 2-3 m. The dams rise above the pond level from 0.5 to 1.0 m and their breadth attains 6-20 m. Mulberry leaves are harvested eight or nine times during a year and their yield amounts to 30, sometimes even up to 75 t wet weight/ha/year. With this food for the silk worms (Bombyx mori) available 2-5t/ha can be collected annually. Wastes from the silk worm culture, agriculture and households are dumped into the ponds and excessive sediment from the ponds is returned as fertilizer to the dams. In order to achieve a maximum yield of fish the ponds are stocked with china carps and Cyprinus carpio, which prefer different food resources. For the upper layer of the pond mainly bigheads (Hypophthalmichthys) and striped bigheads (Aristichthys nobilis) are applied. In the deeper parts it is mainly grass carp (Ctenopharyngodon idella) whereas the bottom resources are mainly used by carp (Cyprinus carpio).

3.3.4 CONCLUSIONS

In summarizing, it becomes obvious that many of the old integrated systems (very often the ecotone type) have been almost forgotten or not given proper attention. The few examples mentioned are only a fraction of the integrated systems which will increasingly play an important ecological and economic role.

It should, however, not be forgotten that many of the integrated systems involve health risks. Thus in Puno Bay diarrhea diseases are of concern, and fishes of Puno Bay in general have rich parasitic fauna. A survey of 159 shore-dwelling families within the city of Puno showed that nearly a third of these were tested positive for intestinal helminthiasis (census March 1983; Sanchez et al., 1989). Much less is known about Lake Hamun, which sometimes becomes rather alkaline and consequently poor in vectors like snails. In paddies the increasing application of pesticides is a major obstacle with respect to the use of fish and other animals. Since, however, many of the integrated systems can be controlled with respect to waterborne diseases the variety of health risks may be reduced by chemical treatment of rice fields. Hopefully new and less harmful technologies may be developed in the near future.

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