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Summary

Isolated wetlands are among the most seasonal of ecosystems in semi-arid Africa. Their role is important but varying throughout the year for a number of different user groups. They are links in a number of different seasonal chains. But these wetlands are also under threat from global change, and thus the chains that they form part of are under threat. Participative integrated natural resource management (PINReM) is urgently needed at these wetlands.

Wetlands are areas where water and nutrients are concentrated. They are therefore areas of high production potential and low production risk, especially in semi-arid regions. Farmers use isolated wetlands especially immediately after the end of the rainy season, to grow crops on water left in the soil as the water recedes, or for irrigated horticulture. If the rainy season crop of millet in the surrounding drylands has been poor, use of wetlands for dry season cropping may increase by 50%.

Pastoralist use of wetlands is very location dependent. Once the rains have ended and surface water has dried up, the wetlands are used as a source of water for their livestock. This allows the livestock to graze the surrounding dryland fields, fallow areas and grasslands. Once the grazing is finished the livestock move further south, in some cases to wetlands that also provide dry season fodder. But if dry season cropping blocks their access to a wetland, the surrounding areas cannot be grazed either. And if there is no dry season grazing at wetlands further south, the wet season grazing in the north can also not be used.

Fishermen utilise wetlands as long as they contain water. Semi-permanent wetlands may be restocked with fish at the start of the rainy season, because only lungfish can survive a dry spell. But in case of hunger during the dry season only these lungfish can be dug up, like water-lily tubers, to serve as famine food.

Collectors of natural products work according to the seasons as well, collecting e.g. water-lily fruit and other plants for food or medicine, wood for construction or cooking, clay for bricks and pottery, etc.

Isolated wetlands in Niger also provide habitat for up to 1.2 million migratory water-birds from elsewhere in sub-Saharan Africa, from North Africa, and from almost all countries in Europe and West Asia, from Portugal and the UK to Siberia.

In Niger alone there are more than 1,000 isolated wetlands of some size (10-2000 ha). Some of these have only been formed 35 years ago. Quantitative information is presented on the various forms of utilisation of these wetlands and their monetary value, which on a per hectare basis far exceeds that of the surrounding drylands.

Global change is increasing the pressure on these wetlands, through population increases, climate change and migration. Participative integrated natural resource management (PINReM) must be introduced as soon as possible, or all stakeholders will end up the poorer, and hungrier.

1. Introduction

Wetlands are areas where water and nutrients are concentrated. As a result they are areas of high production potential and low production risk, especially in semi-arid regions. Wetlands in the Sahel are thus natural resources that are in great demand by farmers, pastoralists, fishermen and collectors of natural products. At the same time they are also essential to large mammals, to water-birds from Africa and Europe/Asia, and to many other animal as well as plant species.

In this paper I concentrate on the importance of the isolated wetlands in the Sahel, away from the large rivers. There are thousands such wetlands, and their importance to different interest groups varies with the seasons. They are links in the various chains of places that allow the different interest groups to live the way they do. When such links are significantly changed or degraded, or even destroyed, the interest groups dependent upon them at will have to alter the way they live. That in turn may affect the utilisation, and thus the character, of the other places used by those interest groups during the course of a year.

Taking the wetlands of Niger as an example, I first briefly describe what wetlands there are. I then describe the utilisation of isolated wetlands in Niger during rainy season and during the dry season, by different interest groups. Various aspects of utilisation are subsequently brought together: positive and negative interactions between user groups, links with uplands, links with areas further away and differences in utilisation patterns between years. This is followed by an overview of likely future developments in the light of global change, and what this may mean for the wetlands themselves and for the different user groups involved. At the end a plea is made for participative integrated natural resource management (PINReM) to be introduced as soon at these wetlands. If that doesn't happen ALL user groups will soon be worse off than they are now. Millennium Development Goals 1 (reduction of hunger) and 7 (reduction of biodiversity loss) will then be that much harder to achieve in the Sahel.

The information presented on utilisation of isolated wetlands in Niger was collected from the literature, mostly in the mid-1990's, and during visits to some 30 isolated wetlands from the border with Burkina Faso to past Zinder, in January-February 1993, 1994, 1997, 2006, 2007 and 2008, and in April 1997. Although some of the quantitative information will be outdated, over the past 15 years the importance of seasonal resource use chains will only have increased at most isolated wetlands in Niger. The situation in other Sahelian countries is quite likely similar.

2. Wetland resources of Niger

2.1 The large floodplains

The river Niger drains a catchment of 1.5 million km^2. It flows over a length of 550 km through SW Niger. The flow at Niamey, the national capital, varies between 0-1800 $m^3 s^{-1}$, with an average of 1030 $m^3 s^{-1}$ (MHE-Niger 1990a). This average flow was only half as large during the 1980's, due to increased off-take and lower rainfall was much lower (MHE-Niger 1991c). Along the river in Niger there are 63.000 ha of floodplain, i.e. on average an inundation zone 570 m wide on either bank. Approximately 10.800 ha of floodplain have been converted to irrigation area, mostly for growing rice (MAE-DEP 1991, p.28; MHE-DFPP 1991).

In the east of the country the Komadougou Yobé forms the border with Nigeria. This river used to flow ten months per year, but in the mid 1990's it only flowed for six months per year. This was due to a prolonged period of lesser rainfall, but also to the construction of dams upstream: in 1991 there were already 18 of them, with a total storage capacity of 2.6 billion m^3 (MHE-Niger 1991a).

Lake Chad consists of two major basins. In its very south-east Niger borders on the northern basin, which receives its water primarily from the Komadougou Yobé and from overflow from the southern basin. Partly as a result of greatly diminished flow in the Komadougou Yobé, the Niger

part of Lake Chad was dry from about 1988-1998. The dry period caused very large parts of it to be invaded by *Prosopis juliflora* shrubs (MHE-Niger 1991a; W.C. Mullié pers. obs.).

2.2 The smaller wetlands

In the north of Niger there are a number of oases, with orchards, grape and date production (de Beaufort and Czajkowski 1986; MHE-Niger 1991d). Little information is available about these wetlands. Throughout the country there are also a number of dry, 'fossil' valleys, sometimes kilometres wide, dating from the time that the Sahara and Sahel were much wetter than now, approximately 6-10.000 years ago. In most of these valleys water hasn't flown for centuries, some still carry water from time to time, while in all these ancient valleys groundwater is often close to the surface (MHE-Niger 1990a-e, 1991b-c).

Finally there are a number of more or less isolated inland wetlands or lakes, called ‘mares’ in French. They are often located in depressions in the old drainage systems. There are more than 1000 in Niger alone, varying in size between 10 and 2000 ha at maximum extent. Some are very temporary, and only hold water a couple of months each year. Others contain water much longer. A number are even permanent, and always, or almost always, have water (MHE-DRE-Niger 1993). These wetlands are enormously dynamic. Some disappear due to silting up (MHE-Niger 1992; Piaton and Puech 1992), but new ones appear as well. One such new wetland is at Dan Doutchi, in a depression that filled up as the drought broke in 1975: it now covers 1500 ha when full (Brouwer and Mullié 1994b). By far the greatest number of these isolated wetlands is to be found south of 15° N, in approximately the 300-600 mm rainfall zone, between the line Mali-Tahoua-Lake Chad and the borders with Nigeria and Benin.

3. Isolated wetland use during the rainy season

The period that isolated wetlands in Niger hold water in a particular year depends on their size and depth; on the size and nature of their catchment; on the rainfall amount and temporal distribution in that catchment that year; and on whether the wetlands receive water only from run-off or also from groundwater seepage. As result the utilisation of isolated wetlands in Niger is tied to the seasons not in a strict manner, but somewhat loosely. The following accounts of wetland utilisation during the rainy season and during the dry season in Niger are therefore indicative only.

Note that, where the annual rainfall averages 600 mm in Niger, the rainy season begins between late May and early July, and ends in September-October. Where the annual rainfall averages 300 mm, the wet season begins in June-July, and ends late August to September.

3.1 Cropping

During the rainy season there is little cropping activity or horticultural activity around wetlands. Only crops like floating rice can cope with rising or permanently high water levels. During the rainy season there are also more problems with pests on irrigated crops than during the dry season (Cheferou Mahatan 1994). Farmers with access to both wetland frontage and upland fields will be working on their upland fields during the rainy season. Upland fields can only be cropped during the rains, and upland fields are where they grow their staple food, pearl millet.

For the people living around a wetland, and using it to draw water from and let their children play in, the wetland can mean increased risk of water-borne human and animal diseases (cf. Tager-Kagan s.a., Sally and Compaoré in Sally et al. 1994).

3.2 Livestock rearing

During the rainy season wetlands can provide drinking water to livestock. Such supplying of drinking water may be more a matter of convenience than of necessity: during the rainy season

there are many pools of surface water away from wetlands, while the fodder available to the livestock is generally green and also full of water.

In a small number of wetlands, but mostly along the Niger river, the grass 'bourgou', *Echinochloa stagnina*, may be grown during the wet season on rising water levels. When the water level has dropped it is harvested for hay.

3.3 Fishing

Fishing activity is generally low during the rainy season. For fish production purposes, non-permanent wetlands need to be restocked with fish each year. This is done once the wetlands hold enough water after the start of the rainy season. Local species as well as exotic species are used for restocking. Other measures to increase fish production also take place during the wet season, such as increasing aquatic vegetation for fish to spawn in (MHE-DFPP 1991). The fishing itself mostly takes place during dry season.

3.4 Hunting and tourism

Hunting was largely banned in Niger in 1974, other than by traditional means. In 1996 hunting was legalised again on a much larger scale (Brouwer et al. 2001). The rainy season is not the preferred season for hunting, except for the collecting of eggs of e.g. Comb Duck *Sarkidiornis melanotos*. In the Liptako Gourma region, north-west of Niamey, these eggs are put under chickens and the hatched ducklings are raised for later consumption (pers. obs.).

For tourism, too, the rainy season is not the preferred season. Although the landscape is beautifully green at that time of year, travel to isolated wetlands along unsealed roads can be quite difficult. There are also many more mosquitoes than during the dry season.

3.5 Collecting of natural products

Local people collect natural products from their wetland during the whole year. These include wood for cooking; wood for construction (trees around wetlands are often larger than those growing further away from water); clay for brick making and pottery; water for domestic purposes, including the washing of clothes; plant (and animal?) products for traditional medicinal and magical purposes (Brouwer and Mullié 1994a).

3.6 Biodiversity

While animals can be present at isolated weltands only during a certain season or seasons, plants are obviously present all year round, even if sometimes only as seeds.

The vegetation of isolated wetlands in Niger often shows a concentric pattern, in which the dominating species varies with the depth and duration of inundation. Closest to the shore there is generally a zone dominated by the grass species *Veteveria nigritana* (shortest inundation time); then follow *Oryza longistaminata* (wild rice), *Echinochloa stagnina* (bourgou), and finally *Nymphaea lotus* and *N. caerulaea* (waterlilies, where there is water a meter or more deep at least four to five months of the year). Some deeper wetlands show all of these zones, others have only the shallower vegetation types present. In addition to these herbaceous species there may or may not be trees, sometimes in dense stands. These include various *Acacia* species, and *Mitragyna inermis*. There are also isolated wetlands in Niger that hardly have any aquatic vegetation present at all (Mullié et al. 1999).

The presence of certain fish species in isolated wetlands in Niger is mentioned in section 4.3. Large mammals should not be very dependent on isolated wetlands during the rainy season, as there will be sufficient surface pools for drinking throughout the landscape. Birds present at isolated wetlands during the rainy season will be exclusively, or almost exclusively, Afro-tropical waterbirds that nest there. The wetlands in the Liptako Gourma region north-west of Niamey

harbour an important population of Black-crowned Cranes *Balearica pavonina*, a Sahelian species that is threatened .throughout its range by disappearance of wetlands, disturbance and capture for the live bird trade (Meine and Archibald 1996; Brouwer and Mullié 2001). There is very little other quantitative information on waterbird presence at isolated wetlands in Niger during the rainy season.

Of the occurrence at isolated wetlands in Niger of other vertebrate animals, and especially of invertebrate animals, very little is known at all.

4. Isolated wetland use during the dry season

4.1 Cropping

The potential of isolated wetlands for agriculture and livestock has been referred to as large but unquantified (MHE-Niger 1990a). In agricultural statistics in Niger a distinction is seldom made between dry-season cropping that is irrigated, and dry-season cropping that is dependent on residual moisture in the soil. At the edges of wetlands there is probably no clear distinction. As the water recedes crops are sown in the emerging soil. As the water stored in the soil is used up by the crop, supplementary irrigation may or may not be necessary. There also exists dry season cropping around tube wells, using irrigation only. For the Illela area south of Tahoua, it was estimated that 75% of dry season cropping was dependent on residual moisture in the soil (cultures de décrue) and 25% was irrigated (with the irrigation water sometimes taken from isolated wetlands, sometimes from tube-wells) (Cheferou Mahatan 1994).

The area used in Niger for dry season cropping, but not including rice, during the years 1984-1991, varied between 42.000 ha and 64.000 ha (MAE-Niger 1993). Dry season cropping was most extensive during 1984 and 1989 (63-64.000 ha, vs <54.000 ha in other years). These two years were respectively a drought year and a year with patchy rainfall and poor millet harvests in many parts of the country. It would seem reasonable to conclude that dry season cropping around wetlands is particularly important following rainy seasons with poor, or poorly distributed, rainfall. In a dry season cropping project at Illlela south of Tahoua, it was found that 70% of income generated by dry season cropping was used to buy grain (Cheferou Mahatan 1994).

Dry season cropping concerns crops like onions, tomatoes, beans, sweet potato, cabbage, lettuce and peppers (pers. obs.). These are crops with a much higher nutritional value than the staple millet, which is important for the producers as well as for local buyers.

Much of the dry season cropping is for commercial purposes, with the harvest traded as far away as Abidjan. Financial returns per hectare per year varied from 60.000 (low input *Dolichos lablab*) to 1.300.000 (onions) F CFA, or from $ 200 to $ 4.300 per ha per year (Raverdeau 1991; Cheferou Mahatan 1994). An upland millet crop would average $ 70 per ha per year (Brouwer and Mullié 1994a).

Around Illela, Niger, women each work about 200 m2 of land during the dry season, while men work abou 2000 m2 (Cheferou Mahatan 1994). In 1994, the land around isolated wetlands in the Illela area was often owned by a relatively small group of people, who rented part of it out at up to $ 200 per ha per year. Motor pumps made it possible for land owners to start working more of their irrigated land themselves, rather than renting it out or employing others to work it (Andreas Mueller, Projet Marécage Illela, pers comm. 1994). These facts point to the existence of socio-economic limitations to the realisation of agricultural production potential of Niger's wetlands. On the other hand, development of dry season cropping may reduce the exodus of young men looking for work in neighbouring countries, and improve employment opportunities for young women (Brouwer and Mullié 1994a).

It is also worth noting that irrigation projects may provide food and shelter to bird pests, particularly during the dry season when normally they would perish (Morel 1971; Mullié1994). And irrigation

projects, too, have a finite life: for irrigated areas in SE Australia the period of useability is estimated at 150-200 years (Meyers 1994).

4.2 Livestock rearing

During the dry season isolated wetlands can provide drinking water for livestock, and, if enough aquatic vegetation is present, also grazing. Herders can bring in local cattle to drink every day or every few days.

Transhumance herders only use a wetland during a limited time of the year. During the year they travel with their herds along a more or less fixed route, sometimes covering thousands of kilometers. Broadly speaking, the travelling herds graze seasonal grasslands in the north during the rainy season, and grass- and shrub lands, fallow areas, crop residues, and sometimes wetland vegetation, further south during the dry season. During the rainy season the travelling livestock drink from local pools or nearby wetlands in the north, during the dry season from wetlands or wells further south.

Estimated livestock numbers, trade and production prices in Niger, from 1980 to 1991, are given in MAE-Niger (1993, p.95-105). Due largely to the 1984 drought cattle numbers in Niger changed from 3.3 million in 1980 to 1.4 million in 1984 to 1.8 million in 1991. The comparable numbers for sheep were 3.0, 2.5 and 3.3 million, for goats 7.0, 1.3 and 5.1 million. Note the rapid recovery after 1984 of the small ruminant numbers, especially goats, compared to cattle. Small ruminants allow for much more flexible responses to environmental changes than do cattle.

Cattle fetched about $ 130-200 per head in 1990, bulls $ 230-300, rams $ 26-43, goats $ 13-20. As an example of economic turnover, in the Region of Tahoua the exploitation rate (trade and slaughter) of cattle, sheep and goats in 1990 was given as 5.1, 9.9 and 6.9% respectively (MHE-DEP 1991). Livestock clearly form a very important part of economic activity in Niger.

There do not appear to be any data on the extent to which livestock in Niger depend on surface water or wetlands for their survival and growth. The only indication is given by MHE-Niger (1991a). Combining data from the Direction Ressources Animales with their own groundwater data, they estimate that Diffa's 600.000 TLUs (Tropical Livestock Units) need about 40 L of water per TLU each day, or 9 million m^3 per year. Of this an estimated 6 million m^3 comes from groundwater. The remaining third would then come from surface water, but it is unclear what proportion comes from surface water at what time of year and in what area. All the same it is safe to say that surface water, and in particular isolated wetlands, are of great importance to livestock production in Niger. Even where groundwater resources are more than adequate to cover livestock drinking water needs, it is much easier for a herder to let his animals walk into the water themselves than to pull up the water they need from as much as 80 m depth (Brouwer and Mullié 1994a).

If the data above, on livestock numbers and exploitation, are combined, and it is assumed that livestock production in Niger is indeed for one-third dependent om isolated wetlands for its water supply, then the value of wetlands to livestock production in Niger was around $ 35 million per year in the early 1990's (Brouwer 2003).

Isolated wetlands themselves also have some drawbacks for livestock. For the Tillabéri area problems of water- and soil-borne diseases of livestock in and around isolated wetlands are mentioned (helminths, anthrax, sheep and goat pox) (MHE-Niger 1990a; Tager-Kagan s.a.). Mention is also made of poisoning of isolated wetlands by leaves from certain tree species falling into the water (MHE-Niger 1990a).

4.3 Fishing

Fishing mostly takes place during dry season, when (newly introduced) fish stocks have had time to grow and/or are driven closer together as the water level recedes. The main species caught are *Clarias gariepinus* (catfish or 'silure'), *Tilapia nilotica*, *T. zilii* and *Lates niloticus* (nile perch or

'capitaine'). Other fish caught include *Bagrus bayad*, *Protopterus annectens* (lungfish) and *Auchenoglanis sp.* (Brouwer and Mullié 1994a).

In 1989, the fish catch in the Region of Tahoua, one of the seven rural Regions of Niger, was estimated at 430 tons, with a value of more than $ 250.000 at the wetlands where they were caught (MHE-DFPP 1991). In the capital Niamey the value of the fish was 5-10 times higher (pers. obs.). In 1993 it was estimated that, with an investment of $ 1 million, the fish production in the Region of Tahoua could be increased to 1.500 tons per year, with an annual value of close to $ 1 million at the then current prices. A total production of 2000 tons per year was considered achievable (MHE-DFPP 1991).

In 1978, 1981 and 1985 the fish production from isolated wetlands in Niger was estimated at 5.000, 3.2000 and 1.100 tons respectively. The low production in 1985 was no doubt influenced by the 1984 drought. At an 'at source' price of 250 F CFA per kg, the fish production from isolated wetlands in Niger would have been worth $ 4.2 million to the fishermen in 1978, and $ 0.9 million in 1985 (MHE-DFPP 1991). The value in Niamey would have been 5-10 times higher (Brouwer and Mullié 1994a). The value in northern Nigeria, where part of the fish production was traded to, is unknown.

Above a certain minimum wetland size, the fish production per ha per year appears to decrease with wetland size. This is probably related to the inflow of nutrients that can stimulate fish production. See also the section on interactions between user groups.

Before 1975 fishermen at isolated wetlands in the Region of Tahoua were almost all from Nigeria (MHE-DFPP 1991). At times this led to conflicts about access rights to wetlands. In the 1980's and 1990's there was training of fishermen from Niger as well (MHE-DFPP pers. comm. 1994).

4.4 Hunting and tourism

As mentioned, since 1996 hunting other than by traditional means is allowed again in Niger. Even before 1996 it was not uncommon for ducks and geese to be hunted with shotguns, at least along the Niger river. We have also seen little boys use catapults, as well as twigs, covered in a sticky substance made from *Euphorbia* sap and placed along the edge of a pool, to catch birds coming in to drink (Brouwer and Mullié 1994a). In the Zinder and Lake Chad areas wintering White Storks *Ciconia ciconia* from Europe and North Africa used to be caught with live decoys and baited lines (Giraudoux et al. 1988; Mullié et al. 1996). In 2006, at an isolated wetland near Birni N'Konni, waterbirds caught as by-catch on fishing lines with many hooks were killed for consumption. Species involved included Purple Heron *Ardea purpurea*, Eurasian Bittern *Botaurus stellaris*, Squacco Heron *Ardeola ralloides* and Little Grebe *Tachybaptus ruficollis* (pers. obs.). The first three are migrants from Europe and/or Asia.

In the local markets a multitude of animal species, including species found at isolated wetlands, are for sale for medicinal and magical purposes. To what extent these animals are caught in Niger itself is not clear (Brouwer and Mullié 1994a).

In neighbouring Burkina Faso, tourists from Mediterranean countries come during the dry season to hunt birds, including water-birds (pers. obs. and discussions with public servants, 2006-2008). As far as I am aware there is no such organised hunting of water-birds by overseas tourists in Niger. Tourist organisations in Niamey in 2007 and 2008 also did not know of any organised hunting at isolated wetlands in Niger, nor of organised tourist excursions to isolated wetlands (pers. obs.).

4.5 Collecting of natural products

Many natural products are collected at isolated wetlands all year round. See section 3.5 for a list. Products collected primarily during the dry season include the fruits and tubers of water-lilies

Nymphaea sp. for human consumption; bourgou *Echinochloa stagnina* to feed livestock; and water for agricultural purposes (Brouwer and Mullié 1994a).

4.6 Biodiversity (birds, mammals, plants, other)

During the dry season large mammals such as antelopes, buffalo, elephants, hyenas, jackals, foxes, and even lions used to come to drink at isolated wetlands in Niger. However, other than foxes there are very few large mammals left in Niger, other than in 'W' National Park on the border with Benin and Burkina Faso in the south-west of the country.

Relatively much, but still not all that much, is known about water-birds in Niger during the dry season. During 1992-1997 water-bird counts were conducted every year during January-February, along the Niger River as well as at isolated wetlands throughout the country. In total more than 100 species of water-bird were observed during those counts, and almost 40 species of raptor. During the dry season Niger is host to an estimated 1.8 million water-birds. Most of these have been born in Europe or Asia, and some fly more than five thousand kilometres to spend the Eurasian winter in Niger. Niger's wetlands are therefore also important to the conservation of Europe's and Asia's biodiversity (Mullié and Brouwer 1994a, 1994b; Mullié et al. 1999; Brouwer and Mullié 2001). Preference of particular species of water-birds for particular types of wetlands in Niger are discussed in Mullié et al. (1999).

Two thirds of the water-birds in Niger, on average about 1.2 million, use the isolated wetlands, depending on how much rain has fallen the preceding rainy season. The Niger River becomes more important when the rains have been poor and the isolated wetlands are only partly filled. Just as for fish, the density of water-birds is greater on smaller wetlands than on larger ones. This is probably because nutrient loading is greater for smaller wetlands: see the section on interactions between isolated wetland uses. What also stands out is that water-bird density is greater on wetlands that have aquatic vegetation than on wetlands that don't. Due to the aquatic vegetation there is apparently more to eat for the average water-bird, and the vegetation provides cover as well (Mullié and Brouwer 1994b; Mullié et al. 1999; Brouwer and Mullié 2001).

Just like for the rainy season, very little is known of the occurrence, during the dry season, of other vertebrate animals, and especially of invertebrate animals, at isolated wetlands in Niger.

5. Synthesis: differences between years; links with uplands and other areas; interaction between groups; developments over recent years

Table 1 gives estimates of the annual values that isolated wetlands in Niger have for different uses. From Table 1 it is clear that isolated wetlands in Niger are natural resources that are very valuable for a number of purposes. For some users, such as pastoralists, isolated wetlands are essential to their way of life. For other groups, having access to wetlands as well as drylands increases the range of crop and livestock production options, from which they can choose depending on how good the local rains and the flood levels of the wetland are or were. As many authors have reported, risk reduction is a major goal for resource-poor farmers in the Sahel (e.g. Ubels and Horst 1993, p.29; Brouwer and Mullié 1994a).

As discussed below, the value of a particular isolated wetland for a particular purpose may vary from year to year. This value depends not only on rainfall at the wetland and in the area immediately surrounding it, but also on rainfall in other catchments and upland areas. Rainfall in semi-arid regions is not only very variable from year to year in one location, but also very patchy spatially. Individual rainfall events can be quite local, but annual rainfall totals can also differ considerably over quite short distances. As an example, during a large international experiment in the Niamey area in 1992, rainfall over the whole year was found to differ by 275 mm or a factor 1.54 over a distance of only 9 km in quite flat terrain: 507 vs. 782 mm (EPSAT experiment; see Lebel et al. 1992). If an isolated wetland is well filled one year but nearby wetlands are not, then it

will be relatively important that year. If the next year the wetland is equally well filled but so are its neighbours, then its relative value will be less.

Values of isolated wetlands for a particular purpose also depend on interactions with utilisation for other purposes. Sometimes such interactions are competitive and negative, sometimes they are positive.

Table 1. Some estimated values of isolated wetlands in Niger.
Value not always linked to a specific season.

Product	Season	Year	Extent and value	Remarks
Cropping	Rainy		?	Value probably quite low; cropping priority is uplands
Cropping	Dry	1991	42-64.000 ha/yr $200-$4300 per ha (uplands $70 per ha)	area greater following poor rainy season in uplands; high nutrition, high value crops
Livestock keeping	Rainy & dry	1991	$35 million per year	value of traded livestock that was dependent on wetlands for water
Fisheries	Rainy & dry	1978-1985	1.100-5.000 tons per year $ 0.9-4.2 million per year	fish catch at all isolated wetlands in Niger, value to fishermen
Fisheries	Rainy & dry	1978-1985	$ 5-20(-40) million per year	fish catch at all isolated wetlands in Niger, city prices
Fisheries	Rainy & dry	1989	430 ton, $250.000 per year	Region of Tahoua only; value in Niamey 5-10x greater; potential 2.000 ton
Hunting & tourism	Dry		?	potential completely undeveloped
Collecting of natural products	Rainy & dry		?	wood, clay, water; plant & animal products
Collecting of natural products	Dry	drought years	?	water-lily fruits and tubers, and lungfish, are emergency food in times of drought
Biodiversity	Rainy		?	almost no information
Biodiversity	Dry		?	average 1.2 million water-birds in Jan-Feb; other species?

5.1 Cropping

5.1.1 Differences between years

Due to differences in water levels, at a particular wetland the same areas are not used for dry season cropping each year. However, that does not mean that the total area useable for e.g. recession agriculture can be reduced with impunity (Brouwer and Ouattara 1995). As mentioned in section 4.2 and Table 1, isolated wetlands in Niger are particularly valuable for cropping purposes following poor millet yields in the adjoining uplands. Dry season cropping is more prevalent in such years, and isolated wetlands can also provide hunger foods like water-lily fruit and tubers (Brouwer and Mullié 1994a).

5.1.2 Links with uplands and other areas

This link between uplands and isolated wetlands during droughts is not just local and temporary. Drought periods can also lead to increased permanent settlement around wetlands. From 1975 to

1988, a period that included two severe droughts, the number of villages on the Nigerian section of Lake Chad increased from 40 to more than 100 (Hutchinson et al. 1992). Similarly, use of the Hadejia-Nguru wetlands in Nigeria for agricultural production increased due to the droughts of the last two decades. This increase was not foreseen and therefore not considered when plans were made for construction of dams and irrigation projects in the catchment upstream (M.C. Acreman pers. comm. 1995). In the Region of Tahoua, Niger, dry periods have on the whole meant an increase in migration to the coast. Wet periods meant migration to the normally drier and less populated northern and western parts of the Region; those people then in part stayed there even when rainfall was less abundant, thus increasing the pressure on the natural resources present (including wetlands) (DDE-Tahoua 1993).

5.1.3 Interaction with other activities and recent trends

Dry season cropping at isolated wetlands can profit from land use in the surrounding areas through the inflow from nutrient-rich sediment and through the transfer of nutrients by livestock (see section 5.2). The dry season cropping can itself be advantageous to fisheries as fish may spawn among the stumps of the previous season's mouskwari sorghum (e.g. Hollis et al. 1993, Aminu-Kano 1994, Framine 1994). Dry season cropping can also lead to extra income that can be used to finance improvements in other areas such as animal health and buying fishing equipment.

On the other hand there can be competition for labour between dry season cropping at isolated wetlands and maintenance of upland fields. Upland field maintenance can include anti-erosion measures. A certain level of anti-erosion measures in a catchment may reduce turbidity and prevent the silting up of the downstream wetland. Many, if not most, Sahelian wetlands already suffer from problems of erosion, silting up, vegetation destruction and/or salinisation (cf. Brouwer and Mullié 1994a, 1994b). These problems are in part related to the low rainfall in the 70's and 80's and associated decrease in vegetation cover, but also to increases in population densities and decreases in vegetation cover (more millet fields, less fallow, cf. Reenberg 1994) in the catchment areas of the wetlands. For wetlands near Zinder in Niger, Framine (1994) estimated that, without proper counter measures, it would take only 10-20 years for a change from aquatic to a marshy ecosystems to be effected.

Too much anti-erosion activity can adversely affect the flow of both water and nutrients to the wetland, especially during years of poor rainfall. Upstream dams, from very small to very large, can similarly cause wetlands to dry out and/or become more saline as the flushing effect of floods is reduced (Brouwer and Mullié 1994a). The recent construction of many small dams for local vegetable growing in nearby riverbeds was reputed to have caused the early drying out of Lake Tapkin Sao near Dogon Doutchi in south-west Niger in 2006-2007 (pers. obs.).

Expansion of dry season cropping around isolated wetlands may lead to more agro-chemicals being washed into the wetland. It may also reduce access by livestock that need the wetlands for drinking water. Less livestock can lead to a reduction of nutrient transfer by livestock from grazing areas to upland fields, but also to the wetlands (see section 5.2). The latter may in the longer term adversely affect the dry season cropping itself as well as the fish production (see section 5.3). On the other hand livestock may damage crops fringing isolated wetlands.

Increased dry season cropping may lead to a reduction of aquatic and fringing vegetation, and thus to a reduction of habitat for water-birds and other animals. Farmers in the Region of Tahoua have cut entire stands of *Acacia nilotica* in order to have more land for agriculture; at the same time there is a lack of firewood production in virtually the whole of the Region (DDE-Tahoua 1993, p.2 and on). Similar cutting of *A. nilotica* stands has been observed at Kokoro wetland near Téra, between a visit in 1997 and a visit in 2008 (pers. obs.). The trees at Tabalak (Region of Tahoua) and Kokoro also served as roosting areas for heron species (pers. obs.).

Increased dry season cropping will lead as well to an increase in disturbance of those birds, and perhaps to increased hunting because of increased damage to crops, actual or perceived. See section 5.6.3 on biodiversity.

Increased dry season cropping would make an isolated wetland less attractive for hunting and for tourism but in providing employment opportunities may also lead to a reduction in seasonal outmigration in search of work. Farmers near Zinder, Niger, have filled in sections of wetland with soil, to increase the cropable area (Framine 1994). Factors slowing down the development of dry season cropping include lack of credit, lack of transport, and poor infrastructure (Cheferou Mahatan 1994).

Raising the outflow level of an isolated wetland, so that it will hold more water for longer for water supply and irrigation purposes, can affect the aquatic and fringing vegetation in a variety of ways, depending on the particular local circumstances. Some trees may not survive an increase in inundation time. or a reduction in oxygen content of the water. Livestock and water-birds may profit from there being more water present later into the dry season, but may be adversely affected by changes in vegetation growth and, for water birds, changes in associated prey species.

5.2 Livestock rearing

5.2.1 Differences between years

No data could be found on differences between years in utilisation of isolated wetlands by livestock. With lesser livestock numbers during drought periods (see section 4.2), utilisation by livestock of wetlands for drinking will also be lower during droughts. However, it may not always be clear whether less water in wetlands has led to less livestock, or a want of fodder has lead to less livestock and thus a lower utilisation of wetlands by livestock.

As indicated in the introduction to section 5, the importance of a particular wetland for watering (and grazing) livestock also depends on the situation at associated wetlands. A particular isolated wetland may be important for livestock only one year in ten, when it can, and the other wetlands cannot, provide what the livestock and herders need. But if that year that wetland is not available because it has been used for other purposes, the whole associated livestock rearing system may collapse.

5.2.2 Links with uplands and other areas

Isolated wetlands are linked to local grazing areas by local livestock, and to more distant grazing areas and wetlands by transhumance livestock. To transhumance herding families wetlands are extremely important as a source of water for their animals during the dry season and, further north, also during the rainy season. The larger wetlands are seasonally also very important for grazing. The wetlands and grazing areas further south help make it possible to exploit the rainy-season livestock production potential of the northern Sahel: without dry-season watering and grazing in the south, there can be no grazing in the north (cf. Breman 1992, Dugan 1990). Conversely, if transhumance livestock rearing becomes impossible in the north, nutrient transfer to wetlands and millet fields may be reduced in the south.

5.2.3 Interaction with other activities and recent trends

Livestock rearing does not appear to benefit from other activities at isolated wetlands, though the herders themselves may trade or buy what is produced or collected there by others. Raising the outflow level of an isolated wetland, so that it will hold more water for longer for water supply and irrigation purposes, could also allow livestock to drink there longer into the dry season.

Fishing and biodiversity, on the other hand, do appear to profit from livestock rearing because of the transfer of nutrients by livestock to isolated wetlands. Studies in other countries make this likely: for Lake Manzala in Egypt Bishai and Khalil (1990) calculated that one ton of nutrient in put meant a production of about 5.5 tons of fish flesh, while Hirigoyen (1898) mentioned four times higher fish production at a mare in Burkina Faso following addition of 4 tons of cereal chaff.

Data from Niger point in a similar direction. The livestock watered at isolated wetlands in Niger have been estimated to contribute up to 10 tons of manure and associated urine per hectare per year, containing 300 kg N, 30 kg P and the associated energy of the organic matter for use by detritus-eating organisms (unpubl. data). This must have an enormous effect on plant and animal production at the wetlands.

It would seem reasonable to assume that total nutrient transfer to a wetland is proportional to length of shoreline or wetland circumference: more shoreline means more access for livestock and thus likely more livestock coming in to drink and leaving behind manure and urine. Fish and other plant and animal production per hectare, on the other hand, are by definition proportional to the area of the wetland. As a wetland of a particular shape is larger, the ratio of circumference (total nutrient loading) to area (nutrient loading per hectare) is smaller. In the case of a round wetland, the ratio of circumference to area equals $2\pi r/ \pi r^2$ or $2/r$, a number that gets smaller as the radius r of the wetland increases. Thus nutrient loading per hectare decreases with increasing wetland size, and so would production per hectare. Fig. 1 and 2 do indeed show that fish production per hectare and water-bird numbers per ha decrease with increasing wetland size. We have not come across any instances were isolated wetlands, as opposed to transient pools of water, have become eutrophic due to input of livestock manure and urine.

It is not clear to what extent dry season cropping around isolated wetlands also profits from the transfer of nutrients by livestock to those wetlands. Given the conflicts between farmers and pastoralists at wetlands, with pastoralists often having to give way, it would be very interesting to investigate that.

Livestock may trample the vegetation and soil in and around wetlands. This can lead to erosion of the shoreline, silting up of the wetland, and/or increased turbidity of the water, affecting plant and animal life in and around the wetland (Mahamane Alio and Abdou Haliko 1993; Framine 1994).

Livestock rearing itself may in turn be negatively affected by cropping activities around wetlands, which can severely limit livestock access to the wetlands for drinking (see section 5.1.3 for examples at Tabalak and Kokoroo wetlands). Increased use of the land bordering on wetlands has led to increasing problems of access to water for livestock, with consequent conflicts between farmers and herders, who are often of different ethnic backgrounds (Bernus 1974 already; Framine 1994).

5.3 Fishing

5.3.1 Differences between years

Years with little rainfall in a particular catchment result in less water in the associated isolated wetland. One would expect this to lead to less fish production in that wetland. A nation-wide drought in 1984 did indeed lead to low fish production the following year, as mentioned in section 4.3. During drought years more aestivating lungfish *Protopterus annectens* may be dug out of the mud of dried out wetlands to serve as hunger food (Raverdeau 1991; Cheferou Mahatan 1994; Brouwer and Mullié 1994a).

5.3.2 Links with uplands and other areas

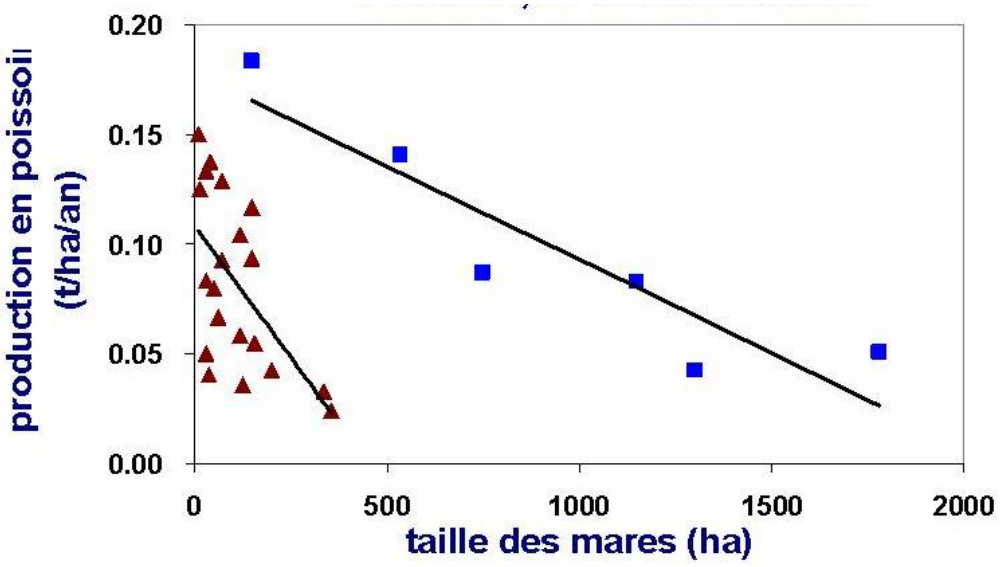
One of the main linking fishing at isolated wetlands to other areas is that fishing in certain wetlands may be started by fishermen who are originally from another region. These fishermen have no proprietary rights to any part of the wetland or its surroundings.

5.3.3 Interaction with other activities and recent trends

The main interaction between fishermen and other user groups is that fish may be traded or sold to local farmers and pastoralists. What is of greater interest ecologically is that fish production probably benefits from the transfer of nutrients by livestock to isolated wetlands. As discussed in

section 5.2.3, one would expect the effect of nutrient transfer by livestock on primary and secondary production to decrease with increasing wetland size. Fig. 1 clearly shows such a decrease. Why the large wetlands function differently from the smaller ones is not known.

Fig. 1. Fish production in the Region of Tahoua in tons/ha/year, as a function of wetland size (after Brouwer and Mullié 1994a)



Fish production may also benefit to a certain extent from dry season cropping, where stumps of the previous season's mouskwari sorghum provide spawning habitat (e.g. Hollis et al. 1993, Aminu-Kano 1994, Framine 1994). Raising the outflow level of an isolated wetland, so that it will hold more water for longer, may allow fish to grow to a bigger size. But the associated change in the hydrological regime would also affect the aquatic vegetation in unknown ways, which in turn may affect the fish. Increased water retention in the upstream catchment would lead to lower water levels and to less sediment transport to a wetland. The latter may be good or bad.

Degradation and destruction of aquatic vegetation by farmers, livestock and/or collectors of natural products may negatively affect fish production. It is not known to what extent fish-eating migratory birds are significant predators of fish in isolated wetlands. Fishermen at certain wetlands do have a by-catch of migratory birds (cf. section 4.3).

Several studies have looked at the potential for fish production in isolated wetlands in the Regions of Tahoua (MHE-DFPP 1991), Zinder (Mahamane Alio and Abdou Halikou 1993) and Tillabéri (Hirigoyen 1989). See Brouwer and Mullié (1994) for a summary of these studies. The following major problems in the development of the fishing industry in the Region of Tahoua were identified: lack of equipment and of training of fishermen; poor commercial organisation; poor infrastructure; poor hygiene; and poor conservation of fish (smoking is not always effective). Because of conservation problems large quantities of fish were often only caught when a buyer had been identified or was on-site (MHE-DFPP 1991).

Proposed management options for improving fisheries in the wetlands of the Regions of Tahoua and Zinder included resowing with *Echinochloa spp.* or *Nymphaea spp.*; introduction of (extra species of) fish through the creation of central hatcheries; removal of *Cyperus spp.*; removal of tree stumps; digging deeper areas in beds of isolated wetlands so fish can survive the dry season better (potentially this could lead to perforation of the 'impermeable' wetland bottoms, thus leading to more rapid drying out of the wetlands!); catchment protection; training and equiping of fishermen; planting of windbreaks against dune encroachment (MHE-DFPP 1991; Mahamane Alio and Abdou Halikou 1993). An improved inventory of wetlands and research on natural and improved fish production in Tahoua's isolated wetlands was also considered desirable.

5.4 Hunting and tourism

As there is little or no hunting or tourism at isolated wetlands in Niger, there are no data about differences between years, links with uplands and other areas, or interactions with other activities. See section 5.6 for such information on water-birds, the (potential) target species of most hunters at isolated wetlands in Niger.

Note that hunters often do not live at the wetlands they hunt at. If the local population does not profit from the hunters, the hunters may not be welcome. The same goes for tourists, of course.

5.5 Collecting of natural products

As mentioned, collecting of natural products from isolated wetlands as hunger food (water-lily fruit and tubers; lungfish) takes place in years of drought. Collectors may be local but may also come from further away. Destruction of the aquatic and fringing vegetation by farmers and/or livestock adversely affects the collection of natural products. So may the introduction, accidental or othwerise, of plants such as Water Lettuce *Pistia stratiotes*, Water Hyacinth *Eichhornia crassipes*, and bulrush *Typha sp.*. Changes in the flooding regime through increased water retention in a wetland's catchment and/or the raising of the outflow level of a wetland, may also affect the collecting of natural products.

5.6 Biodiversity

5.6.1 Differences between years

The only group of species that frequent isolated wetlands in Niger, and about which there is quantitative information, is formed by water-birds. Mullié et al. (1999) showed that when the rains have been good and the isolated wetlands are full, the wetlands contain more water-birds then when the rains have been poor. In such dry years the river Niger, which has its source 3000 km away in Guinea, appears to be a refuge for some of the water-birds normally found on isolated wetlands.

What is important is not only rainfall at and around an isolated wetland itself, but also how that compares with rainfall at and around associated wetlands. In drier years water-birds may congregate at the wetlands that do still have enough water. When these become too dry, too, they may all go to wetter wetlands elsewhere.

For hunters concentration of water-birds at only a few wetlands may be attractive, but the water-birds are then also at their most vulnerable, in part because alternative habitat is a long way away.

5.6.2 Links with uplands and other areas

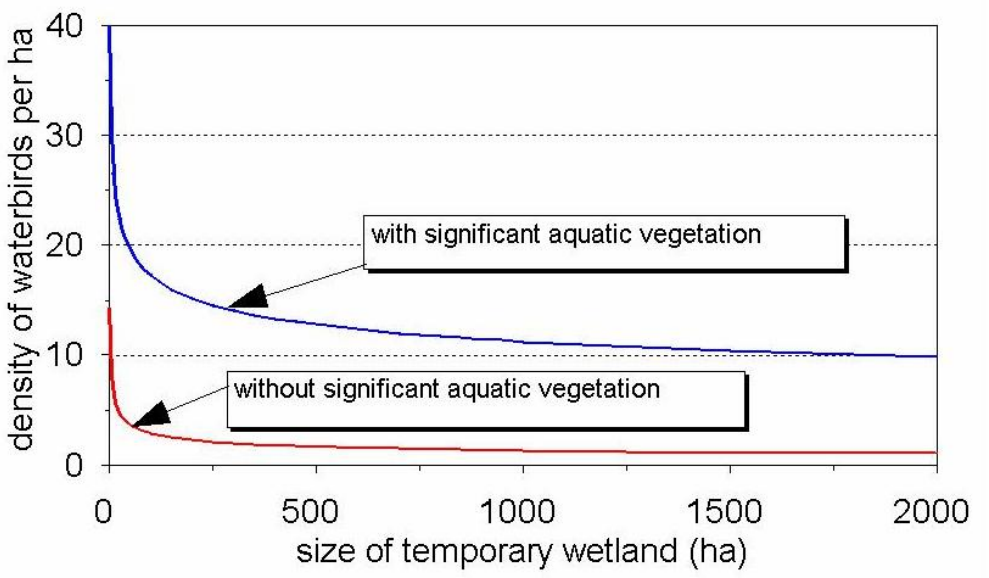
Water-birds at a particular wetland link that wetland with the other wetlands they frequent. These include wetlands in the same area with which the wetland forms a habitat system for all or part of the year; and all the other wetlands along the flyways of the birds concerned. Bird ringing and satellite tracking studies have shown that migratory birds link Niger to at least 74 other countries, from Guinea to the Shetland Islands, across to Sandinavia and Siberia, and down via the Middle East to Madagascar and South Africa. Not all birds ringed or tracked frequent wetlands, but many do. The water-birds on Niger's isolated wetlands are thus a common heritage and their responsibility a task that Niger shares with many other countries. The situation for water-birds in other countries in the Sahel, and elsewhere in semi-arid Africa, will be substantially the same.

5.6.3 Interaction with other activities and recent trends

Biodiversity at isolated wetlands is obviously important to collectors of natural plant and animal products. For water-birds like for fish production (section 5.3.3), transfer of nutrients by livestock to

isolated wetlands probably has a positive effect on food item density for water-birds, and through that on density of water-birds themselves. This effect would diminish with increasing wetland size. Fig. 2 shows that a negative correlation between wetland size and water-bird density has indeed been found for isolated wetlands in Niger.

Fig. 2. Relationship between isolated wetland size and water-bird density (from Mullié et al. 1999)



Notable is the effect of the presence of significant aquatic vegetation on water-bird density. Such vegetation probably increases prey diversity and density, in shallow as well as deeper parts of the wetlands. Stocking with fish may have positive as well as negative effects on biodiversity.

Biodiversity is likely to be negatively affected, immediately or eventually, by increases in dry season cropping; degradation or destruction of aquatic and fringing vegetation by farmers, fishermen, herders and/or livestock; an increase in disturbance by the same groups; changes in the flooding regime through the raising of the outflow level of the wetland and/or increased retention of water upstream in the catchment; too much hunting or hunting at too many wetlands; and over-collection of natural products. At Madarounfa near Maradi, well known for its large numbers of storks and other water-birds in the 1970's (Giraudoux et al. 1988), there was much agriculture but hardly any birds or fishing in 1993/94 (pers. obs.). At Kokoro and Tabalak, as well as at Mari near Tillabéri, dry season cropping occupied about 20% of the edges of the wetlands in 1993/94, which had increased to about 80% by 2007/2008. Water-bird numbers at all three wetlands were much smaller in 2007/2008 than in the early 1990's (pers. obs.). Cause and effect relationships remain to be proven but appear logical.

6. Likely future developments and their effects on the various user groups

The importance of isolated wetlands to many user groups is not just limited to the Sahel. Scoones (1991) gives a similar but more wide-ranging evaluation of the importance of small wetlands in semi-arid areas of Africa. Other relevant publications include Dugan (1990), Zeppenfeldt and Vlaar (1990), Claude et al. (1991), Hollis et al. (1993), and Sally et al. (1994).

Because of the continuing urbanisation, the demand for rice in Niger, and elsewhere in West Africa, will continue to increase. There have been proposals to develop a further 70.000 ha of land for irrigation in Niger, out of 210.000 ha considered suitable, much of it around isolated wetlands. The market for various other crops grown around wetlands will no doubt increase as well. In addition there is the increasing pressure due to population growth, which in Niger is estimated at 3.1% per annum. That growth percentage means a doubling of the population in less than 23

years, and a quadrupling in 45 years. Around wetlands the pressure will grow even faster, due to migration to wetlands from upland areas.

What effects climate change will have on all this is uncertain, but no-one appears willing to bet that the effects of climate change will be positive in the Sahel. This in spite of the fact that the drought of 1973-74 has led to the creation of quite sizeable (up to 1800 ha) new isolated wetlands in Niger (see section 2 above).

All in all, there is no doubt that the human pressure on wetlands in Niger will increase enormously during the years to come. It remains to be seen how the poorest people will fare under such conditions if they are not offered help. Under present conditions, in particular poor people still have a lot of (traditional) access to wetlands and their resources. The danger is that those traditional access rights will be diminished by new developments. Transhumance pastoralists, present at isolated wetlands only part of the year, are likely to lose out to farmers, present all year round. At the same time conversion of upland grazing areas to millet fields has forced pastoralists to try their luck further north, where as yet there is less pressure from agriculture. This has caused for instance Peuhl to graze their herds in formerly Touareg areas, again leading to conflicts. Fishermen, collectors of natural products and biodiversity are also likely to be affected.

What then is the best way to further manage and develop Sahelian wetlands? Unfortunately, there is no simple answer. What is important is that it is realised how things came to be as they are, and what side effects proposed changes to the system may have. Certainly, without creation and/or maintenance of the right infrastructure and macro-economic climate, wetland management and development will come to nought (cf. Breman 1992). What is also clear is that management and planning will have to be participatory to be successful (cf. Dugan 1990, Ubels and Horst 1993, Kouokam 1994). In addition, it will have to pay appropriate attention traditional techniques for utilising the wetlands; to possible tradeoffs between the various types of wetland utilisation for production and conservation; and to the different roles of men and women in the traditional production processes, with women often working smaller areas and growing different crops (Ubels and Horst 1993, p.15, the Gambia; Cheferou Mahatan 1994). Finally, management and development of Sahelian wetlands will without doubt have to take account of the intimate relationships that exist between the use of wetlands; the use of the drylands that surround them; and the use of other areas further away and at other times of year by people and animals that use the isolated wetlands in the Sahel only during particular seasons.

7. Conclusions

The preceding shows that participative, integrated natural resource management (PINReM) is essential if one wants to work towards sustainable use of wetlands and at the same time improve living conditions. Included in such management must be associated educational and health developments. At the same time more still needs to be known about the values (monetary and non-monetary) of wetlands, their products, services and attributes, and how they might be increased in a sustainable way. In this context small scale development is generally less disruptive than large scale development, and can be just as profitable when all costs and benefits are considered. Small-scale activities include more intensive fish management, moderate increases in external inputs into agriculture, and optimisation of the role of livestock in wetland systems.

Such small-scale developments also make it possible to simultaneously protect the environment and maintain biodiversity, e.g. by giving extra protection to particular parts of a wetland. Sometimes such protection is only necessary during a particular part of the year. To know when to protect what and how to manage the rest, good knowledge of agro-ecological and ecological relationships within wetlands systems and their surroundings is essential. Sufficient attention must be also paid to the processes that make a wetland what it is. Only then can justice be done to the species that depend on the wetland, and to the people, often poor, that traditionally use it.

The fragmented occurrence of isolated wetlands in the Sahel complicates setting up PINReM. But if PINReM is not introduced quickly at these wetlands, ALL user groups will soon be worse off than they are now.

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