

Wetlands, biodiversity and poverty alleviation in semi-arid areas: Niger as an example from the Sahel

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Biodiversity includes all the genes, species and ecosystems, as well as the processes that take place within those ecosystems. Those processes can be biological, physical, chemical and socio-economic. Biodiversity therefore arguably includes everything that lives or happens in the landscape or seascape, including underground and underwater.

In all the discussions about biodiversity, processes unfortunately get the least attention. 'Unfortunately', because it is the processes that are the driving forces which, in interaction with each other and with species, maintain the ecosystems. It is also the processes that allow humans to profit from what ecosystems produce. These processes include, for instance, erosion and sedimentation, and all the other processes that influence nutrient cycles and hydrological cycles.

The importance of processes in biodiversity is well illustrated by wetlands. Wetlands are areas where water and nutrients are concentrated. It is these processes of concentration that make wetlands the most productive and most valuable ecosystems in the world, more productive even than tropical rainforests. If, for whatever reason, the nutrient and/or hydrological cycles greatly change, and much less (or much more) water and/or nutrients are concentrated, then the character of a wetland will greatly change as well. The wetland may even cease to exist. That would be a loss for humans as much as for nature.

The productiveness of wetlands is most apparent in arid and semi-arid areas, where the contrast with the surrounding drylands is greatest. Because of this productiveness, wetlands play a very important role in poverty alleviation in arid and semi-arid regions, just as they do elsewhere. Presented here are some illustrations of this poverty-alleviating role, based mostly on data from wetlands in Niger. There is first a description of what kind of wetlands there are in Niger, and what role they play at present in agriculture, livestock rearing, fisheries, and the production of natural products. Numbers are presented on how these wetlands provide a safety net during times of drought and hardship. This is followed by a section on what the future might bring for wetlands in Niger. The article ends with some comments on interaction between the various uses of wetlands in Niger, and the need for their integrated management.

The different wetlands of Niger

The river Niger flows over a length of 550 km through SW Niger. The flow at Niamey, the national capital, varies between 0-1800 m³ s⁻¹, with an average of 1030 m³ s⁻¹. This average flow, by the way, was only half as large during the 1980's, when rainfall was much lower. 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.

In the east of the country the Komadougou Yobé forms the border with Nigeria. This river used to flow ten months per year, but now it only flows for six. This is due to the construction of dams upstream, as well as to a prolonged period of lesser rainfall. Partly as a result of greatly diminished flow in the Komadougou Yobé, the Niger part of Lake Chad, in the eastern-most part of the country, was dry from about 1988-1998. In the north of

Niger there are a number of oases, with orchards, grape and date production. 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, in others flow has stopped only recently. Some still carry water from time to time, while in all these ancient valleys groundwater is often close to the surface

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. Some are even permanent, and always, or almost always, have water. These wetlands are enormously dynamic: some disappear due to silting up, but new ones appear as well. One such new wetland is at Dan Douchi, in a depression that filled up as the drought broke in 1975: it now covers 1500 ha when full. By far the greatest number of these isolated wetlands is to be found south of 15° N, between the line Mali-Tahoua-Lake Chad and the borders with Nigeria and Benin.

Present use of wetlands in Niger

Table 1 gives estimates of the annual value that wetlands in Niger have for different uses.

Table 1. Some estimated annual economic values of wetlands in Niger

Product	Type of wetland	Year	Yield	Remarks
Irrigated rice	Along Niger river	1990	60-70.000 t (10 t/ha)	economically not viable
Dry season cropping	Isolated wetlands	1991	42-64.000 ha \$200-\$4300 per ha high value crops	area greater following poor rainy season
Wet season cropping	Dry fields		4.1 million ha, \$70 per ha staple foods millet & sorghum	
Various natural products	Isolated wetlands		No data available	emergency food in times of drought
Livestock	Isolated wetlands	1991	\$35 million per year	value of traded livestock that was dependent on wetlands for water
Fisheries	Niger river and other wetlands	1992	\$11 million per year	fish catch in Niger river was decreasing
Fisheries	Isolated wetlands Tahoua	1989	430 ton, \$250.000 per year	value in Niamey 5-10x greater; potential 2000 ton

a. The Niger River

Of the irrigation areas along the Niger River, 6-7.000 ha is actively used for growing rice, with a total production of 60-70.000 ton per year (usually two harvests per year). When the irrigation areas were constructed, an annual internal rate of return of 12.5% was expected. In reality it only was 3%, which probably does not even include the loss of fish production etc. associated with the loss of floodplain. In addition, such irrigation areas are considered by many to increase income differences among the population, because of unequal access to the newly created rice fields. In the irrigation areas there is also some cultivation of vegetables and other crops.

Along the borders of the river grows the grass species bourgou (*Echinochloa stagnina*), an important livestock fodder. During the dry season the floodplains, and to a lesser extent the rice stubble, can be important grazing areas: 500.000 cattle graze in and around the Hadejia-Nguru wetlands in northern Nigeria at that time of year. The figures for the Inner Niger Delta are even higher, but for the Niger River in Niger they will be rather lower. It should not be forgotten that, without dry season grazing in the south, no use can be made of the wet season grazing on the grasslands in the north.

In 1991, 12,000 people along the Niger River in Niger were principally involved in fishing. The total added value of fishing to Niger's economy that year was estimated at \$11 million dollars (from the river plus the isolated wetlands). During the 1980's river flow as well as fish catch in the Niger dropped: the river flow recovered, but the fish catch didn't: 6000 t in 1978, down to 900 t in 1985. It is not clear why the fish production did not recover. Perhaps it was because of overfishing, or because spawning areas had disappeared. And for some species the annual migration may have become more difficult. But it is also possible that the deeper parts of the river, the refuge areas for fish during times of low flow, have slowly silted up.

Inland wetlands

Agriculture

Around isolated wetlands in the Sahel a lot of cropping takes place at the start of the dry season. In Niger, during the 1990's, between 42,000 and 64,000 ha were used for this purpose each year. The precise area used for dry season cropping is influenced by how far the water has risen during the preceding rainy season. About one quarter of these crops receive supplementary irrigation. The rest are grown on residual moisture only, left behind in the soil as the water levels of the wetlands recede. In 1993 these usually high value food crops provided an income of between \$200-\$4300 per hectare. For comparison, the 4.1 million ha of the dryland staple crops pearl millet and sorghum, brought in an average \$70 per hectare. In 1994, in the Illela area, the rent for cropping land around wetlands went as high as \$200,- per year. The arrival of motor pumps for irrigation purposes allows owners to cultivate more land themselves, rather than rent it out.

Livestock rearing

Wetlands are very important for the watering of Niger's 1.8 million cattle, 3.3 million sheep and 5.2 million goats (data from 1991). One third of the water demand for these animals is met from surface water. Using water from wetlands and pools for watering livestock requires much less labour than pulling it up from wells, which are sometimes as deep as 80 m. Some herders water their animals at a wetland every day. Others do this every couple of days, because they graze their animals further away. 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 kilometres. Some isolated wetlands are also important grazing areas during the dry season. On the other hand wetlands can be focal points for the transmission of water- and soil-borne livestock diseases and parasites.

In 1991 about 5% of the cattle, 10% of the sheep and 7% of the goats in Niger were traded or slaughtered. Average prices per head in Tahoua in 1990 were about \$170 for cattle, \$35 for sheep and \$17 for goats. Taking these prices as representative for the whole country, this means that about \$35 million of the livestock turnover in Niger in 1991 was directly dependent on wetlands for providing water. That figure will only have increased since then.

Fisheries

In 1989 the fish catch in the *Département* of Tahoua was estimated at 430 tons, with a value of more than \$250,000 at local prices. In the capital Niamey the price of fish can be 5-10 times as high as at the wetlands where they were caught. In 1993 it was estimated that with an investment of \$1 million the fish production in the Tahoua *Département* could be increased to 1500 tons per year. A total production of 2000 tons per year was considered achievable. In general the fish production per hectare is greater for smaller wetlands (above a certain minimum size). This is probably related to the inflow of nutrients that can stimulate fish production: see also the section on land use interactions.

In the past fishermen at isolated wetlands in central Niger were mostly from Nigeria. At times this led to conflicts about access rights to wetlands. Over the past ten, fifteen years there has been training of Nigeriens as fishermen as well. Stocking of wetlands with desired fish species is a common practice. Sometimes these are native species, sometimes exotic. Other measures to increase fish production are also taken.

Collection of natural products

In Niger hunting and trapping of waterbirds in Niger appear to be very limited. There are some local exceptions, for instance in the Niamey area. Hunting was largely prohibited until 1996, other than locally and with traditional means. In the Inner Niger Delta in Mali, on the other hand, up to 200-400.000 waterbirds are harvested each year, forming an important source of animal protein. Other natural products collected in Niger include fruits and tubers of waterlilies; wild rice; bourgou for livestock fodder; plant (and animal) products for traditional medicine and magical purposes; wood for fuel and construction; clay for brick making and pottery; and water for domestic and agricultural purposes.

Tourism and recreational hunting

The potential of Niger's wetlands for tourism and hunting is not known. Tourism organisations have not yet discovered their biological wealth. 'W' National Park is a Ramsar Wetland of International Importance, but is much better known for its elephants and other large mammals in the bush areas. During the 1994-95 season the Park did not even have 1000 paying visitors. A great shame, such a low number, considering that the Park has 354 bird species, 45 large mammals, and no security problems. Luckily tourism in the south of Niger seems to be somewhat on the increase again, now that the political problems in the north have lessened.

The vegetation

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. caerulea* (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*.

Wetlands as a safety net in times of drought and hardship

Wetlands can provide 'hunger foods' like water lily tubers, and lungfish that have burrowed into the mud to survive the dry season. Such foods are especially important in drought years. The area of dry-season cropping around wetlands increases by up to 50% following poor rainy season yields of millet and sorghum. Sometimes 70% of the income from dry season cropping is used to buy enough grain to last until the next harvest. A general increase in dry season cropping could reduce the exodus of young men to the coast, and increase employment for young women.

From 1975 to 1988, a period that included two severe droughts, the number of villages found on the Nigerian section of Lake Chad increased from 40 to more than 100. Similarly, the use of the Hadejia-Nguru wetlands in Nigeria for traditional agricultural production has increased due to the droughts of the last two decades. This was not foreseen in the planning of dams upstream, and the increase in traditional agriculture has exacerbated the water allocation problems.

Likely future developments relevant to wetlands in Niger

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. Around wetlands the pressure will grow even faster, due to migration to wetlands from upland areas. The IPCC (Inter-governmental Panel on Climate change) expects rainfall in the western Sahel to decrease, while at the same time there are plans for many more dams in various countries. If the flow in the Niger diminishes further, the fish catch, for instance, will be reduced, too. Rainfall in the Sahel zone of Niger and Chad, on the other hand, is predicted to increase. During wetter years people move north into normally drier areas, and when rainfall returns to normal they often stay, particularly around wetlands. During dry years there is more migration to the coast.

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.

Wetland use: interactions and threats

There is a lot of interaction, positive as well as negative, between different forms of wetland use. The effects on wetlands of changes elsewhere, upstream, laterally as well as downstream, can be enormous. Due to increased pressure some functions of wetlands may thus be lost.

Until the 1970's, Lake Madarounfa, near Maradi, was an important wetland for waterbirds, including storks from Western Europe. Now it has cropping all around its borders, fish production is greatly reduced due to overfishing, and there are almost no waterbirds anymore. At lakes in the *Département* of Tahoua, entire stands of *Acacia nilotica* have been cleared by farmers to have more land for agriculture. At the same time there is a lack of firewood production in virtually the whole of the *Département*. In the Inner Niger Delta there have been similar problems with the policing of woodcutting. The vegetation is sometimes also destroyed by livestock trampling the borders of wetlands. On the other hand the leaves of some trees can cause poisoning if they fall into the water.

The fauna

Crocodiles still occur in the Niger River and its tributary the Mekrou, but their numbers have dropped greatly because of excessive hunting. A small crocodile population also persists at some isolated wetlands near Zinder in the east. Manatees can still be found in the Niger River, but one needs a lot of local knowledge and patience, as well as luck, to see them. Near Ayorou there are several hundred hippos. When the river is high they spread as far as Niamey and beyond. Other animals such as antelopes, buffalo, hyenas, jackals, foxes, and even lions, come to drink at the river and at isolated wetlands, especially 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 waterbirds in Niger. Every year since 1992 waterbird counts have taken place during January-February, along the Niger River as well as at isolated wetlands throughout the country. In total more than 100 species of waterbird have been observed during those counts, and almost 40 species of raptor. During the dry season Niger is host to an estimated 1.8 million waterbirds. 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.

Two thirds of the waterbirds in Niger, more than one million, use the isolated wetlands, provided enough 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 waterbirds is greater on smaller wetlands than on larger ones. This is probably because nutrient loading is greater for smaller wetlands, which have a greater circumference to surface area ratio, or 'edge effect', than do larger wetlands. What also stands out is that waterbird density is greater on wetlands that do have aquatic vegetation than on wetlands that don't. Due to the aquatic vegetation there is apparently more to eat for the average waterbird, and the vegetation provides cover as well.

Increases in dry season cropping immediately around wetlands have reduced access to watering points for many herders, who are not allowed to cross the fields with their livestock until the crops have been harvested. The farmers and herders involved are often of different ethnic background, which can make the conflicts worse and has even contributed to fatalities. 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. To make matters

worse, meat prices have not kept up with cereal prices: immediately after the second world war the price of a cow was 10 bags of millet, by the early 70's it had gone down to 4-5. The position of herders thus has worsened relative to that of farmers, and the latter have also begun to keep more animals themselves.

Many of the isolated wetlands in Niger are said to be silting up. This is mainly because of the increased erosion in their catchments, due to expansion of agriculture and increased grazing pressure. There is competition for labour between dry season agriculture on receding water around isolated wetlands on the one hand, and soil and water conservation works in the upland fields on the other hand: both activities require considerable investment of labour at the same time of year. But farmers near Zinder have also filled in section of wetlands with soil themselves, to increase the croppable area. There are a number of people who say that, at smaller wetlands, 20-30 years after the arrival of farmers the wetlands are degraded for all users, including the farmers themselves. And silt fills up reservoirs as well as wetlands: reservoir storage capacity is estimated to be halved 20 to 30 years after construction. Changes in the hydrological balance can also influence the groundwater level or cause salinisation.

On the positive side, the livestock watered at wetlands can 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. This must have an enormous effect on plant and animal production at the wetlands. At a lake in Egypt, one ton of (organic) nutrient in put has been equated with 5.5 tons extra fish. Because smaller wetlands have a longer shoreline in proportion to their area than do larger wetlands, this nutrient concentration effect, from livestock manure and from inflow of sediments, is likely to be greater for smaller wetlands. And indeed, in Niger fish catch per hectare and waterbird density have been shown to decrease with increasing wetland size. In the Inner Niger Delta in Mali it looks like waterbird colonies, too, can play an important and positive role in the nutrient cycle and the associated fish production. Fish production is also often higher in areas where fish may spawn among the stumps of the previous season's moukwari sorghum.

In general it can be said that a combination of wetland and dryland areas gives local people a range of production options from which they can choose, depending on for instance the rainfall in a particular year. This helps them minimise their risks, an important management goal in these regions.

The need for integrated wetland management

The preceding examples clearly show 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.

References

- Adams, W.M. 1992. Wasting the rain. Rivers, people and planning in Africa. EarthScan, London. 256 pp.
Alam, M. 1991. Problems and potential of irrigated agriculture in sub-Saharan Africa. *J.Irr.Drain.Engng* 117:155-172.
Ambagis, J., J. Brouwer and C. Jameson (in prep.). Monthly waterbird and raptor counts along the Niger and Mekrou rivers, SW Niger. Submitted to *Malimbus*, journal of the West African Ornithological Association, Feb. 2002.

- Aminu-Kano, M. 1994. Water resources management in the Hadajia-Nguru wetlands. Paper prepared for the IUCN Workshop on the Initiative on Sahelian Floodplains, Tapoa, Niger, 31 October - 2 November 1994.
- Bernus, E. 1974. L'évolution récente des relations entre éleveurs et agriculteurs en Afrique tropicale: l'exemple du Sahel Nigérien. Cah. ORSTOM, sér. Sci. Hum. XI(2):137-143.
- Bouaré, S. 1994. L'impact des crues sur l'avifaune dans le delta intérieur du fleuve Niger, Mali. Paper prepared for the IUCN Workshop on the Initiative on Sahelian Floodplains, Tapoa, Niger, 31 October - 2 November 1994.
- Breman, H. 1992. Desertification control, the West African case; prevention is better than cure. *Biotropica* 24(2b):328-334.
- Brouwer, J. 2001. SYSTANAL: a checklist for analysing ecosystems for the conservation of biological diversity. *Ostrich Supplement* No. 15:178-182. (French and Arabic translations available)
- Brouwer, J. 2001. Analyse des interactions entre bétail et faune sauvage au Niger, avec un accent sur les zones humides. Contribution à l'atelier régional sur 'Faune sauvage et bétail: complémentarité et coexistence ou compétition?'. Tenu de 16 au 19 janvier 2001 à Niamey, Niger. DED, Niamey, Niger et GTZ, Eschborn, Allemagne. Publication électronique.
- Brouwer, J. 2002. SYSTANAL, a checklist for analysing (agro-) ecosystems for the conservation of biological diversity: the ecosystem approach in a nutshell. p.28 in: Reflections on 10 years Rio: views from The Netherlands. On the occasion of the 6th Conference of the Parties of the Convention on Biological Diversity, April 2002, The Hague. Netherlands Committee for IUCN.
- Brouwer, J. and W.C. Mullié 1994a. Potentialités pour l'agriculture, l'élevage, la pêche, la collecte des produits naturels et la chasse dans les zones humides du Niger. In: Atelier sur les zones humides du Niger. Proceedings of a workshop, 2-5 November 1994, La Tapoa/Parc du W, Niger. P. Kristensen (ed.). IUCN-Niger. pp.27-51.
[English version available: *The potential of wetlands in Niger for agriculture, livestock, fisheries, natural products and hunting*]
- Brouwer, J. and W.C. Mullié 1994b. The importance of small wetlands in the central Sahel. *IUCN Wetlands Programme Newsletter* 9:12-13.
- Brouwer, J. and W.C. Mullié 1995. The need for an integrated approach towards management of small scattered wetlands in the Central Sahel. Annex 1 to the report on Workshop D: Conservation of the White Stork in its winter quarters. In: Proceedings of the International Symposium on the White Stork (Western Population), O. Biber, P. Enggist, C. Marti and T. Salathé (eds). pp.296-297.
- Brouwer, J. and W.C. Mullié 1996. Case study: the Sahel. In: M.G. Oquist, B.O. Svensson, P. Groffman and M. Taylor. Non-tidal wetlands. Chapter 6 of *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds.)]. Cambridge University Press, Cambridge and New York. pp. 215-239.
- Brouwer, J. and W.C. Mullié 2001. A method for making whole country waterbird population estimates, applied to annual waterbird census data from Niger. *Ostrich Supplement* No. 15:73-82.
- Brouwer, J. and M. Ouattara 1995. Interactions between wetlands and surrounding drylands in the Sahel: a key to sustainable use. Paper presented at the meeting of IUCN's SAWEG (Sahelian Wetlands Expert Group), Dakar, Senegal, 21-24 May 1995. 16 pp.
- Brouwer, J., W.C. Mullié, F. Codjo and P. Kristensen 1997. The African Waterfowl Census in Niger: combining wildlife and other utilisation objectives. Some reflections on the occasion of the African Waterfowl Census Review and Development Workshop, Parc National des Oiseaux du Djoudj, Senegal, 6-10 February 1996. In: A Preliminary Waterbird Monitoring Strategy for Africa, T. Dodman ed. Wetlands International Publication 43. Wetlands International, Wageningen, The Netherlands. pp.132-138.
[Aussi disponible en Français: *Le recensement des Oiseaux d'Eau en Afrique au Niger: combiner des objectifs de conservation et d'utilisation.*]
- Brouwer, J., S.F. Codjo and W.C. Mullié 2001. Niger. In: L.C.D. Fishpool and M.E. Evans (eds), Important Bird Areas of Africa and Associated Islands: Priority Sites for Conservation. BirdLife International Conservation Series no. 10. BirdLife International, Cambridge, UK and Pisces, Newbury, UK. pp. 661-672.
- Brouwer, Joost, Abdoulaye N'Diaye, Marcel Silvius and Issa Sylla 2001. Protecting Wetlands of International Importance in arid parts of Africa: the need to involve the local population. Paper presented at the 1st International Symposium and Workshop on Arid Zone Environments: Research and Management Options for Protected Areas. Abu Dhabi, UAE, 23rd-25th January 2000
- Cheferou Mahatan 1994. Etude de la filière des cultures de contre-saison, zone du PMI. SNV-Netherlands Organisation for Development Aid, Projet Mares Illela. Niamey, Niger. 80 pp.
- DDE-Tahoua 1993. Contribution à l'élaboration du Plan Quinquennal 1994-1998 du secteur de l'Environnement. Direction Départementale de l'Environnement, Département de Tahoua, République du Niger.
- Dobson, A. and R. Carper 1992. Global warming and potential changes in host-parasite and disease-vector relationships. In: *Global warming and biological diversity*. R.L. Peters and T.E. Lovejoy (eds). Yale University Press, New Haven, USA. pp. 201-217.
- Dugan, P.J. 1990. Conservation de zones humides. P.J. Dugan (ed.). IUCN, Gland, Switzerland. 96 pp.
- Dumont, H.J. 1992. The regulation of plant and animal species and communities in African shallow lakes and wetlands. *Revue d'Hydrobiologie Tropicale* 25:303-346.
- Ellis, J. and K.A. Galvin 1944. Climate patterns and landuse practices in the dry zones of Africa. *BioScience* 44:340-349
- Framine, N. 1994. Pisciculture des zones humides: compatibilité, exploitation et conservation. In: P. Kristensen (ed.), Atelier sur les zones humides du Niger. Comptes rendus d'un atelier à la Tapoa, Parc du 'W', Niger, du 2 au 5 Novembre 1994. IUCN-Niger, Niamey, Niger. pp.17-26.
- Hirigoyen, J.P. 1989. Etude d'identification et de factibilité d'une opération test de développement de la pisciculture extensive dans le Département de Tillabéri, République du Niger. Ministère de l'Agriculture et de l'Elevage, Caisse Centrale de Coopération Economique. Avec la coopération du CTFT, CIRAD, France. Niamey, Niger. 121 pp.
- Hollis, G.E., W.M. Adams and M. Aminu-Kano 1993. The Hadejia-Nguru Wetlands. Environment, economy and sustainable development of a Sahelian floodplain wetland. G.E. Hollis, W.M. Adams and M. Aminu-Kano (eds). IUCN, Gland, Switzerland and Cambridge, UK. xviii+244 pp.
- Gibbs, J.P. 1993. Importance of small wetlands for the persistence of local populations of wetland associated animals. *Wetlands* 13:25-31.

- Hutchinson, C.F., P. Warshall, E.J. Arnould and J. Kindler 1992. Development in arid lands. Lessons from Lake Chad. *Environment* 34(6):16-20&40-43
- IPCC-WGI 1990. Climate change. The IPCC scientific assessment. J.T.Houghton, G.J.Jenkins and J.J.Ephraums (eds). IPCC Working Group I. Published for the Intergovernmental Panel on Climate Change by Cambridge University Press, UK. 365 pp.
- IPCC-WGII 1994. Climate scenarios and socioeconomic projections for IPCC WG II assessment. S.Greco, R.H.Moss, D.Viner and R.Jenne (eds). Intergovernmental Panel on Climate Change Working Group II. 12 pp. + appendices. Limited distribution.
- Kortenhorst, L.F., L.H. Sprey and P.N.G. van Stekelenburg 1989. Some aspects of irrigation development in sub-Saharan Africa. A discussion paper. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. 43 pp.
- MacDonald, I.A.W. 1992b. Global change and alien invasions: implications for biodiversity and protected area management. pp. 197-207 in *Biodiversity and global change*. O.T. Solbrig, H.M. van Emden and P.G.W.J. van Oordt (eds). International Union of Biological Sciences, Paris, France.
- MAE-Niger 1993. Annuaire des statistiques de l'agriculture et de l'élevage 1991. Ministère de l'Agriculture et de l'Elevage, Directions des Etudes et de la Programmation, Service d'Analyse des Politiques et de la Coordination des Statistiques. Niamey, Niger. 111 pp. + figures.
- Mahamane Alio et Abdou Halikou 1993. Recensement des mares du Département de Zinder. Direction Départementale de l'Environnement, Département de Zinder. Zinder, Niger. 12 pp.
- Meyers, W.S. 1994. Australian irrigation: balancing rights and responsibilities, production and conservation. *Soils News* (Newsletter of the Australian Society of Soil Science) no.99, July 1994, p.1-4.
- MHE-DFPP 1991. Organisation de la production et de la commercialisation du poisson dans le Département de Tahoua. Ministère de l'Hydraulique et de l'Environnement, Direction de la Faune, de la Pêche et de la Pisciculture. Rapport de Projet. 50 pp + annexes.
- MHE-DGR-Niger 1992. Etude de la mobilisation des eaux de ruissellement dans trois départements (Tahoua - Zinder - Agadez). Phase II, Etude de factibilité. Vol. IA. Synthèse. Rapport final. Ministère de l'Hydraulique et de l'Environnement, Direction du Génie Rural. Louis Berger International, consultants. Niamey, Niger. 28 pp. + annexes.
- MHE-Niger 1991a. Les ressources en eau du Département de Diffa. Ministère de l'Hydraulique et de l'Environnement. Direction Départementale de l'Hydraulique de Diffa. Projet PNUD/DCTD NER/86/001. Niamey, Niger. 35 pp. + annexes.
- MHE-Niger 1991b. Les ressources en eau du Département de Dosso. Ministère de l'Hydraulique et de l'Environnement. Direction Départementale de l'Hydraulique de Dosso. Projet PNUD/DCTD NER/86/001. Niamey, Niger. 35 pp. + annexes.
- Monteith, J.L. 1981. Climatic variation and the growth of crops. *Quart.J.R.Met.Soc.* 107:749-774.
- Morel, G.J. 1971. Report on the controversy between agriculture and waterfowl conservation in West Africa. Report to the 17th Annual Executive Board Meeting of the International Wildfowl Research Bureau, Slimbridge, Glos., England, 9-10 Dec. 1971. 4 pp.
- Mullié, W.C. 1994. [Capture and trade of the Red-billed Quelea *Quelea quelea* in the Lake Chad Basin: sustainable use of a biological resource.] DFPV, Niamey, Niger. xviii+94 pp. (in French).
- Mullié, W.C. and J.Brouwer 1994. L'importance des zones humides au Niger pour les oiseaux d'eau afrotropicaux et paléarctiques. In: *Atelier sur les zones humides du Niger*. Proceedings of a workshop, 2-5 November 1994, La Tapoa/Parc du W, Niger. P.Kristensen (ed.). IUCN-Niger. pp.57-74.
- [English version available: The importance of wetlands in Niger for afrotropical and paleartic waterbirds]
- Mullié, W.C., J. Brouwer, S.F.Codjo and R. Decae 1999. Small isolated wetlands in the Sahel: a resource shared between people and birds. In: A. Beintema and J. van Vessem (eds), *Strategies for conserving migratory waterbirds - Proceedings of Workshop 2 of the 2nd International Conference on Wetlands and Development held in Dakar, Senegal, 8-14 November 1998*. Wetlands International Publication 55, Wageningen, The Netherlands. pp. 30-38.
- Mullié, W., J. Brouwer, F. Codjo, Abdou Malam Issa, R. Decae and J. Ambagis (in prep.). One million migratory and 'sedentary' waterbirds on isolated wetlands and river sites in Niger: patterns in resource availability, resource use, and waterbird-livestock interactions. Submitted to *Ardea*, December 2001.
- Nicholson, S.E. 1978. Climatic variations in the Sahel and other African regions during the past five centuries. *J.Arid Environment* 1:3-24.
- Nicholson, S.E. 1994. Recent rainfall fluctuations in Africa and their relationship to past conditions over the continent. *Holocene* 4:121-131.
- Piaton, H. and C. Puech 1992. Apport de la télédétection pour l'évaluation des ressources en eau d'irrigation pour la mise en valeur des plans d'eau à caractère permanent ou sémi-permanent au Niger. Rapport de synthèse. Avec J.Carette, Ecole Polytechnique Fédérale de Lausanne, Suisse. Comité Interafricain d'Etudes Hydrauliques, Ouagadougou, Burkina Faso, avec l'aide du Laboratoire Commun de Télédétection CEMAGREF-ENGREF.
- Raverdeau, F. 1991. La contre saison au Niger. Etude des systèmes de culture dans les départements de Tillabery et Dosso. Université de Niamey, Faculté d'Agronomie. Niamey, Niger. 130 pp. + annexes.
- Reenberg, A. 1994. Land-use dynamics in the Sahelian zone in eastern Niger - monitoring change in cultivation strategies in drought prone areas. *J.Arid Environments* 27:179-192.
- Sally, L., M. Kouda and N. Beaumont 1994. Zones humides du Burkina Faso. Compte rendu d'un séminaire sur les zones humides du Burkina Faso. L.Sally, M.Kouda and N.Beaumont (eds). IUCN Wetlands Programme, Gland, Switzerland. 290 pp.
- Scoones, I. 1991. Wetlands in drylands: the agroecology of savanna systems in Africa. Part 1: Overview - ecological, economic and social issues. I.Scoones (ed.). International Institute for Environment and Development, London, UK. 82 pp.
- Tager-Kagan, P. s.a.. Résultats d'enquêtes malacologiques dans les départements de Dosso et Niamey. Mouvements de troupeaux autour des mares visitées. Rapport du Laboratoire de Zootechnique, Institut National de Recherche Agronomique au Niger, Niamey, Niger. 13 pp. + tableaux.
- van der Graaf, S. and H. Breman 1993. Agricultural production: ecological limits and possibilities. Rapports PSS no.3. Projet Production Soudano-Sahélienne, IER-Mali, CABO-DLO, WAU and IB-DLO, The Netherlands. Prepared for the Club du Sahel. Wageningen. 39 pp.

- Van Molle, M. and P. van Ghelue 1991. Global change and soil erosion. *Acta Geologica Taiwanica* 29:33-45.
- Windmeijer, P.N. and W. Andriessse 1993. Inland valleys in West Africa: an agro-ecological characterization of rice-growin environments. ILRI Publication no.52. Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 160 pp.
- Zeppenfeldt, T. et J.C.J. Vlaar 1990. Mise en valeur des bas-fonds en Afrique de l'Ouest. Synthèse préliminaire de l'état des connaissances. Comité Interafricain d'Etudes Hydrauliques. Programme de Recherche en Vue de la Mise en Valeur des Bas-Fonds au Sahel. Avec l'appuie de l'Université Agronomique de Wageningen. Ouagadougou, Burkina Faso. 137 pp. + 28 pp. sur la Fonctionnement Hydrologique des Bas-Fonds par J.Albergel.
