Altenburg & Wymenga ECOLOGISCH ONDERZOEK

A&W-report 1274

WHAT ARE THE POSSIBLE ECOLOGICAL EFFECTS UPSTREAM OF THE PLANNED TAOUSSA DAM (MALI)?

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The study was done in the framework of Projet PvW 07012 (Mali) : *Gestion intégrée des ressources en eau dans le bassin du Niger en amont de Taoussa – Outil d’aide à la décision*.

Cover photo
Niger River downstream of Timbuktu, Inner Niger Delta, February 2009

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SUMMARY

The planned Taoussa dam will hardly affect the Inner Niger Delta itself, but will have a large ecological impact *upstream* on the Niger River. Moreover, the seasonal variation in water level *downstream* will be reduced by some 40%, an inevitable loss of the still present riverine floodplains in eastern Mali and in Niger. In the envisaged water management, the seasonal variation in water level will remain the same after the construction of the dam, although at a higher higher. As a consequence, the zone being permanently covered by water will be extended. Water deeper than 1-2 meter will remain open, but more shallow water may possibly be covered by *Typha* (Cattail). The experience in the Senegal Delta has shown that this is a very unattractive prospect. In the present situation, the river valley downstream of the Inner Niger Delta is an important habitat for the same bird species being concentrated in the Inner Niger Delta.

The Niger River between Timbuktu and Diré with sand dunes and *Faidherbia alba* trees on the foreground and extensive floodplains covered by *Vossia cuspidata* on the other side of the river.

1. INTRODUCTION

To cover the year-round demand of water used for sanity, irrigation and energy supply several dams have been constructed, or are projected, in the Upper Niger River Basin. The first dam, at Markala near Ségou, was constructed already in 1947 to supply water to the irrigation zone of the Office du Niger in the Delta Mort. The Sélingué dam was completed in 1983 to meet the growing demand for energy. The flood control of the Upper Niger increased further with the construction of dams near Talo (2007) and Djenné (planned) in the Bani, the main tributary of the Niger. Two more dams are planned in the near future, namely at Fomi (Guinea), in the upper part of the basin, and at Taoussa between Timbuktu and Gao, downstream of the Inner Niger Delta. This report addresses the possible ecological impact of the Taoussa dam on the northern part of the Inner Niger Delta and the river basin between Timbuktu and Taoussa.

The projected economical revenues (energy, irrigation, potable water) as well as the impact on hydrology, fisheries and other sectors determine whether the expected investments to build a dam are worth it. Zwarts *et al*. (2005) showed the need to include downstream effects in such decision process, since the negative economical impact of downstream changes are easily underestimated. This is the case in particular when large scale floodplains are involved such as the Inner Niger Delta. In the current study we are especially interested in upstream effects of the Taoussa dam, as this dam is planned downstream the Inner Niger Delta, one of the largest floodplains of West Africa comprising outstanding ecological values (Wymenga *et al*. 2002, van der Kamp *et al*. 2005, Zwarts *et al*. 2005, Zwarts *et al*. 2009).

Plans for a dam near Taoussa already originate from the 1950s but became more concrete in the 1980s when the Great Drought urged the need for food security. On a long term the dam should stimulate the local and regional economy, which in turn is expected to create a stable socio-political situation and reduce ethnic tensions. On a short and middle long term the objectives of the dam, as mentioned by Coyne et Bellier (1996), comprise the enlargement of the level of self subsistence in the region through the restoration of the local economy (agriculture, fisheries, pastoralism) and the restoration of groundwater levels and environmental conditions comparable to the pre-drought situation. The Taoussa dam is projected at 128 km upstream of Gao and 280 km downstream of Timbuktu. According to Coyne et Bellier (1996) the lower storage level of the dam will be 254 m IGN comparable to a water level at a river flow of 500 m^3 per second. The hydrological effects have been studied by Coyne et Bellier (1997) and Tecsult (2008), and are summarized in Chapter 3. Possible environmental effects are shortly mentioned in the same studies. The main goal of this study is to evaluate these forecasted ecological effects with field data, and produce a reconnaissance of the potential impact on the biodiversity of the northern delta, including the river basin east of Timbuktu. We do not elaborate on the downstream effects other than mentioning the possible ecological values involved. In this study we focus on the possible changes in wetlands habitats (Chapter 4) and related ecological values, in particular waterbirds (Chapter 5). As background information we briefly sketch the functional relationship between the occurrence of wetlands habitats and the seasonal dynamics in Sahelian floodplains and stagnant waters (peripheral lakes and basins) in Chapter 3.

This study was performed as a part of the Partners for Water project "Projet PvW 07012 (Mali) *Gestion intégrée des ressources en eau dans le bassin du Niger en amont de Taoussa – Outil d'aide à la decision*" which aims at the building of a smart decision support tool for Integrated Water Resources Management in the Upper Niger Basin. The project, financed by Partners for Water (The Netherlands), is carried out by a consortium of Royal Haskoning (lead), Altenburg & Wymenga ecological consultants, DLG Government Service for Land and Water Management, Utrecht, Rijkswaterstaat, Centre for Water Management, Lelystad, and Wetlands International (Wageningen / Sevare).

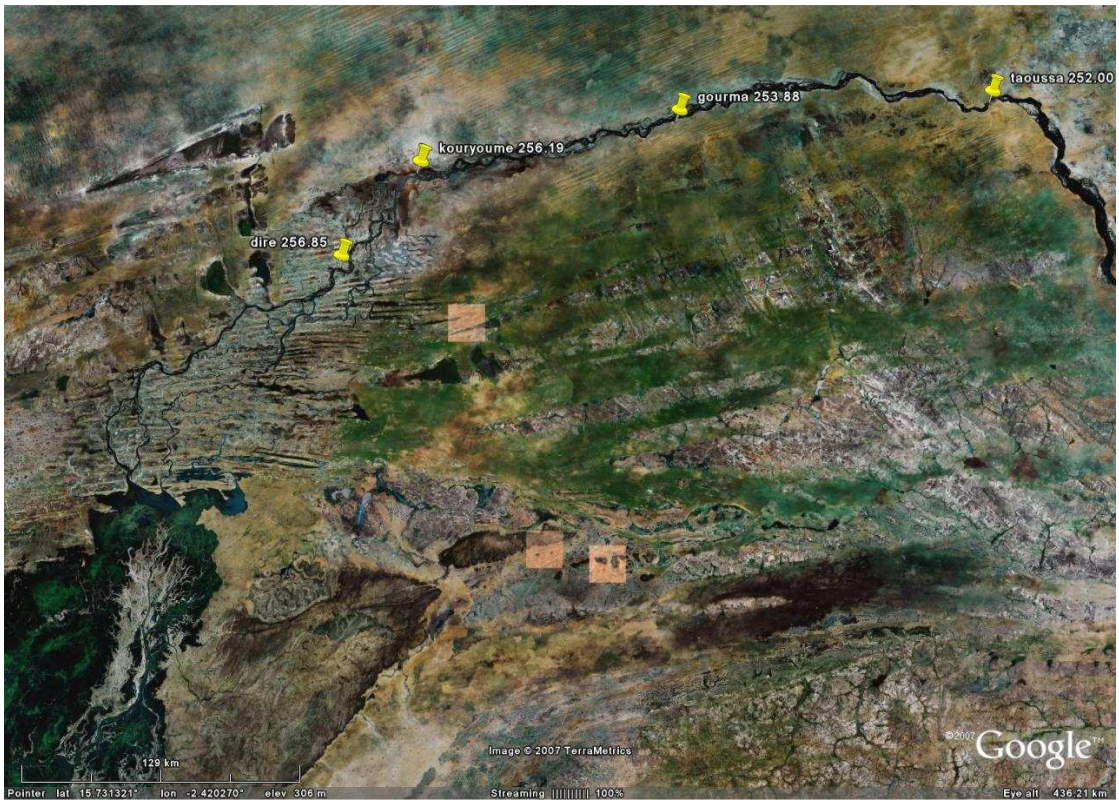


Fig. 1. *The bend of the Niger River downstream of the Inner Niger Delta (corner left below). The map gives the height for four hydrological stations (lowest water level in m + mean sea level), between the planned dam and the Inner Niger Delta.*

2. HYDROLOGICAL BACKGROUND INFORMATION

The Taoussa dam will be situated 270 km downstream of Timbuktu/Koryoumé and 90 km upstream of Gao. The daily water level has been measured in several stations along the Niger River: since 1923 in Diré and Taoussa, since 1954 in Gourma, since 1963 in Koryoumé and since 1964 in Bamba (Fig. 1). The seasonal and annual variation in water level in the present, still natural, variation is thus extremely well known. The water level in Diré varies usually between 257 and 261 m. For Taoussa this is 252 and 256 m, on average. Fig. 2 shows the daily variation for two periods of two years, one with the high peak flood of 1994/95 and one of the extremely dry year1984.

The Taoussa dam will withhold the water at a level of 258.75 m if all gates are closed. Its dead storage level (lowest gate level) the water level will decrease to 254.00 m. The hydrological impact immediately upstream of the dam is visualised in Fig. 3. To maximize the production of electricity, the lake will be filled during the flooding period (August-January) and emptied during the deflooding period in the rest of the year. The minimum working level will some 40 cm above the lowest gate level, thus the seasonal variation in water level will be about 4 metre, being more than the natural variation in extreme dry years but less than the variation in wet years.

2.1. HYDROLOGICAL CONSEQUENCES UPSTREAM OF THE TAOUSSA DAM[1]

Since the fall is low and the river bed not wide, an even small enhancement of the water level will have relatively large consequences upstream over long distances. The fall is extremely low in the northern Inner Niger Delta, only 0.9 cm/km between Diré and Koryoumé. Downstream of Koryoumé, the fall increases to 1.9 cm/km between Koryoumé and Gourma and to 2.8 cm/km between Gourma and Taoussa.

The topographical maps from the 1950s clearly show that the river bed is small between Taoussa and Gourma and gets wider further westwards. At a water level of 254 m at Taoussa the region between Taoussa and Bamba (210 km^2) will be flooded. At a water level of 258 m at Taoussa, also the region between Bamba and Gourma will be affected (640 km^2 being flooded). At the chosen maximal water level of 258.75 m, also the river bed between Gourma and Koryoumé will be filled, at least partly, as a consequence of which a lake of 1572 km^2 will come into existence, being, on average, about 300 km long, 5 km wide and 3 m deep.

[1] This chapter is based on two studies: Coyne et Bellier (1997), TECSULT (2008) and daily water level measurements made available by DNH.

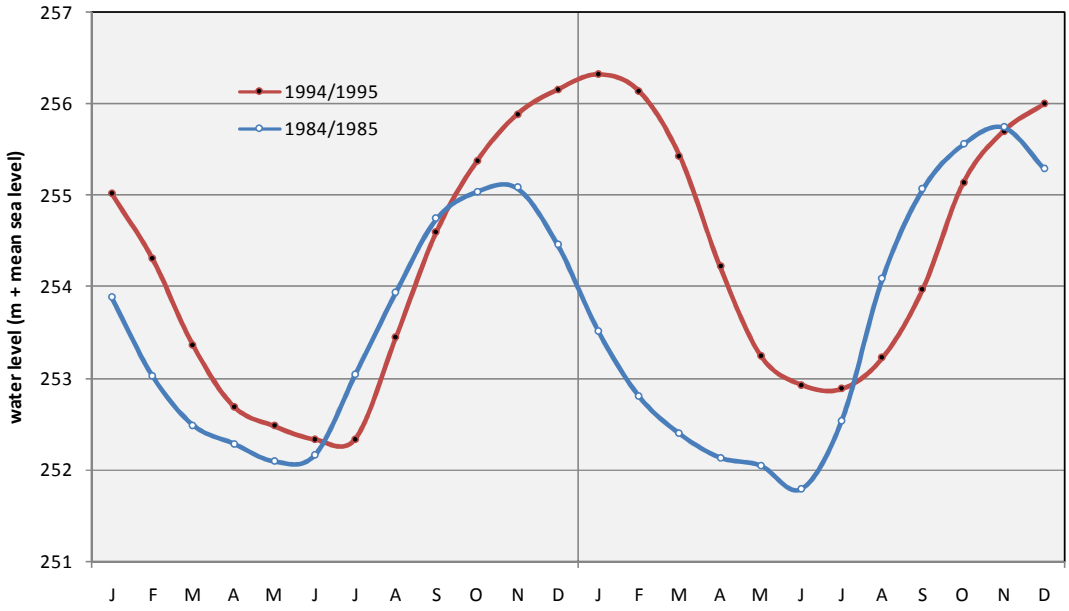


Fig. 2. *The monthly variation in water level in Taoussa in a dry and a wet period. 1984 was the driest year of the 20th century. The flood of 1994 was the highest flood since the late 1960s, but not a high flood compared to the levels reached in the 1950s and 1960s*

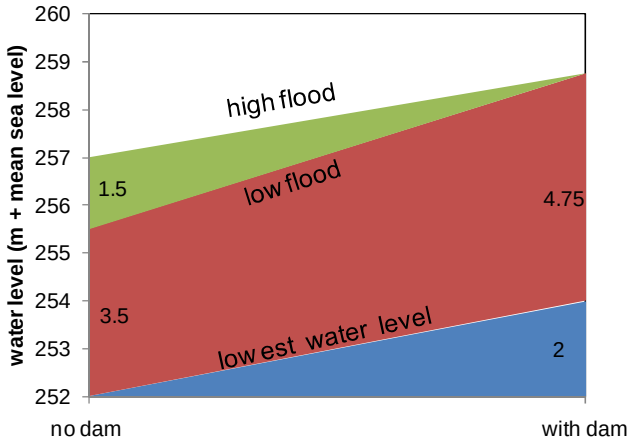


Fig. 3. *In the present situation the water level at Taoussa varies between 252 m and 257 m, at least in a wet year (in a dry year the flood will rise not more than 3.5 m). After the construction of the dam the lowest water level will be enhanced 2 metre, to 254 m, and the peak flood level to 258.75 m., in dry as well as in wet years. Hence the seasonal variation in water level will not change, although at a higher level. Moreover, the year-to-year variation in the seasonal amplitude will greatly disappear*

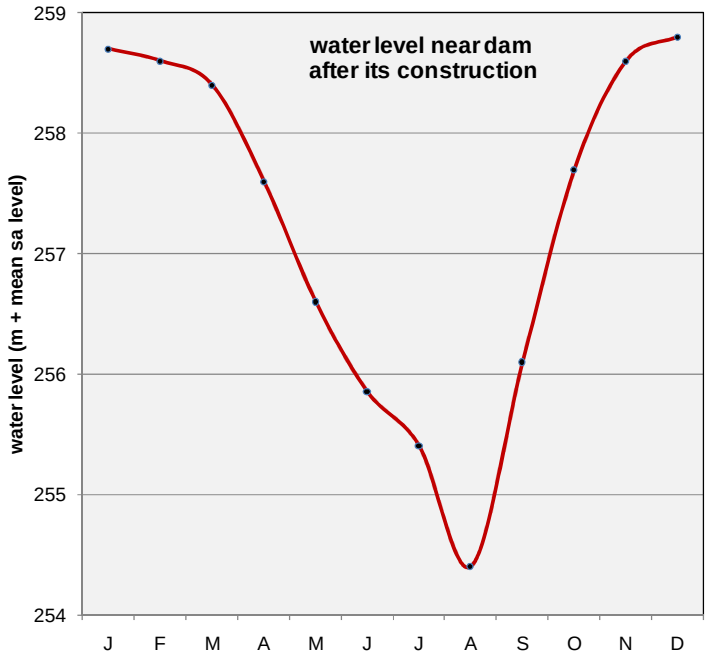


Fig. 4. *After the construction of the Taoussa dam, the lake will be emptied between February – July and be filled between August and January. As a consequence, the water level will vary 4 metre seasonally, being in December-January at its maximum (258.75). The lowest working level is assumed to remain 40 cm above the lowest gate level.*

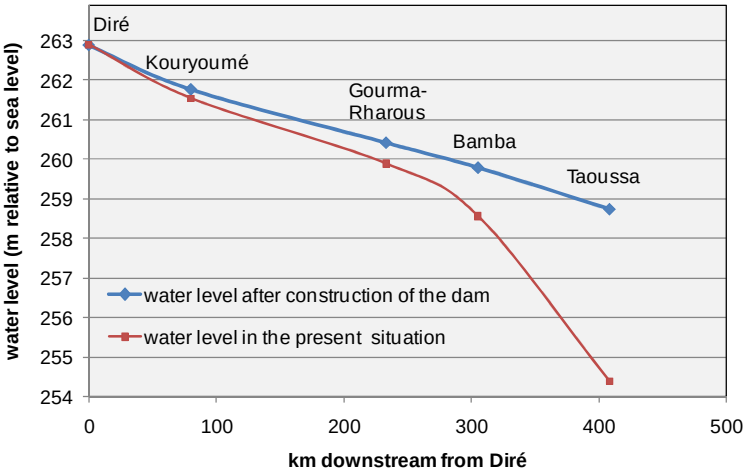


Fig. 5. *The fall of the water level between Diré and Taoussa in the present situation (average over the year) and after the construction of the Taoussa dam (maximal level).*

Fig. 5 gives the fall of the Niger River between the Inner Niger Delta and the Taoussa dam in the present situation compared to the predicted fall. The conclusion is at the chosen crest height of the dam the flooding system in the Inner Niger Delta will not be affected, but that the impact will be much larger in the Niger River closer to the dam: the water level will be raised about 30 cm in Koryoumé, 70-80 cm in Gourma and 110-120 cm in Bamba. These figures refer to the high water level, but what will change in the flooding dynamics at a lower water level? This all depends on the water management. If the gates would remain closed in the dry period (258.75 m), the expectation is that the northern Delta will only be partly be deflooded and that even the water level in Mopti will remain relatively high during the dry period. Although, this is not more than a theoretical possibility, it is good to realise that the Taoussa dam has potentially huge impacts on the functioning of the Inner Niger Delta.

In conclusion: The Taoussa will have a large impact on the seasonal river dynamics 100-200 km upstream. In the envisaged management the lake will be emptied during the deflooding

period, by which the seasonal variation of the water level will be simulated, although at a higher level.

2.2. THE HYDROLOGICAL IMPACT DOWNSTREAM OF THE TAOUSSA DAM

When the Taoussa reservoir will be filled at the start of the wet season, it retards flooding and lowers the peak level downstream. This also reduces the flood extent of the seasonal floodplains. Some months later, when the reservoir is emptied, the low water level is raised, causing an extension of the permanent marshes. These man-induced changes turn the higher floodplains into drylands and the lower floodplains into permanent marshlands; the remaining seasonal floodplains contain less water for a shorter period. The irregular water releases from the reservoir cause erratic short-term fluctuations in water level, unlike the normally gradual daily increase and decrease of water level associated with unhampered flooding and deflooding.

The just listed impacts are the same for all dams constructed in rivers with a large seasonal variation in water flow and will also be evident in the Niger River downstream of the Taoussa dam; see Fig. 6 showing the predicted variation in the water level in Kandadji (Niger), with and without the Taoussa dam. Although the graph was made in order to show the impact of Taoussa on the planned Kandadji reservoir, the graph also illustrates the impact on the riverine floodplains in SE Mali and W Niger.

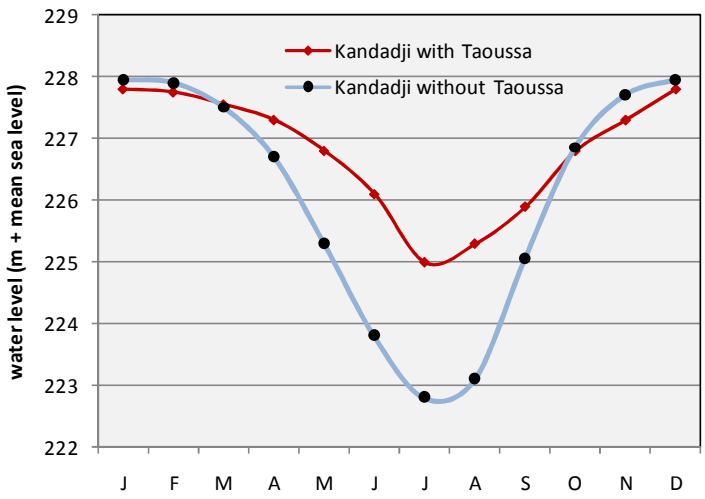


Fig. 6. *The monthly water level in Kandadji with and without Taoussa. Note the relatively small impact in the flooding period, but large impact in dry period. As a consequence, the flooding dynamics in the still remaining floodplains along the Niger will loss a large part of their natural dynamics due to the Taoussa dam upstream.*

3. ECOLOGICAL IMPACT

3.1. INTRODUCTION

Coyne et Bellier (1997) concluded that the Taoussa dam will more or les restore the situation before the Great Drought (1969-1993) and that the higher water level will have a positive impact on the riverine ecosystems. They warned, however, that a semi-permanent inundation of the northern Inner Niger Delta must be prevented and hence there should be strict rules concerning the water management to ensure a seasonal variation in the water level. They gave, however, no arguments why a semi-permanent flooding should be prevented.

Kuper et al. (2002) discussed the effect of the Taoussa dam on the northern Inner Niger Delta and concluded that the effect might be positive as well as negative, without giving further details.

TECSULT (2008) conclude that the proposed management of the Taoussa dam will be very close to the natural seasonal variation in water level and hence the impact insignificant, despite the river bed of the Niger between Taoussa and Bamba will be permanently or semi-permanently covered by water. Further upstream the impact is absent (upstream of Diré) or considered to be positive since the ground water level will be higher and the flooding performance will be enhanced in years with a low discharge. In short, the dam is seen as a tool in the fight against the desertification.

More information about the ecological impact of the Taoussa dam on the Niger River upstream of the dam is badly needed. The main impact of the Taoussa dam will be a change in the duration of the flooding. As a consequence, this will change the zoning of the plant species and, due to the close link between the vegetation and other ecological values, finally also the entire ecological functioning of the entire ecosystem. Thus, what we need to know in the first place, to what degree the Taoussa will affect the zoning of the vegetation in the inundation zone and have a rough idea of the ecological values of the different vegetation zones being affected. We made a short field mission to the northern Inner Niger Delta and the Niger River between Koryoumé and Gourma (26 January – 7 February 2009). We also visited Lac Horo, Lac Télé and Lac Fati since the three lakes lakes differ regarding their water depth and flooding dynamics. These differences may shed light on the envisaged ecological impact of the Taoussa dam in the northern Delta.

3.2. THE NORTHERN DELTA AND RIVER BASIN

The Inner Niger Delta, covering about 30.000 km^2, is situated in Mali between Ke-Macina in the south and Timbuktu in the north. Here the Niger widens into a flat alluvial plain comprising uncountable branches (*majo's*) and gullies meandering through the floodplain interspersed with sandy levees and dunes in the north. This vast area is inundated with a 4-5 m high flood between October and March. The flood performance depends entirely on the rainfall in the Fouta Djalon Mountains in Guinea and shows large seasonal and annual variations. For the characteristics of the flood, such as the timing and the relationships between rainfall, water levels, river flow and the inundated surface area see Zwarts *et al.* (2005).

Although comprising one vast floodplain there are marked differences between the southern and the northern part of the delta. In the southern part, the Diaka and the Niger proper, and many branches in between, drain into the central lakes Walado Debo, Lake Debo and Lake Korientzé. These lakes form the lowest part of the delta being the only region, apart from the river, where water remains during the dry season. North of the central lakes the river is blocked by a system of parallel dune ridges running in a west-east direction. North of Lake Debo the Niger continues via the Issa Ber and the Bar Issa passing dune ridges with floodplain in between. The landscape is marked by higher levees and dunes interspersed with broad and flat alluvial plains, low-lying basins and gullies, all of which are inundated during high water levels. In the western part some extensive floodplains occur such as the plains northwest of Youvarou, east of Lac Tanda and southwest of Timbuktu.

East of Koryoumé the delta is gradually tapering into a broad river bed of 10-15 km wide. Here the Niger is broad (up to 1 km) and deep with heavy meandering branches, gullies and (sometimes) isolated lakes. Several lateral (old) river branches occur, draining the alluvial plain, which are silted up with heavy soils. The river bed is accompanied by higher levees and sand dunes. Many villages and more or less temporary settlements occur along this river trajectory (51 villages on the 110 km between Koryoumé at 3°W and Nana at 2°W [2]. Eucalyptus plantations are planted frequently near the villages and on the levees (observations February 2009).

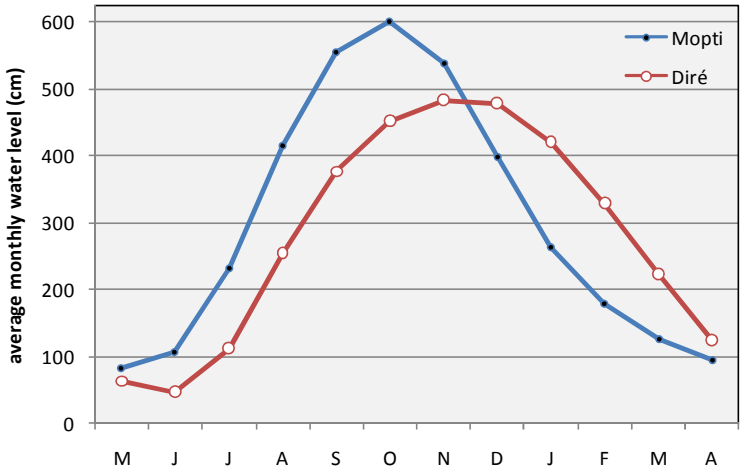
East and west of the Inner Niger Delta peripheral lakes can be found. West of the delta these comprise from south to north: Tanda, Koryoumé, Fati, Télé, Horo and Faguibine, the latter with connected shallow lakes (Takara, Goubèr, Kamango). Except for Tanda and Koryoumé in the south all of these lakes are situated on the west side of rock formations (up to 300-500 m high). The southern lakes Tanda and Koryoumé are flooded annually. Most of the northern lakes do not have an open connection to the floodplain since long and water levels are controlled via sluices, except for Télé and Faguibine. The lakes Horo, Fati and Télé hold water annually, and considering their depth, throughout or during the most part of the year. Horo is fed by the Niger from January till the lake has reached its maximum level (and providing the flood is high enough to feed the lake), mostly in February (on 5 February 2009 water was still running inside at 280 cm on the local scale). The inlet is closed from then on, to exploit the lake for flood recession cultures; these cover nearly the entire lake. Lac Faguibine is fed by a water course running from Lake Télé to the north over a length of 20 km. The lake is only inundated at relative high floods (water level in Diré >261 m) and remained dry for many years since the great drought in the 1970s and 1980s. A recovery of rainfall and flooding after 1994 were responsible for recent inundations in some relatively wet years. Inundation of Faguibine is seen as an important preamble to regain political stability in the region, one of the reasons the Malian government has invested in the removal of sand barriers in the water course between Tele and Faguibine and seeks new ways to ensure the environmental rehabilitation of the lake (UNEP 2008). The lakes on the eastern part of the floodplain (Augoundou, Niangay,Do, Kourarou) are shallow and have mostly been dry since the droughts in the seventies and eighties, apart from the catchment of local rainfall. During the recent high floods these lakes have been flooded again; only lake Kourarou receives water annually.

3.3. WETLAND HABITATS

Wetland habitats in the northern delta and river basin are found in seasonally or permanently flooded zones along the river, in gullies, lakes and in low-lying basins and plains. Habitat types vary with flood duration, maximum flood height and soil type. Four studies describe

[2] On the IGN map of 1959 51 villages are indicated; all these villages were still present in February 2009 with in between regularly small settlements.

the zoning of the vegetation in the inundation zone of the delta: Remaudière (1954), Hiernaux & Diarra (1983), Marie (2002) and Zwarts & Grigoras (2005), but all focus on the central lakes and the southern delta, Little is known about the inundation zone of the northern delta and river basin. Although in general comparable habitat types are found, there may be relevant differences in zoning and species composition since the timing of the flood and differs significantly between Mopti in the south and Timbuktu in the north (Fig 7). Moreover the average annual rainfall in Timbuktu amount to only 200 mm against 500 mm in Mopti. August is the month with the maximal rainfall in the entire Inner Niger Delta, but the rainy season is evidently shorter in the north than in the south. As a consequence, the time between the (first) rainfall and the actual flooding is in the northern Delta 1-2 months longer than in the southern Delta. As discussed by Marie (2002) this has a large impact on the growing conditions of cultivated rice on the floodplain. If there has been sufficient rain to sprout, the rice still needs water. That is why the flood must arrive not later than a fortnight after the last rains. In the northern Delta this is always much later, thus floating rice can only be grown in the southern Delta. What is true for cultivated rice, may also apply to other plant species growing in the inundation zone.



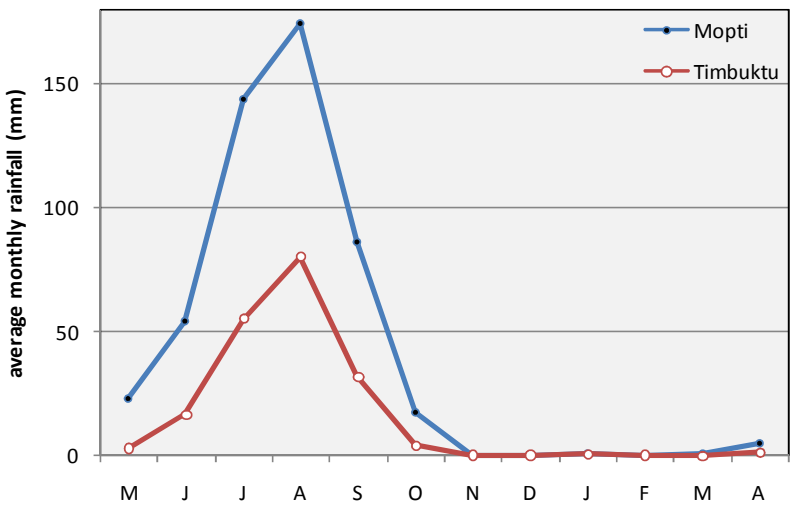


Fig. 7. *Average flood level in Mopti and in Diré to show that there is an average retardation of the inundation of 1-2 months between the southern and northern Inner Niger Delta. Both graphs are based on daily water level measurements at the scale of Mopti and Diré since 1956.*

The lower diagram shows the average monthly rainfall in the southern and northern Inner Niger Delta, based on daily data collected since 1922.

The aquatic and helophytic vegetations in the inundation zone are in general poor and dominated by one or two species. In the deeper parts and the river proper vegetation is absent or consists of aquatic vegetations with amongst others water nymphs (*Najas* sp). and water lilies (*Nymphaea* sp.). Most of the small lakes (mares) are dominated by water lilies, which form an important food source for water birds and local communities. Extensive flooded grass fields are found in the lower parts of the inundation zone, with a flood duration up to seven months. In the central and southern delta these floating meadows (known as *bourgoutière*) consist of *Echinochloa stagina* (*bourgou*) and *Vossia cuspidata* (*didere*), locally also with wild rice *Oryza longastaminata*. *Didere* occupies the zone with a flood duration of up to 5 months. Our field observations in February 2009 show that in the northern delta and the river bed east of Koryoumé also extensive *bourgoutière* are present which more to the north consists largely of *Vossia cuspidate, Echinochloa pyramidalis and E. colona*; *Echinochloa stagina* is les common and found in the deepest parts, often at the edge of these floating fields.

The higher parts of the inundation zone are, in the southern delta, occupied by Vetiveria-fields, dominated by *Vetiveria nigritiana*. North of Niafounke Vetiveria-fields are less common and we did not see them in the river bed east of Koryoumé. Instead, in the northern delta and river basin extensive vegetations of *Aeschymene nilotica* (*poro*) are found in this part of the inundation zone, often bordered by another *Aeschymene species* (locally known as *poro rouge*) on the higher and more sandy parts. Large parts of the lower and higher levees also consist of grassy vegetations, often with *Cynodon dactylon* as dominant species. In the river basin east of Koryoumé many branches occur bordered by sandy levees which are situated upstream with downstream a gradually sloping plain with heavier soils, deposited under the lee of the higher levee. A characteristic zoning consists of *Poro rouge* (often with *Cynodon dactylon* as soil-covering herb) - *Aeschymene nilotica – Echinochloa colona* and/or *Vossia cuspidata – Echinochloa pyramidalis – Echinochloa stagina*. Locally Wild rice is present. It must be stressed, that the delineation between the different zones of *poro*, *didere* and *bourgou* is gradual and may differ between the southern and northern delta, given the marked differences in flood duration and timing of the flooding relative to the rainfall (Fig. 7).

Higher levees as well as parts of the lower plains may be forested, but in general well-developed flood forests are absent in the northern delta and river basin. On lower plains *Acacia seyal*-forests may be found; these are situated within reach of the flood and may be inundated for one or two months at maximum. In a remnant of such a forest, just north of Niafounke, *Vetiveria nigritiana* and *Aeschymene nilotica* were found as undergrowth which confirms that *seyal*-forests may occur in the higher parts of the inundation zone. The higher plains and levees, the latter in the north often as sandy dunes, are occupied by other tree species. In the northern delta *Diospyros mespiliformis*, *Faidherbia albida* and *Balanites aegyptica* are dominant tree species, with *Hyphaene thebaica* on dry sand dunes. More to the north *Balanites aegyptiaca*, *Leptadenia pyrotechnica* and *Acacia tortilis raddiana* predominate, in particular on the drier grounds accompanying the river basin in the north. Extensive and dense indigenous forests are absent in the northern delta, often tree density is low and trees are heavily exploited (in particular species as *Diospyros mespiliformis* and *Acacia seyal*). Instead plantations of *Eucalyptus* sp. and *Prosopis juliflora* are widespread, especially around villages, in the northern delta and in the river basin.

Lake Télé is covered by a dense vegetation of *Echinochloa colona (*locally known as *"bourgou blanc"), Vossia cuspidata* (didéré) and *Echinochloa stagina (bourgou), Polygonum senegalensis* (kouma) and *Ludwigia stolonifera (loubou)*

Productive floodplains (with a high ecological and economic value) may be turned into dense *Typha* fields (with no economical and hardly any ecological value) if the flooding dynamics is reduced to les tha 1 metre.

3.4. WETLAND HABITATS IN PERIPHERAL LAKES

In the framework of this study the peripheral lakes Télé, Horo and Fati were shortly visited, in addition to prior field work in the years before (J. van der Kamp, B. Fofana, M. Diallo), to assess the presence of wetland habitats. Wetland habitats are succinctly mentioned per lake visited.

Lake Télé is situated directly east of Goudam and is fed a water course, connected to the floodplain, which enters the lake on the south side. At the embouchure of this water course a small, delta-like plain is present. In the north the lake changes in a broad valley which runs, paralleled by rock formations, straight to the north to Lake Faguibine. In February 2009 the entire lake held water and also Faguibine was fed through Télé. The delta-plain in the south was covered with an extensive poro-fields with *Aeschymene nilotica* nearly as sole species (also water lilies and Water spinach *Ipomoea aquatica* were scarcely present), standing in about 1 m deep water. The rest of the lake comprised dense *bourgoutière* with *Echinochloa colona*, *Vossia cuspidata* and *Echinochloa stagina*. According to the local guides on the (not visited) east side of the lake open water remained. The situation encountered in February 2009 differed markedly from March 2003 and 2004, when the south part of the lake was dominated by *Polygonum senegalensis* (locally known as kouma) and *Ludwigia stolonifera* (loubou).

Lake Horo is situated northwest of Tonka west of the rock formations of Oro Tondi. The lake is fed via the Oro Guinde, a water course which is connected to the floodplain. At Tonka the water intake is controlled by an inlet (see above). During our visit in February 2009 the lake hold a high water level which still mounted because of the incoming flow at Tonka. Only in the southern part of the lake *bourgou*-like fields could be observed together with patches of *Scirpus* sp. vegetations. The larger part of the lake lacked helophytic vegetations. As in Télé this was in marked contrast with the situation in March 2003 and 2004, when it was estimated that 56 km^2 of Horo was covered by a floating vegetation of *Polygonum senegalense* and *Ludwigia stolonifera*. According to the local guides this vegetation was removed by the local communities.

Lake Fati lies east of Lake Horo in the shadows of the rock formations of Fati Tondi. It is fed via a water course near Tindirmo (free connection to the river). The lake is known to be deeper than Télé and Horo. In February 2009 the larger part of the lake lacked any vegetation but in the middle a extensive band of Cattail *Typha* sp. was present. Cattail is known to be typical for stagnant waters in the Sahelian wetlands; a possible explanation of the presence of Cattail in the lake is that the deeper parts of the lake hold water throughout the years. The other lakes have more dynamic water levels with much (inter)annual variation.

Aeschymene nilotica may be found in the peripheral lakes (Lake Télé, top) but also on the floodplains in the northern Delta and further downstream (bottom).

Water level dynamics and biodiversity in Sahelian floodplains

Zwarts *et al.* (2009) compared several wetlands in the Sahel and showed how the vegetation in these Sahelian wetlands primarily depends on water depth and seasonal fluctuations therein. Another factor is human exploitation, notably grazing. Reed, Cattail and/or Papyrus do not grow in seasonal floodplains, as they are unable to survive the dry period when floodplains turn into semi-arid environments. As soon as floodplains are permanently covered by water, Cattail starts to colonise the shallow waters. This happened on a large scale in the Senegal Delta and locally in the Hadejia-Nguru. The reverse trend could be observed in Lake Chad, where the dense vegetation of Cattail, Reed and Papyrus disappeared when fluctuations in water level increased. These helophytes were replaced by grasses, adapted to extreme flood dynamics and characteristic of Sahelian floodplains (see below). Floating water plants do not dominate the vegetation in the floodplains, apart from Water Lily. Permanent lakes may be covered by Water Cabbage and - since the 1960s - by Water Hyacinth, or by emergent water plants such as Pond Weed. The Senegal Delta is a classic example of how the loss of flood dynamics profoundly changed the ecology of the floodplain, offering Cattail and invasive plants like Kariba Weed a red-carpet welcome.

Seasonal floodplains are mainly covered by grass species that can cope with variable inundation depths and flood durations. *Bourgou* grows where water depth reaches at least several metres in areas which are flooded for more than half of the time. The species is common in the Inner Niger Delta, and was found locally in the Hadejia-Nguru before dams reduced the flooding. *Didere* or Hyppo grass is widespread in African floodplains, where water depth varies between one and three metres. However, in floodplains with less water (e.g. Logone), the species is rare and replaced by wild rice (in about 1 m of water); in even shallower zones, other grasses, such as Rats Tail Grass *Sporobolus pyramidalis* and *S. robustus*, Antelope Grass and Black Vetiver Grass take over. In part of the Logone floodplain the perennial Vetiver Grass was replaced by less productive annual grass species after the Maga dam reduced the already shallow flooding to zero. Highest bird densities in the Inner Niger Delta were found in *bourgou* and *didere* vegetations with about 30 birds/ha, with lower numbers in wild rice (7 birds/ha) and in the Vetiver zone (2 birds/ha; the latter estimate is based on few counts). The few counts in dense Cattail fields in the Senegal Delta indicate that bird density here is close to zero. Extrapolating these densities to aquatic vegetations in other floodplains, separately for the 1960s and 2000s, a decline in overall density of birds in the Senegal Delta and Hadejia-Nguru is apparent, associated with a concomitant loss in flood dynamics, resulting in an increase of Cattail and a decline of *didere* and *bourgou*. Between the 1960s and 2000s, we estimate that the number of wetland-associated birds in the seven Sahelian wetlands has declined by some 40%, given the known habitat changes in the interim period and average bird densities per habitat type. This decline is mainly caused by a reduction in floodplain size (Inner Niger and Senegal Deltas, Sudd) and vegetation dynamics (more Cattail in the Senegal Delta). For instance, the Fomi Dam, planned in the Upper Niger River, will reduce the flood extent of the Inner Niger Delta by 10%, but *bourgou* (associated with deep water), with its high bird numbers, will face a loss of 60% of its area. Can *bourgou* sustain even higher densities, off-setting the loss of habitat, or are densities already at a maximum and will the anticipated loss of *bourgou* fields result in a decline of *bourgou*-associated birds? We believe the latter assumption the most likely. Population trends of several Palearctic bird species are correlated with flood extent, strongly indicating that numbers of some bird species are regulated on the wintering grounds.

4. ECOLOGICAL SIGNIFICANCE

TECSULT (2008) concluded that the Taoussa dam will have only positive ecological impacts since there will be more water in a region which has a lack of water, certainly in the last 30 years. Coyne et Bellier (1996) were also positive, but emphasized that the water management must resemble the natural flooding system as much as possible to minimize the ecological damage. Indeed, the seasonal variation in the water level in the reservoir (Fig. 4) is about the same as in the natural situation. It is clear, however, that large areas just upstream of Taoussa will be permanently flooded and that the flooding dynamics further upstream will be reduced (Fig. 5). The average flood level at Koryoumé is assumed to be raised by 24 cm and in Diré by 10 cm, but in the dry period the water level will not be anymore as low as in the past. How much higher is difficult to say, since information is still lacking to what degree the ground water table will change due to the Taoussa dam. This makes it impossible to do quantitative predictions about the ecological losses and gains upstream of the Taoussa dam, but some general comments can be made.

The Taoussa dam will affect the hydrology in the the river bed between Diré and Taoussa, a distance of about 400 km and a surface area of about 5500 km^2 The digital elevation model (TECSULT 2008) reveals that the affected area may be subdivided into five zones:

Zone	Surface (ha)
Lower inundation zone	74 160
Higher inundation zone	258 840
Non-inundation zone	112 270
High terrace	55 400
Depression of Gourma	66 000
TOTAL	566 670

The inundation zone, measuring some 3300 km^2, will be affected most, of which the majority is found in the river bed downstream of Kouryoumé. This area is not considered anymore as an integrated part of the Inner Niger Delta proper, but from an ecological point of view it does not differ from the seasonal floodplains further upstream.

During our field mission, the same bird species as in the Inner Niger Delta were present and also in about the same densities.

There was, however, some remarkable difference:

1. *Bourgou*, being common in the central and southern Inner Niger Delta, has a restricted distribution in the northern Delta and is relatively rare further downstream, due to the scarcity of deeply inundated areas (> 4 m water).
2. Instead *dideré* is commonly present in all floodplains, since more shallow floodplains are found everywhere in the delta and also along the river bed further downstream.
3. Wild rice covering a large part of the southern delta, is not so dominant in the north.
4. *Poro vert* and *poro rouge* form extensive fields on the floodplains adjacent to the river downstream of Koryoumé. Both species are rather common in the Inner Niger Delta, but are only very locally dominating the entire vegetation.

We know for the central and southern Inner Niger Delta at which densities the different bird species occur in the various vegetation types. We had no time to check whether the densities

were similar in the north, but our counts clearly shows that water and wet bourgoutière and grassland attract the same bird species as in the south and also in comparable densities. To mention some species: Glossy Ibis, Gull-billed Tern, Whiskered Tern, White-winged Black Tern, Purple heron, Intermediate Egret, Great Egret, Cattle Egret, Long-tailed Cormorant, White-faced Whistling Duck and Ruff.

So far, nothing is known about the function of *poro*-fields for waterbirds, reason why we conducted a number of density counts (for methods see van der Kamp *et al.* 2005 and Zwarts *et al.* 2005). In wet poro-fields (water layer between 0-40 cm) we recorded densities of 22.25 Sedge Warbler per ha (n=8, sd = 10.54). Given a rough estimate of 1000 km2 of *poro* between Taoussa and Diré, we arrive at a wintering population of about 2 million Sedge Warblers, more than 10% of the Eurasian population (Zwarts *et al*. 2009). Hence, the ecological impact of the Taoussa dam has clearly a large international component.

There is one question highly relevant regarding the impact of the Taoussa dam: is a spread of Cattail to be expected and if so where. A comparison of seven, large Sahelian wetlands revealed that the flood dynamics had a large, even all overruling, impact on the vegetation (see box for more details). A floodplain has to be dried up to prevent that Cattail colonises open, shallow water and also pushes away *bourgoutière*. This is not different in the northern Inner Niger Delta. In contrast to Lac Horo and Lac Télé, Lac Fati always contains water and is the only lake where Cattail forms dense vegetation in a water column < 1 m. In other, temporary lakes around the northern Inner Delta, Cattail is absent, unless a lake has been filled with water for several years. Cattail is still absent on the floodplains of the Inner Niger Delta and also along Niger River further downstream. We may expect that this will change everywhere the ground water table will be high enough to prevent a drying-out of the ground. Thus, the depression near Gourma may be turned into a large Cattail field, if indeed – as expected – the ground remains covered by water or at least moist. Cattail will not colonize water with a water depth exceeding 1-2 m, but the majority of the reservoir will be shallow, it is to be expected that a large part of the lake will be fringed by extensive Cattail fields.

The experience in the Senegal Delta has shown that this is a very unattractive prospect, also from a ecological point of view. Bird densities counts show that the dense Cattail fields do attract hardly birds.

Hippo’s live in small numbers along the Niger River in the northern Delta and further downstream.

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