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Economic Valuation of Wetland Benefits: The Hadejia-Jama'are Floodplain, Nigeria

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SUMMARY

In northeast Nigeria, an extensive floodplain has been created where the Hadejia and Jama'are rivers converge. The floodplain provides important economic and environmental benefits for both local populations, which may number to around two million inhabitants, and also serves wider regional economic purposes.

For **local populations**, the wetlands provide **essential income and nutrition benefits** in the form of:

* agriculture
* grazing resources
* fuelwood and
* fishing.

Wider **regional economic benefits** include:

* dry-season grazing for semi-nomadic pastoralists
* agricultural surpluses for Kano and Borno states
* groundwater recharge and
* 'insurance' resources in times of drought.

In addition, the wetlands have important toursim, educational and scientific potential as a natural habitat for migratory and native bird species, and for assisting control of bird damage.

However, in recent decades the Hadejia-Jama'are floodplain has come under increasing pressure from drought and upstream water developments that are diverting water from the floodplain. Downstream water developments may also lead to the building of water channels to bypass the wetlands. Unsustainable water uses within the floodplain, notably wheat irrigation, is also putting pressure on the wetlands. These developments are taking place without consideration of their impacts on the floodplain and the numerous benefits it provides.

This paper assesses the economic importance of the Hadejia-Jama'are wetlands, and thus the 'opportunity cost' to Nigeria of its loss, by estimating some of the key economic benefits it provides to local populations:

* crop production
* fuelwood and
* fishing.

The economic analysis indicates that these agricultural, fuelwood and fishing benefits are substantial on both a **per hectare** basis and in terms of the **minimum and maximum amount of floodwater required to sustain them**, even when taking into account the unsustainability of much of the current wheat production in the floodplain. The wetlands can also be expected to yield significant economic returns for some time - provided that the floodplain system is properly managed and sustained.

The present worth of the aggregate stream of agricultural, fishing and fuelwood benefits were estimated to be around

* N850 to N1280 per hectare

* N240-N370 per $10^3 m^3$ of water ('maximum' flood inputs) and

* N375-N565 per $10^3 m^3$ of water ('minimum flood inputs).

When compared to the net economic benefits of an upstream water development project such as the Kano River Project Phase I, the economic returns to the floodplain appear much more favourable. This is particularly the case when the relative returns to the Project in terms of water input use is compared to that of the floodplain system. This result should cause some concern, given that the existing and planned water developments along the Hadejia-Jama'are river system, such as the Kano River Project, are currently and will continue diverting water from the floodplain. The failure to take into account the opportunity cost of this water diversion in terms of the forgone benefits of floodplain production may be leading to serious over-estimation of the net economic returns to these development projects.

Moreover, there are other significant economic benefits provided by the floodplain system than the ones estimated in the analysis. Livestock grazing and groundwater recharge may in particular be extremely important, although recreational, educational and scientific visits and control of bird pests may also prove substantial. The sum total of these additional benefits may actually exceed the estimated returns to floodplain agriculture, fishing and fuelwood.

The economic importance of the floodplain suggests that the benefits it provides cannot be excluded as an opportunity cost of any scheme that diverts water away from the floodplain system. Policymakers should be aware of this problem when designing water development projects in the Hadejia-Jama'are river system. The overall conclusion of the paper is that:

Water developments that divert water from the wetlands should not proceed unless it can be demonstrated that the net benefits gained from these developments exceed the net benefits forgone through wetland loss in the Hadejia-Jama'are floodplain.

Further analysis of all the economic benefits provided by the Hadejia-Jama'are floodplain remains an urgent priority.

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1. Introduction

In northeast Nigeria, an extensive flooplain has been created where the Hadejia and Jama'are rivers combine to form the Komadugu Yobe river which drains into Lake Chad. The Hadejia-Jama'are floodplain wetlands stretch from the towns of Hadejia in the west, Nguru in the north and Gashua in the east. Although referred to as wetlands, much of the floodplain is dry for some or all of the year. In recent years, the maximum extent of flooding has ranged from 70,000 to 90,000 hectares. Since 1987, the floodplain has been the focus of the Hadejia-Nguru Wetlands Project, which is directly concerned with the conservation and sustainable management of the entire floodplain.

The Hadejia-Jama'are floodplain provides essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuelwood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for Kano and Borno states, groundwater recharge of the Chad Formation aquifer and 'insurance' resources in times of drought. In addition, the wetlands are a unique migratory habitat for many wildfowl and wader species from Palaearctic regions, and contain a number of forestry reserves. The region therefore has important tourism, educational and scientific potential.

However, in recent decades the Hadejia-Jama'are wetlands have come under increasing pressure from drought and upstream and downstream water developments. Upstream developments are affecting incoming water, either through dams altering the timing and size of flood flows or through diverting surface or groundwater for irrigation. Increased demand for water downstream for irrigated agriculture may lead to diverting water past the wetlands through construction of bypass channels. Intensified human use within the floodplain itself, notably wheat irrigation, is also putting pressure on the wetlands.

These developments are taking place without consideration of their impacts on the Hadejia-Jama'are floodplain or any subsequent loss of economic benefits that are currently provided by use of the floodplain. Water diverted to upstream and downstream uses clearly has an 'opportunity cost', or alternative use, in the form of the various wetland benefits provided by the floodplain. **Upstream and downstream developments should not proceed unless it can be demonstrated that the net benefits gained from these developments exceed the net benefits forgone through wetland loss in the Hadejia-Jama'are floodplain.**

The following paper attempts to illustrate the economic importance of the Hadejia-Jama'are wetlands by estimating some of the economic benefits provided. The role of the wetlands in the wider regional economic context is first discussed. A valuation exercise is then conducted to quantify the direct use benefits arising from agriculture, fishing and fuelwood in the floodplain area. This is used as the basis for comparing the net benefits of sustainable use of the wetlands to the net benefits of other water uses, including water development projects and intensified use within the floodplain.

2. The Wetlands in a Regional Economic Context

The Environment of the Hadejia-Jama'are Wetlands

The Hadejia-Jama'are wetlands contain a substantial area of dry farmland and savanna woodland set amidst open water, swamp and seasonally-flooded grassland. The dry and wet areas form a spatially complex pattern related closely to the environmental history of the area. Both dry and wet areas are important for their economic activity, although it is the seasonally and permanently flooded areas which give the Hadejia-Jama'are wetlands their distinctiveness and regional economic importance. The area is a complex mix of soil and flooding conditions, with dryland (*tudu*) agriculture on better drained sands, and various forms of wetland (*fadama*) cultivation and seasonal grazing and fishing in and around seasonally flooded areas.

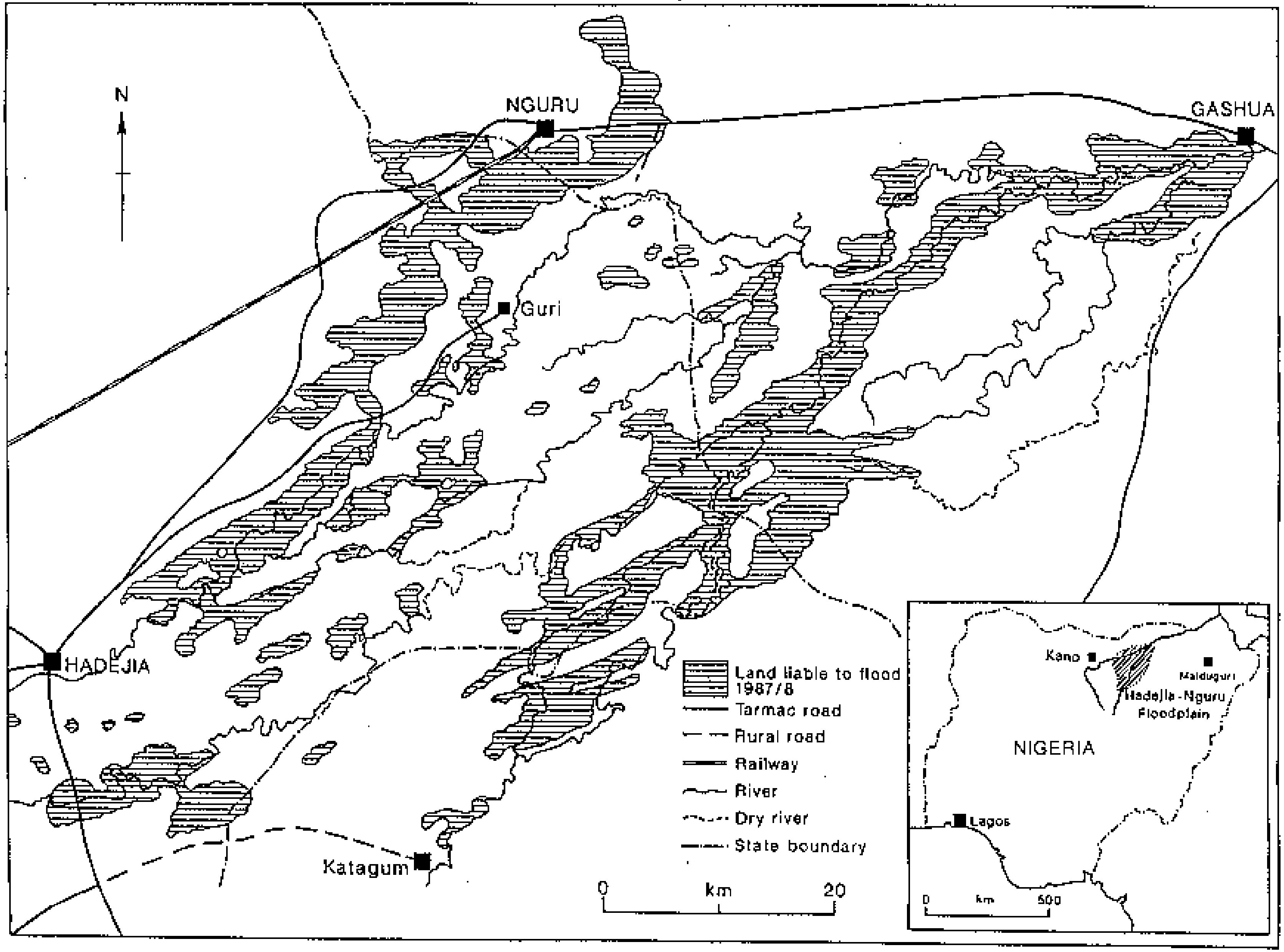
The Hadejia-Jama'are wetlands are formed in an area of confused drainage between Hadejia (Kano State) and Nguru and Gashua (Borno State), where the Hadejia and Jama'are rivers flow through a field of fossil late Quaternary sand dunes (Figure 1). These show themselves as hills sometimes several kilometres long and between 10 and 30 m in height.

The Hadejia and Jama'are rivers rise in Kano and Bauchi States and join to form a combined river, the Komadugu Yobe, which flows on northeastwards to join Lake Chad. Precipitation is 1300 mm per year near Jos in the southwest corner of the basin but under 500 mm in the northeast at Gashua. Rainfall records show considerable variability, with low annual totals between 1972 and 1978 and between 1980 and 1987 (Adams and Hollis 1989; Hollis in press). There is a single short wet season (roughly May to September), and river flow is highly seasonal. Almost 80% of total runoff in the Hadejia and Jama'are occurs in August and September.

The growing season for rainfed crops is therefore short, and the variability of production is high, and closely tied to inter-annual variations of rainfall and periodic drought. The seasonal semi-arid climate and periodic droughts and runs of dry years severely constrain agricultural productivity. For this reason seasonally-flooded valley wetlands are extremely important elements within both the local and regional economy.

Rainfall seasonality means also that river flow is highly seasonal. The timing, extent and duration of flooding in the

Figure 1 The Hadejia Jama'are Flooplain



Hadejia-Jama'are floodplain depends on both the seasonal flood in the rivers and the status of groundwater beneath. These are intimately connected. Where the River Hadejia enters the Hadejia-Jama'are floodplain, it drains an area of some 26,000 km^2. The Yobe at Gashua drains 84,000 km^2 (Adams and Hollis 1989). Both rivers lose flow to groundwater on the sedimentary Chad Formation which underlie the wetlands and much of the Chad Basin.

Drought and the impact on the Hadejia of the Tiga Dam, built to supply irrigation water to the Kano River Project, appear to have reduced flooding in recent decades. At one time the wetlands may have covered an area of approximately 2000 to 3000 km^2. However, the area flooded has been consistently receding. From 1964 to 1971 over 2000 km^2 of flooding occurred, and since 1983 flooding has covered less than 900 km^2 each year. Fewer than 300 km^2 were inundated in the drought year 1984 (Adams and Hollis 1989).

The Nature of Economic Activity in the Wetlands

The economy of the Hadejia-Jama'are wetlands is based primarily on agriculture, fishing, animal husbandry and forestry. Most of these uses are sustained by the floodwater arriving annually in the Hadejia and Jama'are rivers.

Agriculture in the Hadejia-Jama'are floodplain involves dryland farming on upland **tudu** land, and use of the low-lying and seasonally flooded **fadama** land for rice farming, flood-retreat farming and irrigated cropping. The use to which land is put can vary between years depending on the extent and duration of flooding. Low flooding, for example, can mean that rainfed crops are grown on land previously growing fadama crops. Upland farming on tudu land is rainfed, and is based on millet and guinea corn (sorghum), both of which are adapted to drought. Other crops such as cotton or groundnuts are also planted in a relay or intercropping system. The production of these crops relies on the timing and quality of the wet season, and is closely integrated with fadama cultivation. Most households exploit both environments, and require both for their subsistence.

Rice is the most important crop grown on seasonally flooded land, the methods of cultivation being broadly similar to those used elsewhere in West Africa, such as the Niger Inland Delta in Mali. The timing of the arrival of the flood is critical to the success of rice cultivation. Too early a flood prevents the rice from germinating (following rainfall) before it is drowned. Too late a flood creates a danger of crop loss through desiccation. Flood-recession crops such as cowpeas are grown as the waters retreat from black cotton clay soils, and again the timing and predictability of flood-recession is vital. Irrigation takes place in the dry season from residual surface water in channels and sometimes pools. Traditionally this was done with **shadoof** traditional pumps, but since 1980, small petrol pumps have become common. In some cases these lift water from shallow groundwater aquifers using tubewells.

Fishing in the wetlands takes place at various times of year and with different kinds of gear appropriate to different environments. The recruitment of young fish to the population, and hence the sustainability of the fish catch,is linked to the timing and extent of the annual flood. Poor floods cause poor fish recruitment. Many fish undergo a lateral migration from channels into the floodplain to breed. The most important single fishing period is the 'run' of fish as this migration takes place, although fishing in the drying pools at the end of the dry season is also important.

The Hadejia-Jama'are wetlands are an important dry season grazing resource for the semi-nomadic Fulani pastoralists. Sheep, goats, cattle and a few camels are grazed. Pastoralists move into the area as the dry season develops and grazing elsewhere becomes short. The flooded grasslands (particularly *Echinochloa stagnina*) are especially important. The timing of flood retreat and the topography of the floodplain basins does much to determine whether these areas are grazed or cultivated. *Echinochloa* is also harvested and exported from the wetland as fodder. The Hadejia-Jama'are wetlands are of considerable economic significance as a major source of food and fuelwood.

Production in the Hadejia-Jama'are floodplain supports a substantial population at relatively high levels of nutrition and income. The economic importance of the area has in the past been little recognised because the floodplain has until recently been relatively remote and little studied, while efforts for development have been focused on major projects elsewhere, such as the large-scale irrigation schemes. In fact, the volume and value of food and other agricultural commodities produced in the floodplain is significant in comparison with the output of such development projects, and in particular the area irrigated in the floodplain is large compared to that developed in formal schemes elsewhere. The amount of government investment in the floodplain required to achieve this economic output is remarkably small.

Regional Economic Importance of the Wetlands

The economic significance of the wetlands extends much further than the immediate floodplain area. In most years an agricultural surplus is produced, primarily in rice and vegetables, which is traded in Kano and Borno States, and as far as the cities of southern Nigeria. Fulani pastoralists migrate into the wetlands in September as the floods recede, particularly from Kano, Borno and Bauchi States. The floodplain therefore has a considerable importance in supporting pastoralism over a large area of dry savanna across the whole region. In drought years the dependence of both farmers and pastoralists on access to the seasonally flooded areas increases, with immigrants to the floodplain rising to as much as 5% of the population (Adams and Hollis 1989).

In addition, the floodplain wetlands are vital in the recharge of groundwater across large areas of Kano and Borno States through replenishment of the aquifers of the Chad Formation. However, groundwater recharge has also been affected in recent decades by drought and upstream water developments. Groundwater storage beneath the floodplain was largely stable during 1964-1971 and 1975-1982, but fell by an estimated aggregate of 5,000 10^9 m^3 as a result of drought and reduced flooding in the 1980s (Adams and Hollis 1989).

The flooded area also has important wildlife conservation benefits. Tens of thousands of waterfowl use the wetlands in the dry season, including internationally significant numbers of wintering Palaearctic species. These populations prompted IUCN to identify the area as a conservation priority, and provided the initial rationale for the establishment of the Hadejia-Nguru Wetlands Conservation Project (Stowe and Coulthard 1990).

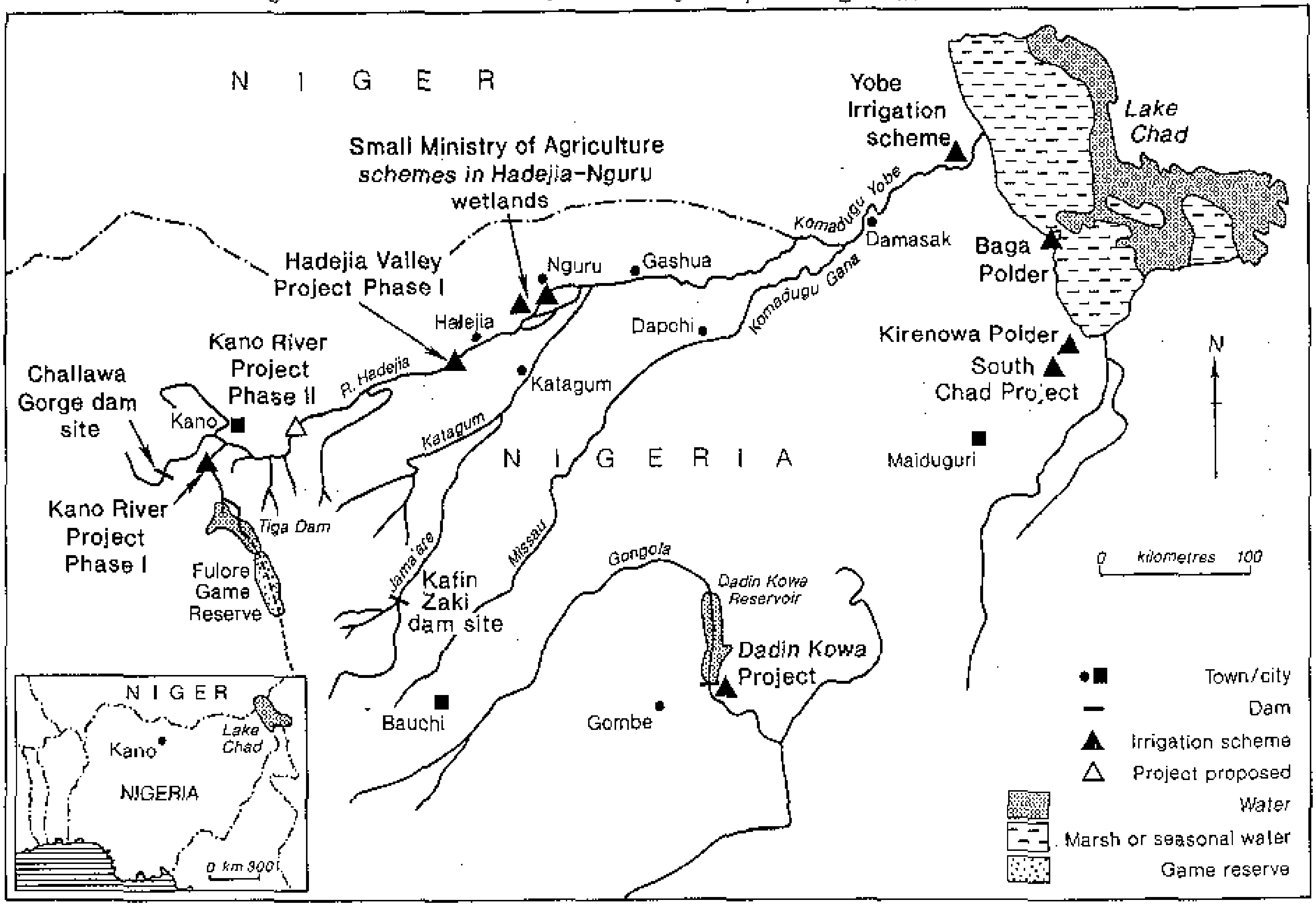
The Impact of Upstream Development on the Wetlands

The amount of water reaching the upstream end of the Hadejia-Jama'are wetlands is determined by natural influences on river flow (particularly rainfall, and the problem of drought) and human influences in the form of upstream development projects. Northern Nigeria has suffered from sets of years of low rainfall in the 1970s and 1980s in much the same way as the Sahelian countries further North. Indeed, the Hadejia-Jama'are wetlands are just on the southern boundary of the Sahel Zone. The impacts of these dry years has, however, been compounded by the effects of upstream dams and water abstraction for irrigation (Adams and Hollis 1989).

Tiga Dam is already built on the Kano River, and supplies the large-scale irrigation scheme, the Kano River Project (Figure 2). The dam delays the wet season flood-peak because the reservoir has to fill up before water is spilled, and there is also a considerable amount of evaporation from the reservoir surface. Water diverted into the irrigation scheme is also lost (via transpiration by crop plants) and thus does not reach the Hadejia-Jama'are floodplain.

When a second dam, at Challawa Gorge, on another tributary of the Hadejia (Figure 2), is finished, its effects will be similar. The two dams together will not only substantially regulate the Hadejia flows, but will also be used to release water specifically for another irrigation scheme, the Hadejia Valley Project, close to the wetlands. The plan is for wet season flows to be stored and released at a steady rate down the river through the year, using the channel as a giant supply canal, and to store small amounts behind a barrage at Hadejia. Here it will be used to irrigate crops by gravity. The steady all-year flow and the barrage across the floodplain at Hadejia will substantially reduce the flood peak in the river and hence the extent and duration of flooding downstream. The dams will also increase infiltration to groundwater and evaporation, and thus reduce the

Figure 2. Water Development Projects, N. Nigeria.



amount of water reaching the wetlands. A further dam has been planned for some years on the Jama'are River (Kafin Zaki). If built, it will have similar impacts on flows reaching the wetlands.

Thus there is a clear choice to be made between using the water in the Hadejia and Jama'are rivers for irrigation and water supply in and around Kano and Hadejia (upstream of the wetlands), and allowing it to enter the wetlands to support agriculture fishing and other economic activities there. Moreover, although some water flowing into the floodplain is lost through evaporation and transpiration, much of the 'loss' in river flow is due to infiltration and hence recharge of the Chad Formation aquifer. This helps to maintain groundwater at levels which can be reached by simple bucket wells in villages and watering points many miles from the river channel. As noted above, however, both drought and upstream water development have caused the depth of groundwater in the Chad Formation to fall through the 1980s.

Impacts of Wetland Use on Downstream Development

Water in the Hadejia-Jama'are (Yobe) rivers is also used downstream of the wetlands in Borno State, by rice farmers and irrigators between Gashua and Geidam, and to a lesser extent by irrigators further downstream towards Lake Chad (Figure 2). Reduced river flows, due to drought and the Tiga Dam have had a serious effect on these farmers. A fierce debate has emerged between Borno and Kano States about the sharing of the river water. Popular opinion in Borno concludes that Kano State has appropriated water which ought to flow to Borno. There have been high-level negotiations between the two states, hampered by the lack of data on surface flows and their relations with groundwater within the basin. Such debates must involve at least two river Basin authorities (Chad Basin and Hadejia-Jama'are), two State Water Boards, and State and Federal Ministries of Agriculture. There is an added complication that for parts of its length, the Komadugu Yobe forms the Nigeria-Niger border, and the government of the Republic of Niger has been drawn into the debate about the use of water in the basin.

Water used upstream of the wetlands will not be available for use either within the wetlands themselves or further downstream. This means that the interests of users of the wetlands are to an extent aligned with those further downstream in recognising the threat of further upstream development. However, this common interest is not complete, because water use in the wetlands also reduces the amount available to downstream users. Floodwater spreads out in the complex channel system of the wetlands, and there is a considerable amount of flow to groundwater, and also evaporation. Furthermore, use of water in the wetlands is increasing as irrigation spreads. Since 1980 The Kano State Agricultural Development Authority (KNARDA) have promoted small pump irrigation, and what is called 'fadama rehabilitation', or flood control through the construction of sluices in natural floodplain basins, for better rice production. There has been a dramatic expansion of wheat irrigation using pumps since 1987 (Kimmage 1991).

To an extent, therefore, the economic activity of the Hadejia-Jama'are wetlands is a threat to would-be users of water downstream, just as the large-scale irrigation in Kano State is a threat to users within the wetlands. Moreover, the wetlands are remote from both State capitals, and the importance of the economic activities within them (and their absolute dependence on floodwater) may not have been fully appreciated in the past.

A technical 'solution' to the problem of finding enough water for Kano and Borno has been suggested which would be very damaging to the farming, fishing and other activities of the wetlands. This is a proposal to build a canal to carry water past the wetlands between Hadejia and Gashua to increase flows to the lower Yobe and (theoretically) Lake Chad (see Adams and Hollis 1989 for details). An FAO team were in the field in 1990 investigating the feasibility of this plan. It would have a direct impact on agriculture, fishing and grazing in the wetlands, bringing about a substantial reduction. It would also have more complex effects, particularly on groundwater flows. The evidence suggests that most aquifer recharge takes places when the rivers overflow their banks, i.e. when the wetlands are flooded. Reducing that flooding would reduced aquifer recharge and hence would contribute to lowering of aquifers over quite a wide area of the Chad Formation. There would be serious economic and welfare implications associated with the need for deeper wells in the drylands to the North of the river.

Links and Trade-Offs

The choices to be made in the use of the water in the Hadejia and Jama'are rivers are extremely complex and difficult. There are difficult trade-offs to be made between uses upstream, in the wetlands or downstream. To a large extent, these uses are competitive for the limited amount of water available. Both users within the wetlands and those further downstream are threatened by consumptive use in Kano State. Irrigation at the top of the river basin threatens all downstream users. This is particularly serious since irrigation and hence water demand is expanding in both the wetlands and the downstream floodplain.

In the absence of a clear development plan for the basin, and lacking the data necessary to calibrate a full hydrological model, it is difficult to reach an entirely satisfactory solution. Nonetheless, it is clear that a great deal more needs to be known about the economics of each of the competing uses of water, and that information has to be placed within a clear decision- and policy-making structure. Otherwise the use of water will not only be economically inefficient, but also many people will suffer needlessly because of its maldistribution.

3. Economic Appraisal Methodology

Given the competing uses for water, any upstream or downstream development that diverts water intended for the Hadejia-Jama'are floodplain carries an additional cost. This cost is the loss in wetland benefits arising from any detrimental impacts on the floodplain. Thus, the net benefits of a development project cannot be appraised in terms of its direct benefits and costs alone. The forgone net benefits of disruption to the Hadejia-Jama'are wetlands must also be included as part of the costs of diverting water away from the floodplain to development projects.

For example, assume that there is an upstream irrigation project on the Hadejia River that is providing water for agriculture. Given **direct benefits** (e.g. irrigation water for farming), BD, and **direct costs** (e.g., costs of constructing the dam, irrigation channels, etc.), C^D, then the **direct net benefits** of the project are:

$$NB^D = B^D - C^D.^{1} \qquad (1)$$

However, by diverting water that would otherwise flow into the downstream wetlands, the development project may result in losses to floodplain agriculture and other primary production activities, less groundwater recharge and other external impacts. Given these reductions in the **net production and environmental benefits**, NB^W, of the Hadejia-Jama'are wetlands, then the true net benefits of the development project (NB^P) are $NB^D - NB^W$. The development project can therefore only be acceptable if:

$$NB^P = NB^D - NB^W > 0. \qquad (2)$$

If the wetland benefits are significant - as they appear to be in the case of the Hadejia-Jama'are floodplain - then the failure to assess the loss of wetland benefits will clearly lead to an over-estimation of NB^P. This is tantamount to assuming that there is no opportunity cost of diverting floodwater from the wetlands.

Evidence from other countries suggests that in the case of large-scale water development projects this assumption may be misleading. For example, an *ex-post* analysis of the large-scale Ghezala irrigation project in Tunisia took into account disruptive hydrological and other environmental impacts on the neighbouring Ichkeul National Park and surrounding areas. The analysis revealed that these costs contribute to making the project economically unviable (Thomas, Ayache and Hollis 1990). The floodplain of the Park provides important fishing and grazing uses for local communities, as well as tourism/educational benefits and essential environmental functions (de-salinization

[1] In what follows, it is assumed that all costs and benefits are discounted at some positive rate into present value terms.

of the water table, sewage treatment, control of birds). These benefits are being threatened by Ghezala and other upstream irrigation schemes. However, the net benefits of fishing and grazing **alone** easily exceed the returns to irrigation.[2] From rule (2) above, it follows that diverting water to feed the Ghezala scheme is not beneficial.

A similar assessment of the benefits of the Hadejia-Jama'are floodplain is required in order to determine the relative benefits of using water for upstream or downstream developments compared to its use when released into the floodplain. The basic methodology for assessing and valuing the economic benefits of tropical wetlands is described by Barbier (1989a and 1989b) and shown in Figure 3.

It is useful to distinguish between **direct use** values, **indirect use** values and **non-use** values. Direct use of the wetlands would include, for example, grazing of floodplain pastures, fuelwood collection, floodplain agriculture and fishing. Recreation and tourism activities, such as bird-watching, would also involve direct use of the wetlands, as would navigation along water courses. However, various ecological functions of the wetlands may have indirect use values. Their values derive from supporting or protecting economic activities that have directly measurable values. As noted above, the groundwater recharge by the floodplain replenishes the Chad Formation aquifer supplying village well-water. Existence and bequest values are examples of values completely unrelated to use. Both are closely bound up with the **uniqueness** of natural environments. For example, some people might derive satisfaction just from knowing that a unique waterfowl habitat such as the Hadejia-Jama'are wetlands exists and will be preserved. Similarly, some individuals may have no intention of using the floodplain, but value the fact that the wetlands will be preserved for future generations to enjoy. Finally, individuals may also express a preference for preserving the wetlands today as insurance against the risk of losing any benefits which might prove valuable in the future. This **option value** is an extra 'premium' on the value of the wetlands, beyond its current use and non-use values, and will most likely be significant if individuals are averse to taking risks, if the future value of wetland benefits are expected to be high even if currently unknown, and if wetland loss is irreversible.[3]

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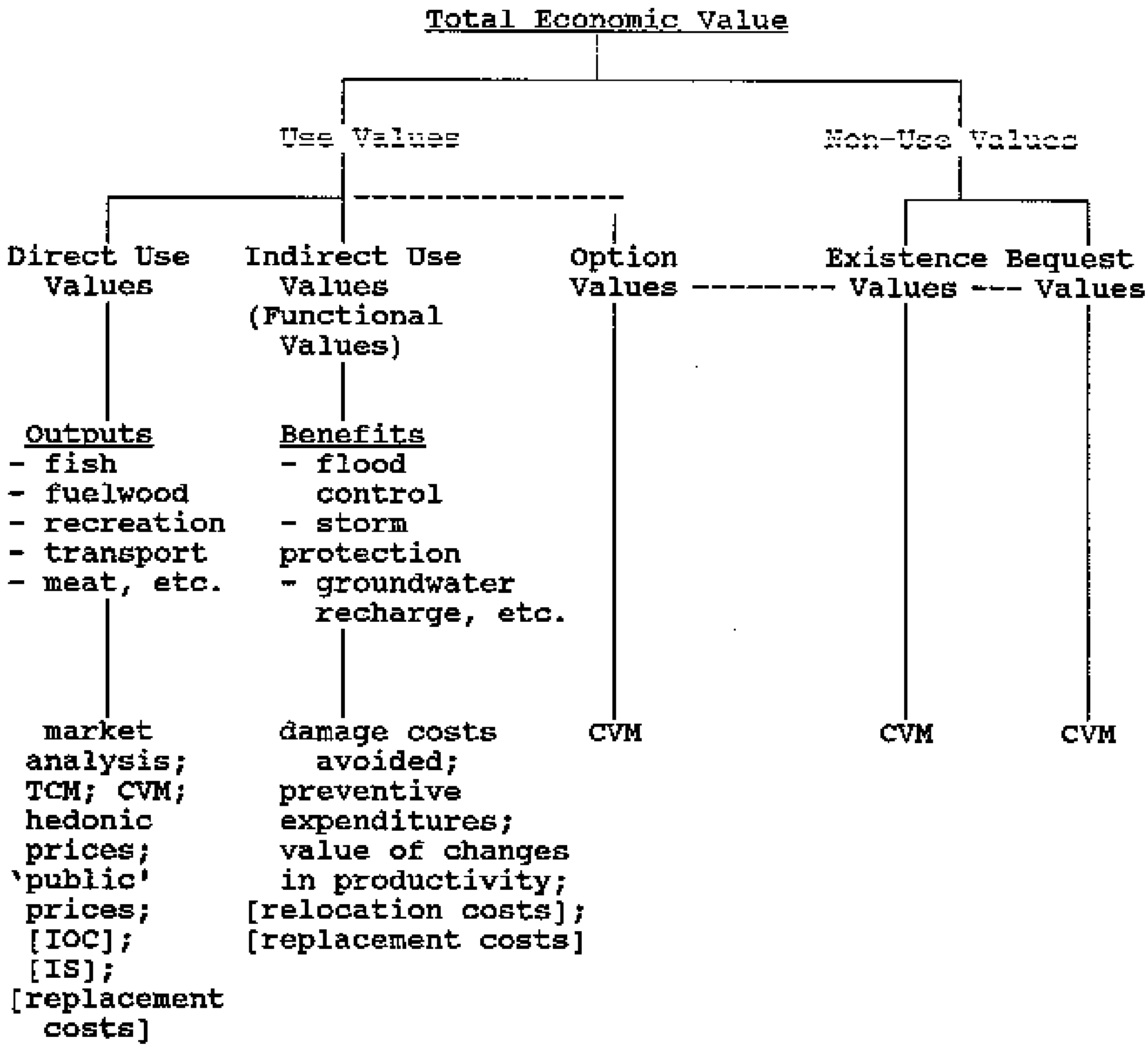
[2] Depending on the annual water requirement of the Park's floodplain, the net benefits from fishing and grazing vary between US$0.05 and 0.33 per cubic metre (m^3) of water. The *ex post* analysis showed that the net benefits to irrigation in Ghezala were actually negative, - US$0.6 per m^3, given the high costs incurred by the scheme.

[3] Although the bequest, existence and option values associated with the Hadejia-Jama'are wetlands are of importance in assessing the overall economic value of the wetlands, they are

Figure 3. Valuing Wetland Benefits



Notes:
CVM = contingent valuation method
TCM = travel cost method
IOC = indirect opportunity cost approach
IS = indirect substitute approach
[ ] = valuation methodology to be used with care

Source: E. Barbier, The Economic Value of Ecosystems: 1. - Tropical Wetlands, LEEC Gatekeeper 89-02, London Environmental Economics Centre, London, 1989.

Figure 3 indicates the various techniques appropriate to measuring each type of wetland benefit. Valuing the benefits derived from tropical wetland resources - as above in the case of fishing and grazing in Ichkeul Park, Tunisia - is relatively straightforward, usually involving the value of the production gained from directly exploiting these resources. For example, one study for the Hadejia-Jama'are floodplain indicates that the total value of the annual production was Naira (N) 250-280 million for agriculture, N45 million for fishing and N14 million for fuelwood (Kimmage and Adams 1990).[4] However, measuring the indirect benefits of wetland environmental functions, such as groundwater recharge, or of any option, existence or bequest values, is more problematic. More sophisticated techniques of contingent valuation, travel cost method and hedonic pricing are now increasingly being used to value temperate wetlands in Europe and North America, but have yet to be applied to tropical wetlands.[5]

Because the ultimate aim of all economic activity is to satisfy individuals' needs and wants, the objective of valuing the direct use, indirect use and non-use benefits is to measure society's **willingness to pay** (WTP) for these various benefits. In a competitive economy with no constraints on the movement of prices, one can assume that market prices reflect the WTP for goods and services. However, two complications arise in conjunction with wetland uses in developing countries.

First, in many developing countries, market prices may be distorted by deliberate interventions or imperfect competition such as the existence of exchange rate controls, price ceilings or supports, subsidies or taxes, monopoly conditions and so forth. Also, the significant size of the informal/non-market sector may reduce the reliability of market prices as measures of value. In such instances, the use of **shadow prices** is often advocated. These are actual prices 'adjusted' to eliminate any distortions caused by policies or market imperfections so as to reflect true WTP. As we are ultimately concerned with the opportunity cost to society of allowing water to continue flowing into the floodplain compared to its diversion for other development uses, then actual prices should be adjusted to

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only significant in calculating the forgone values from wetland destruction if they can be 'captured' by Nigeria (e.g., through international payments to help Nigerians 'preserve' the wetlands) or if these values are held by Nigerians themselves.

[4] The original figure of N2 million for fuelwood in the paper has now been corrected by the authors.

[5] For a review of these valuation techniques and their applications to temperate wetlands see Farber and Costanza (1987) and Pearce and Turner (1990, ch. 21). For the application of contingent valuation in a developing country context, see Briscoe et al. (1990).

reflect economic values. However, there are limits to the indiscriminate use of shadow prices in place of market prices, which in certain cases may introduce larger discrepancies than the simple use of even imperfect, market prices.[6]

Second, many wetland values are not directly reflected in market prices at all. This is true for all the environmental functions, for resources harvested for own use by households, for most recreation and water transport services, and for all non-use values. In some cases, techniques such as travel cost methods, contingent valuation and hedonic pricing might be employed to estimate WTP directly. As noted above, however, these techniques are not easily applicable in remote and rural settings in developing countries. The alternative is second-best, and sometimes third-best, approaches to valuation, such as indirect substitute, indirect opportunity cost, relocation costs and damage costs avoided methods, which do not relate uniquely to WTP but may yield 'proxy' economic values.

A further consideration is whether current uses of a wetland are necessarily sustainable. Direct uses of a wetland area, harvest of fuelwood and timber, including farming, fishing, grazing and may over the long run lead to significant environmental degradation. Where it is apparent that current levels of exploitation undermine the sustainability of wetland resources and environmental functions, this must be taken into account in the analysis. As will be discussed below, in the Hadejia-Jama'are floodplain, concern is being raised over the sustainability of current levels of wheat production which has rapidly expanded throughout the area in recent years (Kimmage 1989 and 1990). If current levels of wheat production for example, are assumed to be sustained well into the future whereas in fact production may dramatically collapse in a few years, then the analysis may be grossly overstating wetland benefits in terms of wheat production.

One approach to this problem would be to include an **alternative sustainability scenario** in the evaluation as part of a sensitivity analysis Barbier (1989a). For example, supposing that the sustainable yield of fuelwood from a wetland area is around 5 m^3/ha, which means that this amount of wood could be extracted over a long time horizon, say over 30 years, without disrupting any wetland ecological functions or endangering fuelwood supplies. But assume that current use is actually 10 m^3/ha, which current indications suggest may cause significant fuelwood depletion and environmental degradation from year 15 onwards. A sensitivity analysis could reflect this scenario by showing high current benefits from fuelwood extraction but at the expense of declining, and perhaps even zero, benefits from environmental functions over the long run.

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[6] On this point, see the discussion in Gregersen et al. (1987, ch. 6).

A second approach would be to incorporate into the analysis the concept of an **environmentally compensating project.** As suggested by Barbier, Markandya and Pearce (1990), the methodology is to assume that within the project 'portfolio' there should be included at least one project that 'compensates' for the environmental degradation generated by other projects in the portfolio. This implies that the benefit of preserving sustainable use is **at least equal** to the cost of the compensating project. In the case of over-harvesting of fuelwood in a wetland area, the analysis would first have to calculate the costs of the environmental degradation caused by unsustainable fuelwood use. This amount would then provide the 'upper bound' for the costs of including an additional project, such as a reforestation scheme, that would offset the environmental impacts of excessive fuelwood extraction.

4. Economic Valuation of the Hadejia-Jama'are Floodplain

Data limitations currently prevent a comprehensive analysis of the relative benefits of allocating water to upstream and downstream developments compared to allowing it to continue flowing into the Hadejia-Jama'are floodplain. However, as indicated by rules (1) and (2) above, calculating the net benefits provided by the wetlands supplemented by other field surveys, NB_W, is the crucial component often missing from appraisal of development projects. To the extent that development projects threaten the floodplain, then the net economic benefits of the wetlands indicate the opportunity costs of diverting water to the development projects.

In this section, an assessment of the benefits provided by the Hadejia-Jama'are wetlands is attempted. Constraints on data limit coverage of wetland benefits to **direct use of key resources only** - agriculture, fishing and fuelwood. The main source of data for calculating these direct use benefits is from Kimmage and Adams (1990), supplemented by field surveys undertaken by the two authors. Where appropriate, actual prices are adjusted to economic values using shadow prices.[7] Views on the sustainability of resource use, especially for wheat production, are also discussed, and the implications incorporated through

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[7] Throughout the analysis, the term **financial** will be used to distinguish the values of commodities based on actual or market prices and the term **economic** to distinguish the values of commodities based on adjusted or shadow prices. Following standard practice, all commodities will first be expressed in financial values before being converted to economic values, regardless of whether or not the commodities are actually exchanged in markets or not. In fact, as the majority of agricultural, fishing and fuelwood production is for subsistence, the calculated 'financial' prices and costs of production should not be interpreted as what most individuals engaged in producing these commodities actually receive or pay.

sensitivity analysis. To facilitate comparison with competing uses of water, values are expressed not only in per hectare terms, but also in terms of volume of river flow and seasonal water releases from upstream projects. Finally, other wetland benefits, such as important environmental functions, are briefly reviewed, and possible methods for valuing them indicated.

Estimating Net Benefits - Agriculture, Fishing and Fuelwood

Total cultivated area in the Hadejia-Jama'are floodplain is estimated at about 230,000 ha, of which approximately 77,500 ha occurs in the dry season and 152,500 ha in the wet season. Of the latter, 112,000 ha is upland, mainly rainfed cultivation (*tudu*) and 40,500 ha is floodplain proper (*fadama*). However, these distinctions are somewhat artificial. An increase in the extent of flooding and in water depth can easily transform *tudu* land into *fadama*. Moreover, as farmers in the floodplain typically own both types of land, cultivation is inextricably linked. Any threat to the floodplain, therefore, would change *tudu* cultivation as well.

Table 1 indicates the current annual net benefits from fourteen agricultural crops grown in the Hadejia-Jama'are floodplain. The crops are distinguished as **tradeables** and **non-tradeables.**[8] Financial prices for all crops were estimated from surveys of prices and seasonal price changes in Nguru market in 1989 and 1990. These prices were converted to economic prices, using c.i.f. import prices at the official 1989 exchange rate, Naira (N) 7.5 = US$1, for the three tradeable crops (rice, wheat and soyabeans) and using the standard conversion factor of 0.85 for Nigeria for the non-tradeable crops.[9]

Calculation of the average annual output of each crop is based on low and high estimates of production from field surveys of farm households in the floodplain. Combining the price and output data results in annual gross economic benefits of N1578 per ha for agriculture in the floodplain. Using estimates by Anderson (1987) indicating that net economic benefits from agriculture in Kano State are generally 15% of gross benefits,

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[8] Following the conventional definition, a non-tradeable crop has a domestic supply price, at the given level of local demand, that exceeds the f.o.b. price of exports but falls below the c.i.f. price of imports (Squire and van der Tak 1975). Thus sorghum, maize and groundnuts were all classified as non-tradeables as their local market prices were considerably lower than the c.i.fi prices of imports. This is not surprising given that mainly traditional varieties of these crops are grown in the region, mainly for local consumption.

[9] The standard conversion factor of 0.85 is the rate recommended by the World Bank for adjusting the economic values of non-traded commodities in Nigeria. We are indebted to Robert Warner of the World Bank for this information.

Table 1. Agriculture - Net Benefits, Hadejia-Jama'are Floodplain, N. Nigeria, 1989/90
(N7.5 = US$1)

CROP	Average Output (t)	Financial Price (N/t)	Economic Price (N/t)	Financial Benefits (N '000)	Economic Benefits (N '000)	Net Economic Benefits (N '000) 4/
Tradeable 1/						
Rice	22335	4770.00	3144.90	106538	70241	10536
Wheat	43350	4010.00	1382.88	173834	59948	8992
Soyabeans	6000	3310.00	2137.50	19860	12825	1924
Non-Tradeable 2/						
Sorghum	50315	720.00	612.00	36227	30793	4619
Maize	15705	842.00	715.70	13224	11240	1686
Groundnuts	3855	4980.00	4233.00	19198	16318	2448
Millet	50415	842.00	715.70	42449	36082	5412
Cow-Peas	25035	3310.00	2813.50	82866	70436	10565
Tomatoes	15955	662.50	563.13	10570	8985	1348
Onions	11925	662.50	563.13	7900	6715	1007
Peppers	32400	1336.00	1135.60	43286	36793	5519
Sweet Potatoes	2925	600.00	510.00	1755	1492	224
Aubergine	1740	662.50	563.13	1153	980	147
Pumpkins (no.)	1414500	3.00	2.55	4244	3607	541
TOTAL 3/	281955			563103	366455	54968

TOTAL AGRICULTURE HA: 230000

NET ECONOMIC BENEFITS/HA (N/ha): 239 4/

Notes: 1/ The economic prices of all tradeables are the c.i.f. import (border) prices converted at the official 1989 exchange rate of N7.5 = US$1.

2/ Non-tradeables are defined as crops whose prices exceed f.o.b. export prices but are less than c.i.f. import prices. The economic prices of all non-tradeables are the financial prices adjusted by the standard conversion factor of 0.85.

3/ The total for average crop output excludes pumpkins.

4/ Anderson (1987) found the net economic benefits of crops in Kano State to be 15% of gross economic benefits.

Source: Calculations based on Kimmage and Adams (1990) and field surveys undertaken by these authors; World Bank economic data; World Bank (1989); IMF (1990) and Anderson (1987).

the net economic benefits of agriculture in the Hadejia-Jama'are floodplain are N239 per ha per annum.

However, these net benefits may be an underestimate as they are for only fourteen crops grown in the floodplain. Six other crops - okra, yakuwa, cucumber, cotton, guava and mango - are also cultivated widely within the region, but no specific price or production data are available for these crops. Okra and yakuwa are grown by most households but usually in small amounts around field boundaries. Guava and mangoes are grown by perhaps 10 to 15% of households. Anderson (1987) has demonstrated that fruit trees such as mangoes yield significant fruit, fuelwood and shelterbelt benefits in Kano state.

Fishing takes place in approximately 100,000 ha of flooded land, with around 73,150 rural households in the floodplain participating in this activity throughout the year. Only 12% of these households include 'full-time' fishermen. The rest comprise dry season fishing households (21%), wet season fishing households (15%) and households that only fish at fishing festivals (52%). Moreover, of the 8750 'full-time' fishing households, only 980 may be sufficiently close to permanent water bodies to allow them to fish on an actual full-time basis.

Table 2 indicates the net annual benefits per ha from fishing in the Hadejia-Jama'are wetlands based on data from six seasonal periods over the dry and rainy seasons. The pattern of fish catches varies throughout the year, as the seasonal variations in fishing intensity relate to differential access to *fadama* fishing sites and to the flooding period. In general, the highest catches are recorded during the 'fish-run' period of the falling flood; i.e., at the end of the wet season and the beginning of the dry season when fish begin retreating from the *fadama*.

Estimates of fish prices were based on price data from Nguru market for the four most important species of fish caught, *kawara*, *karfasa*, *tarwada* and *musco*, for the period between the mid-dry season 1989 and the mid-dry season 1990. Economic prices for each season were calculated by employing the standard conversion factor (0.85). Survey data provided information on fishing intensity by season (i.e. total fishing days per household per season), which when multiplied by the total number of fishing households, yields the total fishing days per season. Financial costs were calculated based on a rural cost of agricultural day labour of N7.79 per day, which were converted to economic costs by employing the standard conversion factor. The resulting estimate of annual net economic benefits from fishing in the Hadejia-Jama'are floodplain comes to N179 per ha.

Net benefits from fuelwood production in the Hadejia-Jama'are floodplain are calculated by distinguishing rural subsistence use from urban consumption (Table 3). With an estimated 86,000 rural households in the region and an average monthly fuelwood consumption per household of 50 kg, total rural fuelwood use is around 51,600 tonnes annually. Fuelwood collected from the

Table 2. Fishing - Net Benefits, Hadejia-Jama'are Floodplain, N. Nigeria, 1989/90
(N7.5 = US$1)

FISHING SEASON	Total Catch (t)	Financial Price (N/kg)	Economic Price (N/kg)	Total Financial Benefits (N '000)	Total Economic Benefits (N '000)	Total Fishing Days (Days)	Total Financial Costs (N '000)	Total Economic Costs (N '000)	Net Economic Benefits (N '000)
DSB	1728	7.48	6.35	12918	10980	768075	5983	5086	5894
DSM	931	9.75	8.29	9079	7717	621044	4838	4112	3605
DSE	313	5.35	4.55	1674	1423	313082	2439	2073	-650
WSB	562	7.25	6.16	4077	3466	375260	2923	2485	981
WSM	717	6.35	5.40	4555	3872	478401	3727	3168	704
WSE	2012	6.50	5.53	13077	11116	569839	4439	3773	7342
TOTAL	6264			45381	38574	3125700	24349	20697	17877
AVG		7.11	6.05						

TOTAL FISHING HA: 100000

NET ECONOMIC BENEFITS/HA (N/ha): 179

Notes:
DSB = Dry season beginning
DSM = Dry season middle
DSE = Dry season end
WSB = Wet season beginning
WSM = Wet season middle
WSE = Wet season end

Economic values are financial values adjusted by a standard conversion factor of 0.85.

Financial costs based on a rural cost of agricultural day laborer of N7.79 per day. Total fishing days calculated on the average number of fishing days per household per season (73,150 fishing households total).

Source: Calculations based on Kimmage and Adams (1990) and field surveys undertaken by these authors; and World Bank data.

Table 3. Fuelwood - Net Benefits, Hadejia-Jama'are Floodplain, N. Nigeria, 1989/90
(N7.5 = US$1)

FUELWOOD CONSUMERS	Total Output (t)	Financial Price (N/t)	Economic Price (N/t)	Total Financial Benefits (N '000)	Total Economic Benefits (N '000)	Total Financial Cost (N/t)	Total Economic Cost (N/t)	Net Economic Benefits (N '000)
Rural	51600	120	102	6192	5263	30	26	3947
Non-Rural	63500	120	102	7620	6477	40	34	4318
TOTAL	115100	120	102	13812	11740			8265

TOTAL FUELWOOD HA: 400000

NET ECONOMIC BENEFITS/HA (N/ha): 21

Notes: Economic values are financial values adjusted by a standard conversion factor of 0.85.

Financial costs are based on an initial felling/trimming cost of N18/t, cost of chopping down into bundles of N12/t and a transport cost to local urban centres of N10/t.

Source: Calculations based on Kimmage and Adams (1990) and field surveys undertaken by these authors; and World Bank data.

floodplain is also consumed in local towns and urban centres, notably Gashua, Hadejia and Nguru. Applying the same monthly rate of 50 kg of fuelwood used per household to the 106,000 'non-rural' households yields a total urban consumption of fuelwood of 63,500 tonnes.

Financial prices of the rural and non-rural fuelwood uses were estimated at N120 per tonne, which reflected average retail price in the markets and by the roadside throughout the floodplain. The standard conversion factor of 0.85 gives an economic price of N102 per tonne. The financial costs of fuelwood supply for both rural and non-rural uses were calculated on the basis of initial felling and trimming costs of N18 per tonne and costs of chopping down into bundles of N12 per tonne. Non-rural supply incorporated an additional transport cost to local urban centres of N10 per tonne. With an estimated 400,000 ha of land in the floodplain yielding fuelwood, the net economic benefits of all fuelwood produced annually in the wetlands are N21 per ha.[10]

Present Value of Net Economic Benefits

A cost-benefit analysis of the net economic benefits over time from agriculture, fishing and fuelwood in the Hadejia-Jama'are floodplain was also conducted. The analysis assumes that the benefits provided by the floodplain do not arise just in a single year but that the wetlands, if properly managed, are capable of yielding a continuous stream of such benefits over a number of years. The sum of the stream of benefits discounted into present values indicates the present worth of the wetlands in terms of agriculture, fishing and fuelwood. As shown in equations (1) and (2) above, this estimate of the present worth of the wetlands, NB^W, is the benchmark for comparing the returns to development projects, NB^D, that may threaten the floodplain system.

The cost-benefit analysis comprises three parts:

* a base case scenario, which assumes that the net economic benefits per ha for agriculture, fishing and fuelwood would be maintained at current levels for each year of the analysis;

* an alternative sustainability scenario, which assumes that much of current wheat production in the wetlands cannot be

[10] Estimating total area for fuelwood production is extremely difficult. The figure of 400,000 ha is rather arbitrary. In 1950, the area of inundation in the floodplain was estimated at around 3265 km^2, with map projections suggesting perhaps an additional 1000-2000 km^2 of wood/savanna/shrubland intermingled. Although the area of inundation has fallen well below 1000 km^2 in recent years, the maximum possible extent of floodplain area yielding wood might be around 3000-5000 km^2.

sustained and will therefore decline rapidly over the next 4-5 years; and

* a standard sensitivity analysis, which incorporates different assumptions concerning time horizons (30 and 50 years) and discount rates (8% and 12%) in both scenarios of the analysis.

The results of the analysis are displayed in Table 4. Depending on the discount rate and time horizon, the present value of total net benefits under the base case range from N895 to N1359 per ha. The net benefits from agriculture range between N607 and N921 per ha, from fishing between N197 and N300 per ha and from fuelwood between N91 and N139 per ha.

However, serious doubt has recently been expressed over the sustainability of wheat production in the Hadejia-Jama'are floodplain. Kimmage (1989 and 1991) has argued that government efforts to subsidize domestic wheat production through generous subsidies and imposing a ban on wheat imports have led to rapid expansion of pump-irrigated wheat in the floodplain area. As a result of the subsidization (up to 50%) of all inputs and services for wheat cultivation and an increase in the domestic producer price of wheat by a factor of ten between 1986 and 1989, cultivated wheat area in the Hadejia-Jama'are region increased from around 200-300 ha prior to 1983 to almost 47,000 ha in the 1989/90 season. Much of the recent expansion has been through clearing and burning acacia scrubland, which generally has thin topsoils with low clay content and poor levels of organic carbon. Given the poor quality and structure of most of the soils, intensive cultivation of wheat in the floodplain region, especially on cleared scrubland, could lead to substantial land degradation within a few years. In scrubland areas, crop yields are likely to fall rapidly, with soil fertility irreversibly degraded within 4-5 years (Kimmage 1991).[11]

Of total wheat cultivation in the Hadejia-Jama'are floodplain, approximately 80% of the recent large scale clearances of acacia scrubland may be affected by severe degradation problems. As these clearances currently account for about 70% of the total area under wheat, the 'unsustainable' element in wheat cultivation is likely to be in the region of 26,100 ha. In the cost-benefit analysis, an alternative sustainability scenario is projected by 'adjusting' net benefits from agriculture over time. The basic assumption is that yields on the 26,100 ha of

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[11] Erosion tests carried out at Samaru in northern Nigeria have shown that the annual erosion rate, negligible under natural conditions, can accelerate to as high as 21 tonnes/ha (mean 10 tonnes/ha) when the land is cleared and cropped. The breakdown of soil structure under continuous cultivation leads to substantial problems of runoff and wind erosion. Intensive cultivation reduces the mean carbon content of soils by 50% or more, causing even greater degradation of soil structure. The impact on yields can be dramatic (Kimmage 1991).

'unsustainable' wheat cultivation fall by 20% per year after the first year, eventually declining to zero by the sixth year. As shown in Table 4, adjusted agricultural net benefits are marginally lower, ranging from N558 to N838 per ha. Total net benefits are also adjusted lower to between N846 and N1276 per ha.

Expressing the discounted net economic benefits of the floodplain in 'per hectare' terms gives one useful comparison with the present worth of upstream and downstream water development projects. However, given that these projects are essentially competing with the floodplain for the use of water, expressing net economic benefits in terms of 'water use' may provide a more useful comparison.

Two additional versions of the cost-benefit analysis were therefore conducted, with discounted net economic benefits re-calculated in terms of cubic metres (m^3) of water use by the floodplain. Both versions also contain a base case, a standard sensitivity analysis of time horizons and discount rates, and an 'adjusted' case to account for unsustainable wheat cultivation. The results are indicated in Tables 5 and 6.

Table 5 displays present value net economic benefits based on an average annual river inflow of 2549 10^6m^3 into the Hadejia-Jama'are floodplain over 1985-87.[12] This volume of river inflow essentially corresponds to the **'maximum'** amount of water input required by the floodplain to sustain agriculture, fuelwood harvesting and fishing. As Table 5 shows, total net economic benefits from the agriculture, fishing and fuelwood supported by the floodplain range from N256 to N389 per 10^3m^3 of river inflow. When adjusted for unsustainable wheat cultivation, the net economic benefits range from N242 to N366 per 10^3m^3 of river inflow.

A hydrological simulation model has been developed to determine the amount of water releases required from all existing and planned upstream development projects to avoid severe disruptions to the Hadejia-Jama'are floodplain (Adams and Hollis 1989).[13] The total release of regulated flooding amounts to 1648 10^6m^3 per year. Although such a regime of controlled releases may be

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[12] Based on a hydrological model of the water balance of the floodplain over 1964-1987. The volume of river inflow has declined considerably over this period, again reflecting the impact of drought and diversion of water by development projects. See Adams and Hollis (1989).

[13] The controlled flooding under this regime includes a release of 350 10^6m^3 in August from Tiga Dam, an annual release of 248 10^6m^3 and an additional release of 100 10^6m^3 in July from Challawa Gorge Reservoir, and releases of 100 10^6m^3 per month over October-March and an additional release of 350 10^6m^3 in August from Zaki Reservoir.

Table 4. Present Value Net Economic Benefits per Hectare, Hadejia-Jama'are Floodplain, Nigeria (N/ha) a/

(N7.5 = US$1, 1989/90)

Base Case	(8%, 50 yrs)	(8%, 30 yrs)	(12%, 50 yrs)	(12%, 30 yrs)
Agriculture	921	848	625	607
Fishing	300	276	203	197
Fuelwood	139	127	94	91
Total	**1359**	**1251**	**923**	**895**
Adjusted Agriculture b/	838	773	574	558
Adjusted Total	**1276**	**1176**	**872**	**846**

Notes: a/ Economic benefits averaged over the total production area of 730,000 ha (400,000 ha for fuelwood, 230,000 ha for cropland and 100,000 ha for fishing).

b/ NPV of agriculture adjusted for unsustainability of wheat production. Approximately 56% of current wheat hectarage assumed unsustainable.

Source: Based on Tables 1-3.

Table 5. Present Value Net Economic Benefits per River Inflow Hadejia-Jama'are Floodplain, Nigeria (N/'000 m^3) a/

(N7.5 = US$1, 1989/90)

Base Case	(8%, 50 yrs)	(8%, 30 yrs)	(12%, 50 yrs)	(12%, 30 yrs)
Agriculture	264	243	179	174
Fishing	86	79	58	57
Fuelwood	40	37	27	26
Total	**389**	**358**	**264**	**256**
Adjusted Agriculture b/	240	221	164	160
Adjusted Total	**366**	**337**	**250**	**242**

Notes: a/ Based on the average annual river flow into Hadejia-Jama'are floodplain of 2549 Mm^3 over 1985-87.

b/ NPV of agriculture adjusted for unsustainability of wheat production. Approximately 56% of current wheat hectarage assumed unsustainable.

Source: Based on Tables 1-3 and Adams and Hollis (1989).

Table 6. Present Value Net Economic Benefits per Controlled Water Release, Hadejia-Jama'are Floodplain, Nigeria (N/'000 m^3) a/
(N7.5 = US$1, 1989/90)

Base Case	(8%, 50 yrs)	(8%, 30 yrs)	(12%, 50 yrs)	(12%, 30 yrs)
Agriculture	408	375	277	269
Fishing	133	122	90	87
Fuelwood	61	56	42	40
Total	**602**	**554**	**409**	**396**
Adjusted Agriculture b/	371	342	254	247
Adjusted Total	**565**	**521**	**386**	**375**

‡
Notes: a/ Assumes a total controlled water release of 1648 Mm^3 per annum from upstream water development projects on the Hadejia and Jama'are rivers.

b/ NPV of agriculture adjusted for unsustainability of wheat production. Approximately 56% of current wheat hectarage assumed unsustainable.

Source: Based on Tables 1-3 and Adams and Hollis (1989).

insufficient to maintain groundwater recharge at present levels, the regime would provide the **'minimum'** amount of water input required to sustain floodplain agricultural, fishing and fuelwood benefits. As indicated in Table 6, these benefits total to between N396 and N602 per 10^3m^3 of controlled flood releases. Under the sustainability scenario, the adjusted total is between N375 and N565 per 10^3m^3 of controlled releases.

Comparison with Development Projects

Comprehensive cost-benefit analyses have not been carried out for existing and planned development projects along the Hadejia and Jama'are rivers to compare with the above analysis of floodplain benefits. However, some information does exist on the costs and benefits of the Kano River Project Phase I to allow a comparative analysis to be conducted.

The Kano River Project, which lies to the south of Kano city and along the Hadejia River, was one of the first large scale irrigation schemes developed in northern Nigeria. Begun in the late 1970s, the Project is a gravity fed scheme supplied from water stored in the Tiga Dam, with a secondary reservoir at Ruwan Kayan which holds one month's water supply. The first irrigated crops were planted in 1981. Farming is mostly done by smallholders, on plots of 1-2 ha. By 1985/86, the Project was fully operational, with over 7,000 ha of dry season crops (wheat and tomatoes mostly) and almost 12,000 ha of wet season crops (mainly rice, maize, cowpeas and millet). Water use in the Project is high, estimated at 15,000 m^3 per ha annually. Although feasibility studies and a small pilot project for an additional 40,000 ha of irrigated cropland have been conducted, Phase II of the Kano River Project has yet to be initiated (Adams and Hollis 1989).

Although a complete cost-benefit analysis of the Project has not been conducted, some information does exist on the costs and value of production when the Project became **fully operational** over 1984-1986. Calculations of the **current** net economic benefits of the Project are indicated in Table 7. Although crop production and hectarage in the Project are based on 1985/86 data, to facilitate comparison with the returns to the Hadejia-Jama'are floodplain system, the same 1989/90 crop financial and economic prices from Table 1 are used. Similarly, the same assumption that net economic crop benefits are 15% of gross benefits is employed.

Table 7 indicates that, once fully operationally, net economic crop benefits **per ha** of the Kano River Project appear extremely high (N865/ha). They easily exceed the net economic benefits per ha of floodplain agriculture (N239/ha, see Table 1), and are virtually double the total net benefits from floodplain agriculture, fishing and fuelwood (N438/ha, from Tables 1-3). However, as in the case of most irrigation projects, the Kano River Project also has high net operating costs. Over 1984-86, these ranged from a low of 7.7% to as much as 37% of the total value of crop production.[14] As shown in Table 7, when the net operating costs are deducted from net economic crop benefits, the resulting net economic **project** benefits are reduced to just N19/ha. Thus the current returns per ha to the fully operational Kano River Project do not compare favourably with those of floodplain agriculture, fishing and fuelwood.

Moreover, with an annual water requirement of 15,000 m^3 per ha, the Kano River Project is highly intensive in its water use. When expressed in terms of **water input** rather than in hectarage cultivated, current net economic benefits are extremely low - around N1.10 per 10^3m^3 of water used (see Table 7). Net project economic benefits are only N0.02 per 10^3m^3 of water input. In comparison, the flood-recession agriculture of the Hadejia-Jama'are floodplain requires substantially less water. Thus, even when the 'maximum' annual water input into the floodplain of 2549 10^6m^3 is used, net floodplain agricultural benefits currently amount to N21.6 per 10^3m^3 of river water inflow. Total net economic benefits from agriculture, fishing and fuelwood amount to N31.8 per 10^3m^3 of river water inflow.

Based on the current net crop and project benefits calculated in Table 7, a cost-benefit analysis was conducted for the Kano River Project Phase I. Adjustments to the time horizon and discount rate were included in a sensitivity analysis. The results are shown in Table 8. In comparison with the present value net benefits of the Hadejia-Jama'are floodplain (see Tables 4-6), it is clear that the present worth of the Kano River Project is much lower. Only the present value of net crop benefits **per ha** are substantially higher for the Project compared to the floodplain. As discussed above, however, to exclude current operating costs gives a misleading indication of the net economic returns to the Project. In addition, the present value of net crop benefits **per 10^3m^3 of water use** for the Project is substantially lower than for floodplain recession agriculture (see Tables 5 and 6), let alone for total net floodplain benefits.

In sum, the returns to agriculture, fuelwood and fishing in the Hadejia-Jama'are floodplain appear to exceed substantially that of the Kano River Project Phase I. This would suggest extreme caution in assuming that an irrigated agricultural project, such as the Kano River Project, is an economically better use of water. A straight comparison of the net economic returns to irrigated crop production and floodplain recession agriculture often gives such a misleading impression. The above analysis confirms the need for an economic analysis of a water development project not only to include net project operational costs as part of **direct costs** of the development but also to incorporate as **opportunity costs** the alternative uses of the water for

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[14] Net operating costs of the Project include capital expenditure, capital works, recurrent costs and head office expenditure, less any Project income (Adams and Hollis 1989).

Table 7. Net Economic Benefits, Kano River Project Phase I, N. Nigeria
(N7.5 = US$1)

CROP 1/	Output (t)	Area Planted (ha)	Yield (t/ha)	Financial Price (N/t)	Economic Price (N/t)	Financial Benefits (N '000)	Economic Benefits (N '000)	Net Economic Benefits 3/ (N '000)
Tradeable								
Rice	6940	1735	4.0	4770.0	3144.9	33104	21826	3274
Wheat	9348	4674	2.0	4010.0	1382.9	27929	9597	1440
Non-Tradeable								
Sorghum	2767	2306	1.2	720.0	612.0	4997	4247	637
Maize	8212	4131	2.0	842.0	715.7	5843	4967	745
Groundnuts	661	551	1.2	4980.0	4233.0	34561	29377	4407
Millet	3078	3078	1.0	842.0	715.7	5843	4967	745
Cowpeas	225	281	0.8	3310.0	2813.5	22971	19526	2929
Tomatoes	33405	1670	20.0	662.5	563.1	4598	3908	586
Peppers	302	20	15.1	1135.6	1135.6	7881	7881	1182
Others 2/	16402	661	24.8	665.6	565.8	4619	3926	589
TOTAL	81340	19107				152248	110222	16533

NET ECONOMIC CROP BENEFITS PER HA (N/ha): 865 3/

LESS NET OPERATING COSTS PER HA (N/ha): 846 4/

NET ECONOMIC PROJECT BENEFITS PER HA (N/ha): 19

NET ECONOMIC CROP BENEFITS PER WATER INPUT (N/ '000m3): 1.10 5/

NET ECONOMIC PROJECT BENEFITS PER WATER INPUT (N/ '000m3): 0.02 5/

Notes: 1/ Crop output based on 1985/86 production and hectarage; crop economic and financial prices as in Table 1.

2/ Mainly vegetables.

3/ See Table 1 for the calculation of net economic crop benefits.

4/ Net project operating costs include capital expenditure, capital works, recurrent costs and head office expenditure. The proportion of these costs to the total value of crop production in 1984 was 7.7%, in 1985 21.1% and in 1986 37%. An average of these three figures was used to calculate net operating

5/ Water input estimated at 15,000 m3 per ha per year.

Source: Calculations based on Adams and Hollis (1989) and World Bank data.

Table 8. Present Value Net Economic Benefits, Kano River Project Phase I, Nigeria

(N7.5 = US$1, 1989/90)

Per Hectare a/	(8%, 50 yrs)	(8%, 30 yrs)	(12%, 50 yrs)	(12%, 30 yrs)
Crop (N/ha)	10,586	9741	7186	6970
Project (N/ha)	233	214	158	153
Per Water Use b/				
Crop ($N/10^3m^3$)	13	12	9	9
Project ($N/10^3m^3$)	0.3	0.3	0.2	0.2

‡

Notes: a/ Based on total crop cultivated area of 19,107 ha in 1985/86.

b/ Assumes an annual water use of 15,000 m^3 per ha.

Source: Based on Table 7 and Adams and Hollis (1989).

downstream benefits, such as floodplain agricultural, fishery and fuelwood production.

Moreover, in the above analysis the estimation of the comparative returns to the Kano River Project may have been reduced further by a considerable amount if the following factors were also taken into account:

* The economic analysis of the Kano River Project did not include sunk capital costs of around N180 million nor a 'gestation period' for crop production during the project start-up from 1981 to 1985/86. Rather, the analysis was based on current costs and benefits only and assumed the project to be fully operational in the initial year of the analysis. A full project appraisal that would take into account capital costs and a 'gestation period' would yield even lower, and perhaps even negative, present value returns.

* No comparable 'sustainability' scenario was constructed for the analysis of crop benefits from the Kano River Project. It is likely that problems of land degradation, and possibly salinization, may affect future yields in the Project, especially for wheat.

* The agricultural, fuelwood and fishing benefits are only some of the total economic benefits provided by the Hadejia-Jama'are floodplain system. If full account is taken of other benefits, the opportunity costs of diverting water to development projects such as the Kano River Project may be even higher.

5. Other Floodplain Benefits

In addition to supporting agriculture, fuelwood use and fishing, the Hadejia-Jama'are floodplain provides numerous other benefits that are less easy to value. Some of these benefits are extremely important, and collectively, they may even exceed the value of floodplain agriculture, fuelwood and fishing.

<u>Livestock and Grazing</u> The floodplain provides important grazing resources both for sedentary farmers (Hausa, Kanuri and Fulani) with livestock settled within the wetlands area and for nomadic Fulani herdsmen who use the floodplain for dry season pastures. Although it is clear that livestock production in the area is both high and increasing, there is currently little data available on livestock numbers, herd composition, in- and out-migration of herds, herd off-take or carcasses and livestock products (e.g., milk/yoghurt, hides) delivered to market (Kimmage and Adams 1990). Additional data must be acquired on the productivity of different floodplain grazing resources (e.g., pasture land, scrubland, marshes, forests). The role of livestock rearing in the community should also be assessed (Jimoh 1991). If such data were available, then calculating the value of the average annual animal production attributable to

floodplain grazing would be relatively straightforward. For example, Thomas, Ayache and Hollis (1990) used such an approach in valuing the grazing benefits of the Ichkeul marshes in Tunisia.

Non-Timber Forest Products

In addition to producing fuelwood, the forest reserves and brushland of the floodplain yield important non-timber forest products that are significant to the livelihoods and subsistence of local communities. Some are important marketed commodities that generate substantial income. These include leaves harvested from the *doum* palm, which are either processed into mats and other products or sold as raw material, baobab leaves, which provide an ingredient for soups and stews and honey produced through beekeeping. The harvesting and processing of doum palm leaves is a dry season activity, and many people migrate to the wetlands area - even from Niger - to harvest the palm. Mat-making from doum is also a specialized activity of many floodplain villages. Mats and other doum products (e.g., rope, baskets) are sold locally or exported to other regions. Baobab leaves are used widely and are especially important as a 'drought food'. In local markets the leaves are sold for around N20 per sack. Honey produced by local beekeepers is a highly valued commodity. Local prices range from N10-20 per kilogramme (kg), with an annual production of 100-150 kg per hive being common.

Wildlife Habitat - Tourism, Educational and Scientific Benefits

Recent surveys indicate that the Hadejia-Jama'are wetlands are an important habitat for migratory wildfowl, with the number of birds sighted varying from 20,000 to 50,000, covering thirteen identified duck and related species. The majority counted in the 1988 and 1980 surveys were Palaeoarctic species (92% and 81% respectively); however, in the 1989 survey the numbers of Paleoarctic and Afro-tropical species were more closely matched (55% and 45% respectively). In all three years, wildfowl were concentrated at a small number of sites; in 1988 95% of those counted were found at only nine sites which all held more than 500 birds, and in 1989 90% of all wildfowl were found at eight sites. In addition to the migratory wildfowl, the wetlands contain cormorants, egrets, glossy and sacred ibises, herons, marsh harriers, black kites, storks, white pelicans and at least 27 species of waders (Stowe and Coulthard 1990).

The rich and highly concentrated bird populations of the wetlands suggest that they have potential value in terms of scientific, educational and tourism benefits. Current uses of the wetlands for these purposes are, however, negligible. Poor tourist infrastructure and transportation in Northern Nigeria are major constraints on the development of any tourist potential. Nevertheless, an important objective of the Hadejia-Nguru Wetlands Conservation Project strategy for Phase II (April 1991 - March 1994) is to conduct further scientific investigations of the bird populations to study species diversity, wintering and breeding habitats and individual species. Efforts will also be stepped up to increase educational visits by schools and to develop tourist potential (HNWCP 1991).

Conservation of the wetlands as an important wildlife habitat therefore has important **option values** for future tourism, educational and scientific uses. The wetlands may also have an important non-use **existence value**, in that individuals who have no intention of visiting the wetlands may value the fact that it exists as an important wildlife habitat. Accounting for these values is extremely difficult, however, and may require sophisticated techniques of contingent valuation and travel-cost methods. These values also only have significance as opportunity costs if Nigeria can somehow 'capture' these values (e.g., through receiving international financing for 'preserving' the wetlands) or if these values are held by Nigerians themselves. Brown and Henry (1989) applied travel-cost methods to derive current and option values for viewing elephants in Kenya. A similar approach could be applied to bird-viewing in the Hadejia-Jama'are wetlands.

Controlling Bird Damage

Many of the bird species that use the Hadejia-Jama'are wetlands as a permanent or migratory habitat are potential agricultural pests. In particular, ruff, which is the most numerous species in the wetlands, is regarded as a major pest that damages the rice crop. Although pest damages to floodplain crops do occur, shooting and snaring is rare, which suggests that the problem is manageable locally. Estimates based on bird surveys suggests that over 50,000 ruff use the wetlands each year (Stowe and Coulthard 1990).

One important benefit of the wetlands is that, by providing a natural feeding habitat for ruff and other birds that are potential agricultural pests, the floodplain essentially prevents the birds from inflicting additional crop damages to fields outside the wetland area. If the wetlands did not exist, the birds would have no choice but to feed on farmland instead, much of which might be created by local irrigation schemes and development projects. Although difficult to measure, valuing the benefit of the wetlands in terms of controlling crop damage by birds would involve estimating a damage cost function based on the extent to which migratory and native birds take to feeding on agricultural land if there is continued destruction of their natural feeding areas within the wetlands.

Groundwater Recharge

Perhaps the most important environmental function of the Hadejia-Jama'are wetlands is its role in recharging the groundwater aquifer of the Chad Formation. Evidence presented by Adams and Hollis (1989) shows a clear relation between the loss of floodplain inundation and the rate of groundwater recharge. Over 1964-1971, when over 2000 km^2 were flooded almost every wet season and from 1975 to 1982 when inundation remained around

1000-2000 km^2, groundwater storage beneath the floodplain was largely stable. But during the drought years of 1973-74 and since 1983 when the extent of flooding dropped appreciably, groundwater recharge fell by an estimated aggregate amount of 5,000 10^9m^3. Continual loss of groundwater storage and recharging will have a significant impact on the numerous small villages throughout the region that depend on the aquifer for domestic use and agricultural activities.

Estimating the benefits of the wetlands' groundwater recharge function is a difficult, but not an insurmountable, problem. By combining hydrological information on the groundwater recharging supplied by the wetlands, the impacts on the water tables supplying village wells and direct estimates of villagers willingness-to-pay (WTP) for water, it may be possible to value this recharging function. A recent study in Brazil demonstrates how surveys of actual and hypothetical water-use practices can provide estimates through contingent valuation methods of the WTP that vary according to household socioeconomic characteristics, qualitative differences in water supply and delivery systems (Briscoe et al.).

In the absence of time and resources to apply such direct WTP estimation methods, it may be possible to estimate indirectly the benefits of the wetlands' groundwater recharge function. One approach is to measure the additional 'externality costs' of a depletion scenario based on continual loss of groundwater storage versus a conservation scenario whereby the recharging function is preserved, Munasinghe (1990) indicates how this approach provides a benchmark value for the damage costs of aquifer depletion in the Philippines. It may also be possible to value indirectly the recharging function by estimating the impact of losses in water supply from the village wells on agricultural production. The changes in agricultural productivity associated with the decline in water use could then be used to value the recharge function of the wetlands. However, more difficult to value through this approach would be the impact of groundwater recharge on domestic water use.

6. Conclusions of the Economic Valuation

The economic analysis of the agricultural, fuelwood and fishing benefits provided by the Hadejia-Jama'are floodplain in Northern Nigeria indicates that these benefits are substantial on both a per hectare basis and in terms of the minimum and maximum amount of floodwater required to sustain them. Not only are these wetland benefits currently important, but they can be expected to yield significant economic returns for some time - provided that the floodplain system is properly managed and sustained. Even when taking into account the future unsustainability of much of the current wheat production in the floodplain, the economic analysis calculates the present worth of the aggregate stream of agricultural, fishing and fuelwood benefits to be around N850 to N1280 per ha. Or, given the 'maximum' and 'minimum' flood water inputs required to sustain the system, the benefits vary between N240-N370 per 10^3m^3 of water and N375-N565 per 10^3m^3 of water respectively.

When compared to the net economic benefits of an upstream water development project such as the Kano River Project Phase I, the economic returns to the floodplain appear much more favourable. This is particularly the case when the relative returns to the Project in terms of water input use is compared to that of the floodplain system. This result should cause some concern, given that the existing and planned water developments along the Hadejia-Jama'are river system, such as the Kano River Project, are currently and will continue diverting water from the floodplain. The failure to take into account the opportunity cost of this water diversion in terms of the forgone benefits of floodplain production may be leading to serious over-estimation of the net economic returns to these development projects.

However, there are other significant economic benefits provided by the floodplain system than the ones estimated in the analysis. Livestock grazing and groundwater recharge may in particular be extremely important, although recreational, educational and scientific visits and control of bird pests may also prove substantial. The sum total of these additional benefits may actually exceed the estimated returns to floodplain agriculture, fishing and fuelwood.

The economic importance of the floodplain suggests that the benefits it provides cannot be excluded as an opportunity cost of any scheme that diverts water away from the floodplain system. Policymakers should be aware of this problem when designing water development projects in the Hadejia-Jama'are river system. Further analysis is also required of the type of 'regulated flooding' regime suggested by Adams and Hollis (1989), which could maintain much of the floodplain system intact while still allowing some upstream water developments. Further investigation of all the economic benefits provided by the Hadejia-Jama'are wetlands is also needed, and the sustainability of production within the floodplain area should be more thoroughly examined.

References

Adams, W. M. and Hollis, G. E. (1989). Hydrology and Sustainable Resource Development of a Sahelian Floodplain Wetland, Report to the Hadejia-Nguru Wetlands Conservation Project, London.

Anderson, D. (1987). The Economics of Afforestation: A Case Study in Africa, John Hopkins University Press for the World Bank, Washington DC.

Barbier E.B. (1989b). The Economic Value of Ecosystems: 1 - Tropical Wetland. Gatekeeper 89-02 London Economics Centre, London.

Barbier E.B. (1989a). Economic Evaluation of Tropical Wetland Resources Applications in Central America. London Economics Centre, London.

Barbier E.B., Markandya, A. and Pearce, D.W. (1990) "Sustainable Agricultural Development and Project Appraisal", European Review of Agricultural Economics 17: 181-196

Briscoe, J., Furtado de Castro, P., Griffin, C., North J. and Olsen, O. (1990). "Toward Equitable and Sustainable Rural Supplies: A Contingent Valuation Study in Brazil", The World Bank Economic Review 4(2):115-134.

Brown, G. Jr. and Henry, W. (1989). The Economic Value of Elephants. LEEC Discussion Paper LEEC 89-12, London Enviornmental Economics Centre.

Farber, S. and Costanza, R. (1987). The Value of Coastal Wetlands for Protection of Property against Hurricane Wind Damage. Journal of Environmental Economics and Management 14: 143-51.

Gregersen, H.M., Brooks, K.N., Dixon, J.A. and Hamilton, L.S. (1987). Guidelines for Economic Appraisal of Watershed Management Projects. FAO, Rome.

HNWCP (1991). Strategy for Phase II: 1991-94, Nguru, Nigeria.

Hollis, G.E. (1991). "The Impact of Drought and Dams on the Functions of the Hadejia-Gashua Floodplain, Nigeria", Wetland Ecology and Management (in press).

Jimoh, M.A. (1991). "Pastoralists in the Hadejia Nguru Floodplain: Survey of Two Communities", HNWCP, Nguru, Nigeria.

Kimmage, K. (1989). "The Evolution of the Wheat Trap: the Nigerian Wheat Boom, mimeo, Dept. of Geography, University of Cambridge, Cambridge.

Kimmage, K. (1991). "Small-Scale Irrigation Initiatives: the Problems of Equity and Sustainability", Applied Geography 11:5-20.

Kimmage, K. and Adams, W.M. (1990). The Economic Value of Production in the Hadejia-Jama'are Floodplain, Nigeria, Report to the Coordinator, Wetlands Programme, IUCN, Department of Geography, University of Cambridge, Cambridge.

Munasinghe, M. (1990). Managing Water Resources to Avoid Environmental Degradation: Policy Analysis and Application, Environment Working Paper No. 41, World Bank, Washington DC.

Stowe, T.J. and Coulthard, N.D. (1990). "The Conservation of a Nigerian Wetland: The Hadejia-Nguru Wetland Conservation Project, RSPB Conservation Review, 3:80-85.

Thomas, D.H.L., Ayache, F. and Hollis, T. (1990). "Use Values and Non-Use Values in the Conservation of Ichkeul National Park, Tunisia", Environmental Conservation (forthcoming).

Turner, R.K (1990) "A Case Study of Wetlands", ch. 21 in D. W. Pearce and R. K. Turner, Economics of Natural Resources and the Environment, Wheatsheaf, London.

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