CPWF Project Report

Basin Focal Project NIGER

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Program Preface

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

The CPWF conducts action-oriented research in ten river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface

Challenge Program Water and Food: Basin Focal Project NIGER
Faced with increasing food and water insecurity as a result of climatic and anthropogenic (demography, land use) changes, the CGIAR Challenge Program for Water and Food commissioned research in 10 river basins to study the links between water, food and poverty. Looking at the Niger river basin, we carry out a diagnosis of the hydrologic and agronomic potential, before attempting to identify how good agricultural water management may reduce vulnerability in the region, and preserve local ecosystems. Major future threats and opportunities, as well as the influence of institutions on water and agricultural development are discussed.

The study indicated that while many technical solutions are available and identified, institutional issues as well as generalized poverty undermine their sustained uptake by communities. Further research is required in order to determine how to overcome socio-economic and institutional issues.

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Research Highlights

The Basin Focal Project Niger was one of ten projects commissioned by the CGIAR Challenge Program Water and Food to study the links between water, food and poverty at the basin scale. A research for development programme, the CPWF notably aimed to "to alleviate poverty and enhance food, health and environmental security through improvements in agricultural water management". Organised in 6 work packages gathering researchers from Europe, Africa and Australia, the BFP covered issues of water availability and access and agricultural water productivity, but also analysed institutions, interventions and water poverty aspects.

A selection of the highlights of the project which aimed to identify key research questions and recommendations on ways to reduce rural poverty through improvements in agricultural water management are provided below. The full list is provided in the Conclusions and Recommendations section of the report.

Water availability

- After severe droughts in the 1970s and 1980s, rainfall increased after 1993 but levels are still low. Reduced rainfall affected runoff in the basin differently. In the upper basin, runoff deficit was high and more consequent than rainfall deficit, due to the cumulative effect of reduced rainfall on groundwater levels. In Sahelian parts runoff coefficients increased, partly due to reduced rainfall but mainly to increased agriculture and reduced natural vegetation. These variations in climate and river regime are essential to take into account when designing future dams
- Climatic scenarios for the Niger basin predicting increased temperatures, variability, dry spells and extreme events as well as reduced rainfall in western parts of West Africa will increasing the strain on already vulnerable agriculture.

Agriculture and water productivity

- Agricultural withdrawals already impact on ecosystems such as the Inner Delta and Niger Delta. Extending dry season irrigation will require additional dams and will impact heavily on wetlands and their biodiversity, notably the environmental services and the livelihoods of a million herders, fisherman and traditional rice growers in the Inner Delta. The construction of the Fomi dam will result in the loss of 3700-4900t of fish per yr.
- Small scale irrigation is currently more water efficient and recommendations for its sustainable and equitable expansion should be examined
- Fisheries are rarely included in national or pro-poor policies because their importance has not properly been evaluated
- Despite possible synergies between farmers and herders (grazing crop residues against manure/fertilizer), conflicts are on the rise and would require the correct implementation of legislation to support pastoralism.
- Improvements in rainfed agriculture can significantly reduce poverty thanks to the large population dependant on it. Current farmer strategies to reduce risks (due to rainfall deficit) prevent intensification and solutions to reduce

crop failure risk are necessary for farmers to invest in fertiliser and other inputs which are essential to boost yields.

- WP provides an indication of water use but interpretation and formulation of recommendations appears complex (especially where water is not scarce or under competition)
- WP calculations must be refined due to uncertainties in yield and water use. Return flows and the current other uses of "wasted" water must be closely examined to ensure improvements in water efficiency do not negatively affect downstream and other uses

Institutions

- The progressive introduction of new legislation and structures (decentralisation, IWRM, NGO projects) and the continued dominance of customary laws creates a legal pluralism, leading to confusion and conflicts. The change dynamic can however result in positive institutional innovations, notably the increased recognition of women, youth or minority groups often discriminated against under traditional law.
- Land tenure is affected by the legal pluralism and reforms favouring individualized tenure and land titles. New participative and communal land titling systems may help protect the tenure rights of the poor

Water poverty

- The analysis of spatially referenced child mortality, child morbidity and the wealth index identified three major poverty hotspots in the Niger basin, situated in Southern Mali and the Inner Delta, North East Burkina Faso and North West Nigeria
- Education and access to improved water quality are consistently statistically correlated with the poverty indices in these hotspots. These variables are relatively stationary across the study area and can therefore be addressed with whole of catchment scale policies with less attention to regional differences.

Interventions and future threats

- Projected dam building will inherently produce negative impacts downstream. Tradeoff analysis must be undertaken in consultation with local stakeholders to ascertain which element must be favoured (hydropower, irrigation, fisheries, ecosystems…) and how to minimize negative impacts.
- The increase in basin population from 95 million in 2005 to between 186 and 384 million according to the scenarios will lead to greatly increased demands on natural resources and increase vulnerability of rural poor communities. Future population trends depend essentially on the speed of fertility decrease, which currently exceeds 6-7 children per woman and in countries like Mali is not decreasing, leading to an increase in the population growth rate.

Executive Summary

The Basin focal project Niger

The Basin Focal Project Niger was one of ten projects commissioned by the CGIAR Challenge Program Water and Food to study the links between water, food and poverty at the basin scale. A research for development programme, the CPWF notably aimed to "to alleviate poverty and enhance food, health and environmental security through improvements in agricultural water management". Faced with increasing food and water insecurity as a result of climatic and anthropogenic (demography, land use) changes, the BFPs were also asked to look specifically at the issues of water productivity in the basin, in order to reduce the strain of agriculture on water resources in the coming years.

Organised in 6 work packages gathering researchers from Europe, Africa and Australia, the BFP covered issues of water availability and access and agricultural water productivity, but also analysed institutions, interventions and water poverty aspects. A final 6th work package was in charge of creating a knowledge base, to compile and manage the data, reports and maps produced by the project.

The Niger basin

Spanning 9 countries and over 1 200 000 km², the Niger river basin presents a variety of diverse and complex issues. A large transboundary basin supporting over 95 million people, it is characterised by extreme rural poverty. The United Nations Human Development Index, a composite ranking based on national income, life expectancy and adult literacy rate, ranks all of the Niger Basin countries in the lowest quintile of countries. Basin countries suffer from a generalised state of underdevelopment (roads, electricity, health, water supply) as well as insecurity and corruption issues.

Water availability

Often portrayed as water poor notably by the Water Poverty Index, the basin is above all faced with economic water scarcity. Looking at water availability, we see that the basin covers a wide range of agroclimatic zones, from over 4000mm in the Extreme South to less than 400mm (0mm some years) on the fringes of the Sahara desert. While a quarter of the basin is under Sahelian or Semi-arid climate, in the rest of the basin, south of 13°N, rainfall exceeds 700mm and is broadly sufficient for rainfed agriculture.

Difficulties arise due to the spatiotemporal variations in rainfall and its effect on flows. The Niger river is highly dependant on rainfall and as a result presents high seasonal and fairly high interannual variations. Rainfall is very concentrated in the year, leaving northern regions of the basin with very short growing seasons (2-4 months) and in the South, short dry spells or excess rainfall can cause crop failures. Decreased rainfall in the 1970s and 1980s caused a shift in isohyets and devastating droughts in the Sahel region. Runoff deficit was highest in the Upper Basin and more consequent than rainfall deficit, due to the cumulative (memory) effect of reduced rainfall on groundwater levels. In Sahelian parts of the basin runoff coefficients increased, partly due to reduced

rainfall but mainly to increased agriculture and reduced natural vegetation, leading to higher flood peaks, erosion, sediment transport and dam silting. These variations in climate and river regimes must be borne in mind when dimensioning the projected dams in the basin.

Since 1993, rainfall is on the increase again, but future climatic changes cast uncertainties on future water resources. Simulations have been carried out for the horizon 2050 with the HadCM3 model and A2 scenario. According to this GCM/scenario, there would be a slight decrease in rainfall but an increase in runoff over most of the upper Niger river basins in West Africa, but not over the Upper Benue river basins.

Agriculture, livestock and fisheries

Agriculture relies predominantly on rainfall (95% is rainfed) and cropping zones have therefore adapted to rainfall and roughly follow isohyets. In the extreme north, land is just sufficient for occasional pasture, heading south we find millet sorghum, then banana, plantain, cassava, yam and finally rice in the south as well as irrigated areas in Inner Delta in Mali, in Niger and Nigeria. Irrigation and blue water use are under developed with only 3% of agricultural land irrigated and river withdrawals representing 1.5% of annual flows. Large perimeters exist in Mali and Nigeria, but traditional systems such as recession flooding, lowland and free flooding dominate in terms of surface area. Farmers and donors now increasingly attempt to control water supply better. A number of small dams exist already in Burkina Faso, Mali, Côte d'Ivoire and are being actively developed as part of NGO and private projects.

There is a vast land potential for irrigation, however in terms of water resources, extending dry season agriculture will place strain on water stocks. Without additional dams, it is already not possible to increase dry season irrigation in the Office du Niger in Mali. Dams to support low flows would facilitate this but would also further reduce flows in the Inner Delta, reducing the extent of the flood, affecting livelihoods of a million herders, fisherman and traditional rice growers in the Inner Delta as well as the wetland ecosystems. Current agricultural withdrawals already have an impact on the Inner Delta wetlands of Mali, on the Niger delta in Nigeria and on production of hydroelectricity of the Kainji dam in Nigeria. Nevertheless, faced with food crises and climatic changes, donors are willing to fund the expansion of irrigation and the NBA plans to increase irrigation levels from 265 000 ha to 1,5M ha in 2025, mostly in Nigeria and Mali, increasing withdrawals from 9 billion m3 to nearly 30 billion m3 by 2025.

Livestock and fisheries are present across the basin and both provide essential livelihood strategies for millions of farmers/rural poor. 50 000 000 herders breed 138 000 000 livestock units (camels, bovines, small ruminants) across the basin. Production is predominantly extensive and the North-South distribution of livestock is function of their resistance to drought and their aptitude to exploit natural rangelands. There are two major livestock breeding modes: nomadic pastoralism which covers large distances annually and breed large herd of zebus, and the sedentary breeding, typically a few small ruminants and some larger bovines. The former is notably severely impacted by the development of agriculture, which notably restricts access to grazing land and water points.

Despite possible synergies between farmers and herders (grazing crop residues against manure/fertilizer), conflicts are on the rise and would require the correct implementation of legislation to support pastoralism.

Fishing activity is mainly concentrated around the large floodplains (Inner Delta) or reservoirs (Selingue, Kainji, Jebba, Lagdo). Out of 100 000 professional fishers in the basin supporting roughly 900 000 people, 62,500 are in the Niger Inner Delta and 13,000 in the large reservoirs. Total fish catch in the basin is about 240,000 tonnes per year (estuarine delta not included), with a value of almost 100 million US dollars. It has been estimated that fish represents a significant fraction of the animal protein in Africa, with 40% in Nigeria and 49 % in Cameroon. National or pro-poor policies have not, up to now, taken into account the fisheries sector, partly because their importance has not properly been evaluated. The projected demographic increase as well as the construction of dams and water withdrawals will exert increasing strain on fishers. Fish culture in ponds, around irrigated perimeters, and in cages in reservoirs can constitute a valuable solution to perturbed fisheries, however the communities presently involved in fishing are poorly prepared to manage this new activity.

Agricultural water productivity

Calculated values of WP in irrigation show that values are low 0.14 and 0.67 kg/m3, partly due to low yields, excessive withdrawals and water wastages. Improvements are possible but will require significant awareness raising as countries currently don't recognise the need to reduce water consumption. Plans to extend the Office du Niger may in part reduce water wastage as the density of plots will increase and therefore transport losses will decrease. However an increase in dry season agriculture which consumes more water due to higher ET will go against WP increases. Market gardening activities in dry season have a much greater WP than rice, thanks to a high value crop and less water wastages. Small scale irrigation where users pay for fuel to pump their water are more water efficient, however its expansion also implies more dry season withdrawals. Recommendations to develop small scale irrigation in a sustainable and equitable way should be examined.

Whatever type of irrigation, substantial yield increases are accessible without excessive investments, as farmers gain in experience and the industry becomes more organised. WP calculations should also be refined, as yield statistics should be independently verified, withdrawals data is scarce and return flows poorly quantified. Studies must assess whether return flows contribute to river flow, groundwater recharge, or are harvested by nearby farmers, and similarly the production of grasses and banana plants planted and cropped in drainage canals must be quantified.

In fisheries, correlations between flood level and fish production on one hand, and inflow and flood level on the other, allow us to derive a marginal WP in the Inner Delta where a reduction of 1m3/s during the flood period reduces fish catch of the next year by 28 tonnes. Fisheries therefore appear highly vulnerable to changes in rainfall but also impoundments (dams) and abstractions. WP in aquaculture could be calculated but as traditional fishing is a non water consumptive activity, only a marginal FWP can be calculated.

The full calculation of LWP requires data which needs refined notably amounts grazed and water evapotranspired by fodder and crop residues. Water productivities were calculated from theoretical average water consumption for animal feed using rain use efficiency. The order of magnitude of LWP is relatively low (0.002 to 0.05 kg per m3 water) which seems logical considering the place of herbivores in the trophic chain. WP should also be calculated using kJ or $ in order to reflect the increased value of meat over certain crops. The best water productivities are situated in the Sahel and the lowest in the zones above 1200 mm rainfall.

Similarly to rainfed WP, in extreme zones, the values of LWP are less intuitive and more complex to interpret. Indeed low LWP in southern latitudes does not reflect poor performance, but simply excess water, which when looking at livestock in isolation appears wasted. In northern latitudes, livestock may be the only possible use of the biomass and hence low water productivity values may not necessarily be representative of a poor performance or productivity. Eitherway, to interpret water productivity it is necessary to go back to the maps spatialising the numerator and denominator. Options to improve productivity and water productivity include a better health and vaccination coverage, commercialisation of crop residues and animal by products and better selection of shrubs and trees for use as fodder. Maps of rangeland also reveal that there is everywhere a great availability in natural rangeland, contrary to what the conflicts between livestock and agriculture infer.

The order of magnitude of rainfed water productivity is around 0.1 km/m3, around 10 times lower than under temperate climates. Within a narrow isohyet band, WP varies according to yields, however, in interclimatic zones, interpretation of RWP becomes more complex and leads to paradoxes. High WP could imply that planners should concentrate agriculture in these water efficient areas, when water resources become scarcer. However if high WP occurs only because of the very low rainfall and yields are low, then this does not imply a good investment in agriculture to reduce poverty and food insecurity. Conversely, where yields are high but where rainfall is high, WP will be low implying that water is underused. Interpretation is therefore complex and requires referring to both numerator and denominator, i.e. yield and rainfall maps. WP can provide an additional parameter in the agricultural system but does not constitute a sole indicator by which to measure performance and formulate decisions. Standard definitions and methodologies for WP are also required to enhance the ability of WP to allow comparisons.

WP results are of interest to the basin planner who wishes to know where excess water could be harnessed (for other uses potentially) but they don’t reveal whether that excess water should or could be better used for agric, or whether it is available for other uses. Issuing recommendations on how to exploit this water requires a complete understanding of the agricultural limitations as well as an assessment of the current uses and value of this drained water. WP must indeed consider the other uses of water, as water not used by agriculture, may already be used by other parts of the system (groundwater recharge, downstream users, local climate regulation, ecosystems) and therefore improving

efficiency in agriculture to reduce losses may be reducing available water elsewhere.

Overall to improve RWP it is clear though that water is rarely the limiting factor and indeed improvements in nutrients are required. Even to reduce dry spells, SI is shown to have a very limited influence unless coupled with nutrient enrichment. Combining these could provide an interesting solution/investment, as current strategies of west African farmers are to reduce the risk of crop failure and therefore resort to extensive agric with very low or no inputs. Interventions aimed at increasing fertilizer inputs, are rarely sustainable notably due to the fear of crop failure. Therefore SI could help to reduce the risk of crop failure, and in parallel, promote the increase use of fertilizer. Otherwise four main strategies exist: increase the rainfed production area, increase land productivity of the rainfed agriculture (independently of water), develop water efficiency where it is scarce (essentially north of 700 mm for millet and sorghum) and increase plant tolerance to water excess.

Institutions

Partly due to its importance at the regional level (transboundary water dependence, 91% for Niger), the continued authority of traditional chiefs but also the influence of formal colonial powers and development projects, the Niger basin presents a complex institutional and political context. The poor performance of agriculture despite significant hydrologic and agronomic potential appears influenced by the governance of water and land resources, as institutions determine incentive structure of the stakeholders and affect their behaviour (Ostrom 1990, North 1990, Runge 1992). A case study by WP4 around the building of the Talo dam in Mali confirmed the marginalisation of women and young people as well as breeders who lose access to water and land for cattle.

Despite efforts to develop IWRM at the basin scale partly through the Niger Basin Authority or ECOWAS, water management in the basin appears fragmented and resources are not yet managed adequately. At the national level, institutional reforms such as decentralization and IWRM notably encouraged by former colonial powers have sometimes only begun and have yet to be fully enacted, partly due to the lack of funds, capacity etc. In some cases, it is also simply from lack of application of the regional policies etc, or that national policies don’t cover certain aspects/situations (land and water).

While the new legislation is not passed or certainly implemented, customary laws remain dominant but this overlap of new legislation and structures creates a legal pluralism. New structures are created by decentralization reforms and other state interventions and policies but also through participatory governance requirements (IWRM principles) and development projects (grassroots NGO’s Developments programs) who create their own authorities and committees (e.g. to manage wells etc). The dynamics between these structures create a change dynamic, which is susceptible to weaken traditional authorities and institutions. It also makes arbitration more complex, and can lead to land and water governance problems and conflicts. Traditional law varies per ethnic group and community and in some cases legal pluralism results in positive institutional innovations,

notably the increased recognition of women, youth or minority groups often discriminated against under traditional law.

Water rights are greatly embedded in the land rights in most of the customary tenure systems, hence land tenure security also conditions the secure access to water resources and therefore investments in agriculture. The legal pluralism is seen as one of the main cause of agriculture productivity stagnation and rural poverty, due to the insecurity it creates in terms of definition, allocation and enforcement of land rights and consequently for the dependant water rights.

Formal land titling is often lacking and land tenure reforms often threaten existing informal land tenure agreements and fail to recognise the communal tenure as viable and economically efficient. New "bottom up" and participative land titling systems, in line with the commitment to decentralisation, are required to help to protect the tenure rights of the poor. In general, innovation is needed to design local systems to secure water and land access and property rights, rather than attempting to replace it with systems "imported".

Institutional indicators analysed for this project notably reveal the extent of this reliance on traditional collectively owned land and the low level of land security (except in Chad, Nigeria and Niger). Further analysis of the institutional characteristics of the basin countries also highlights the lack of homogeneity between the countries, despite tendencies to regroup them as "informal-fragmented".

Water and poverty

Water poverty occurs when people are either denied dependable water resources or lack the capacity to use them. The lack of a comprehensive metric that reliably captures the multi factorial characteristics of water poverty has led to a raft of measurement techniques, each with advantages and disadvantages. Just like poverty indicators, these require moving from raw data towards a composite aggregated indicator. Such indicators have become increasingly widespread and favoured by decision makers, as they provide a more legible, though often simplified view of the reality on the ground. The added simplicity facilitates communication and comparison, but reduces objectivity and representativity. Indicators which measure a relatively mono-dimensional and objective situation (e.g. childhood mortality rate) may offer the closest depiction of the situation in these communities.

Rather than attempting to develop another poverty index, the aim was to assess and develop methods to detect and analyse a hypothetical relationship between water and poverty through statistical methods and poverty mapping. Significant correlations do not imply causality but point towards water resource factors which may influence poverty. To account for a high proportion of subsistence livelihoods and a large non-market, hybrid economy we used child mortality, child stunting and a composite wealth index as poverty metrics. Data was taken from the Demographic and Health Surveys.

The analysis of spatially referenced child mortality, child morbidity and the wealth index identified three major poverty hotspots in the Niger basin, situated in

Southern Mali and the inner Delta, North East Burkina Faso and North West Nigeria. When assessing the role of water and non water related determinants in explaining the observed poverty distribution, we found that education and access to improved water quality are the only variables that are consistently significant and relatively stationary. They can therefore be addressed with whole of catchment scale policies with less attention to regional differences. The variables demonstrated to be statistically non-stationary (i.e. their influence varies across the landscape) may be more appropriately addressed using a geographically targeted policy approach. TARWR was only occasionally associated with poverty, suggesting that social or institutional factors of water use are more important than water availability. Increased irrigation development and other variables were occasionally correlated with decreases in poverty but were not systematically reliable or significant determinants.

Similar studies evaluating the significance of explanatory variables in poverty mapping have found limited correlations between poverty and agro-ecological or socioeconomic determinants. A statistical relationship between water quality and child health poverty measures seems consistent with the vital role given to water and sanitation in alleviating poverty. Improvements in agricultural water management have the potential too to reduce poverty, but the pathway is more complex and the impact therefore less immediate. Indeed beyond reliable water access, the ability to derive profit from water depends on several additional conditions such as access to land, labour, seeds, fertiliser, pesticides, tools and machinery, fuel, storage, transformation processes, roads, markets and political security.

Overall, it is difficult to isolate one contributing factor to poverty. Interactions between environmental, social and institutional factors are complex and an evaluation of poverty and its causes requires analysis at multiple spatial resolutions. One must also consider the capabilities (e.g. level of training, diverse income sources, capital and support networks) of a household or community, as these determine whether they will fall or subsist in a state of poverty, not simply the absence, presence or quality of water.

Interventions

Agriculture in the basin faces an array of problems (access to water, poor soil fertility, pests, crop diseases, lack of inputs, access to markets) and is subject to additional threats and challenges, including deforestation, siltation, water pollution, invasive plants and perhaps most importantly climate change and variability, unregulated water development (dam building) and population increase. Improvements in agricultural water management have the potential to reduce poverty in the basin. Successful interventions have been introduced over the years, however solutions to achieve sustained and widespread impacts on rural poverty are still lacking.

Recommended interventions are highly contextual and require rigorous analysis for each watershed in the basin. These include: developing infrastructure (wells, reservoirs), multiple use systems (notably integrating livestock and fisheries with agriculture), adapt crop demand to water supply & vice versa (sowing dates, water harvesting, supplemental irrigation), drought tolerant crops, fertiliser use

etc. Improvements in rainfed agriculture can have significant impact on poverty reduction and food security due to the large population dependant on it. Current farmer strategies to reduce risks (due to rainfall deficit) prevent intensification. Solutions to reduce the risk of crop failure such as rainwater harvesting, drought tolerant crops etc are necessary if farmers are to invest in fertiliser and other inputs which are essential to boost yields.

Farmers also need to be linked to input and output markets, financial services, have access to training, storage, but also secure access to land and water (possibly through communal land tenure agreements). Mitigation strategies such as early warning systems and storage options are required to help reduce the impact of extreme events. Good clear governance is required to ensure water resources are developed in an equitable, participatory and sustainable way.

Future threats

Results from climate change modelling present many uncertainties and contradictions, however on average there is a trend towards: an increase in T°, in variability and extreme events, a later start to the rainy season, more dry spells, and overall more rain in central part of WA and decrease in the West. To model the effect on yields increases uncertainties as we must account for increased evaporation, possible decreased rainfall and increased CO2 fertilisation, but there is little doubt that climate change risks increasing the strain on already vulnerable agriculture.

Under the Niger Basin Authority investment plan, several large dams are due to be built. This will have effects on local people but also on people downstream. Various scenarios have been studied in the literature, and all scenarios will inherently have an impact on one element of the system. Tradeoff analysis must be undertaken in consultation with local stakeholders to ascertain which element must be favoured (hydropower, irrigation, fisheries, ecosystems…) and how to minimize negative impacts. Expansion of the Office du Niger irrigation project for instance will result in a decreased flood in the Inner Delta, affecting traditional rice growers, herders and fisheries. Fish production will notably reduce by 8500t/yr.

Projected population increase in the basin could well jeopardise current and future development efforts. The basin population estimated around 95 million in 2005 is expected to double by 2050 in the lowest scenario and could be multiplied by 4 if fertility remains constant. Current fertility rates exceed 6-7 children per woman and as mortality has started decreasing, demographic increase rates now exceed 3% per year. More worryingly, in countries like Mali (contrary to Ghana) fertility is not decreasing, resulting in a progressive rise in demographic increase rate. Future population trends will therefore depend on the speed of fertility decrease and the prevalence of pandemics such as HIV/AIDS. Clearly the additional demand on water and food resources to feed up to 300 million additional people added to the projected change in diets, climate change, and water demand for industry and hydropower, will lead to significant pressure on natural resources and ecosystems and increase vulnerability of rural poor communities.

Synthesis Report

1. Introduction

Faced with increasing food and water insecurity as a result of climatic and anthropogenic (demography, land use) changes, the CGIAR Challenge Program for Water and Food commissioned research in 10 river basins to study the links between water, food and poverty. Looking at the Niger River basin, we carry out a diagnosis of the hydrologic and agronomic potential, before attempting to identify how good agricultural water management may reduce vulnerability in the region, and preserve local ecosystems. Major future threats and opportunities, as well as the influence of institutions on water and agricultural development are discussed.

2. Overview of Niger River basin

2.1. Geography

Situated in West Africa, the Niger river with a total length of 4200 km is the third longest watercourse in Africa after the Nile and Congo/Zaire. Spread across ten West African countries and spanning from hyper-arid to subequatorial climate, the basin covers a surface area of 2,170,500 km^2 making it the 9th largest in the world (Showers, 1973). The northern section of the basin, which extends towards the Sahara desert and into Algeria, is considered hydrologically inactive. The *Active* basin covering 1,272,000 km^2 will be used for the purpose of this project. The nine countries sharing the active basin are members of the Niger Basin Authority (NBA): Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Nigeria and Niger. 65% of the active basin is situated in Mali and Nigeria (Table 1). Algeria has an important part in the inactive desert basin.

Table 1: Basin size per country (in km^2 and in proportions) (Marquette 2008)

Country	**Basin size per country (km²)**	**Proportion of basin within country (%)**	**Proportion of country within basin (%)**
Benin	44,967	3,5	38,7
Burkina Faso	86,919	6,8	31,5
Cameroon	86,381	6,8	18,4
Côte d'Ivoire	23,550	1,9	7,3
Guinea	98,095	7,7	39,9
Mali	263,168	20,7	20,9
Niger	87,846	6,9	7,4
Nigeria	562,372	44,2	61,5
Chad	19,516	1,5	1,5
TOTAL Active Basin	1,272,814	100	-

2.2. Hydrology

The Niger River starts its journey in the mountains of Guinea and Sierra Leone (50km^2 are in Sierra Leone) before travelling North East towards the Sahara, and during the raining season it forms a vast flood plain in Mali known as the inland Delta. After the Inland Delta it eventually buckles back towards the South East and Nigeria, where it is joined by the River Benue and finally reaches the Atlantic Ocean through the Niger Delta in Nigeria.

From the stand point of water resources, the Niger Basin can be divided into four zones with more or less homogeneous physical and geographical characteristics (Figure 1).

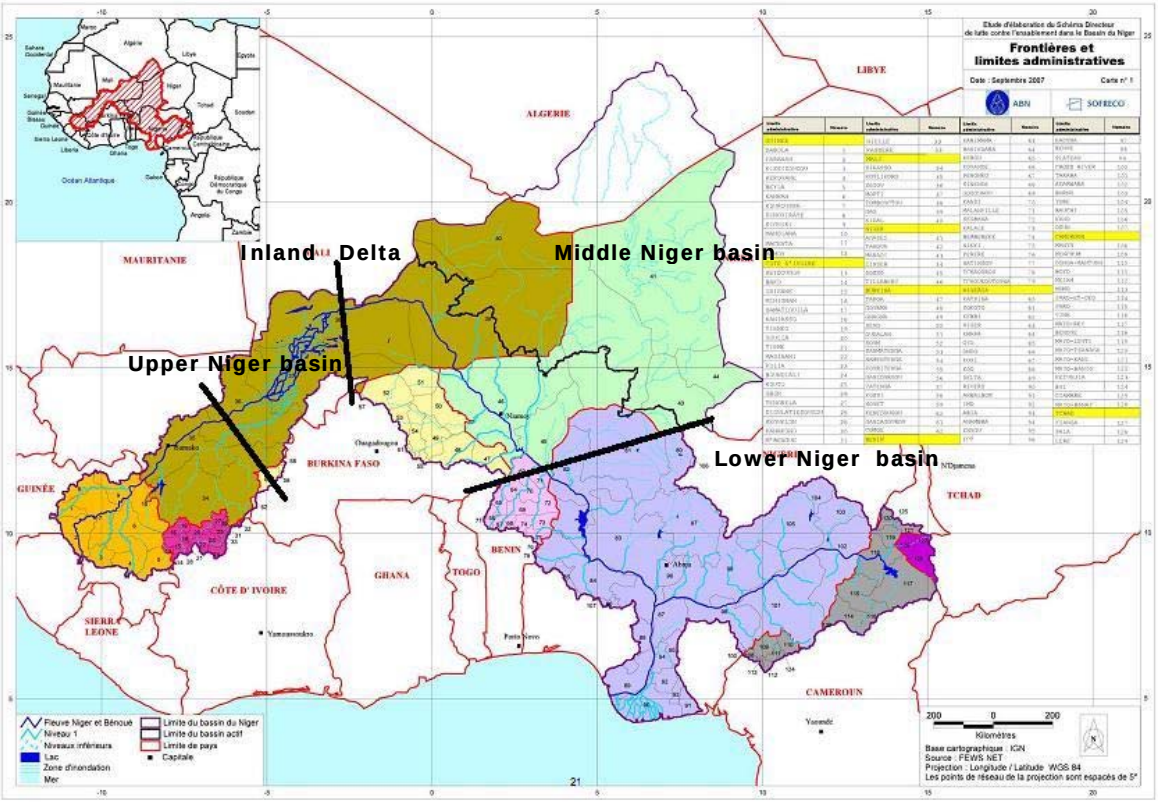

Figure 1: Niger River Basin: the different countries involved, and main regions (Mahé et al 2009).

The Upper Niger Basin; it is found in Mali, Guinea, and Ivory Coast. It covers a surface area of 257 000 km^2 out of which 140 000km^2 are situated in Guinea, serving as the watershed and is seen as the portion which can be used to partially regulate water flow through out the length of the river.

The Inland Delta; Entirely situated in Mali, it covers a rectangular area facing south west and north east with a length of 420 km and a width of 125 km between Ke-Macina and San in the south and Timbuktu in the north. It has a surface area of 84000 km^2 and comprises four agro-ecological zones: the living delta, the middle Bani-Niger, the dead delta and the lakeside zone between Gao

and Timbuktu. It accounts for almost all of the rice cultivation which is the staple food in Mali. This is done thanks to the Markala Dam.

The Middle Niger Basin. It lies within Mali, Niger, Benin and Ivory Coast. It stretches from Timbuktu to Benin, covering an area of 900.000 km^2, 230 000 km^2 of which are inactive. It is made up of a series of irrigated terraces. Water flow in this basin largely depends on additional influx from the Inland Delta and navigation is hampered by waterfalls.

The Lower Niger Basin: It lies between Cameroon, Nigeria and Chad. Rainfall varies from 700mm in the North (Sokoto) to more than 3 000 mm in the South (Niger delta). It is characterized by big dams for hydro-electric power production, irrigation and by industrial activities on the rest of the basin. Energy production is mainly derived from the Kainji, Lagdo and Jebba dams which supply 68% of Nigeria's electricity needs and 22% of her total energy needs.

The first two sections display an endorheic behaviour; whereas the total annual mean flow entering the Niger Inner Delta is estimated at 46 km^3, the mean annual flow is only 33 km^3 at Taoussa, immediately after the inner delta, which can reach 30,000 km^2 in flood season. Within the Middle Niger, the river loop receives 6 tributaries from Benin and Burkina Faso. The mean annual flow entering the Lower Niger is 36 km^3, but with the contribution of its main tributaries (above all the Benue River), the mean annual flow entering the sea at the mouth is 180 km3.

2.3. Agroclimatic zones

The Atlantic monsoon divides the climate in two seasons: dry season and wet season. Their relative lengths correspond to variations in rainfall and temperature. These values progress following a North South gradient between the Atlantic Coast and the fringes of the Sahara desert. Spatial rainfall distribution over the basin is relatively homogenous on East-West axis but vary from a few mm of rainfall per year (to zero mm some years) in the Northern reaches of Mali and Niger to more than 4000mm in Southern Nigeria/Cameroon. Average values of isohyets enable us to identify six major climatic zones (Figure 2).

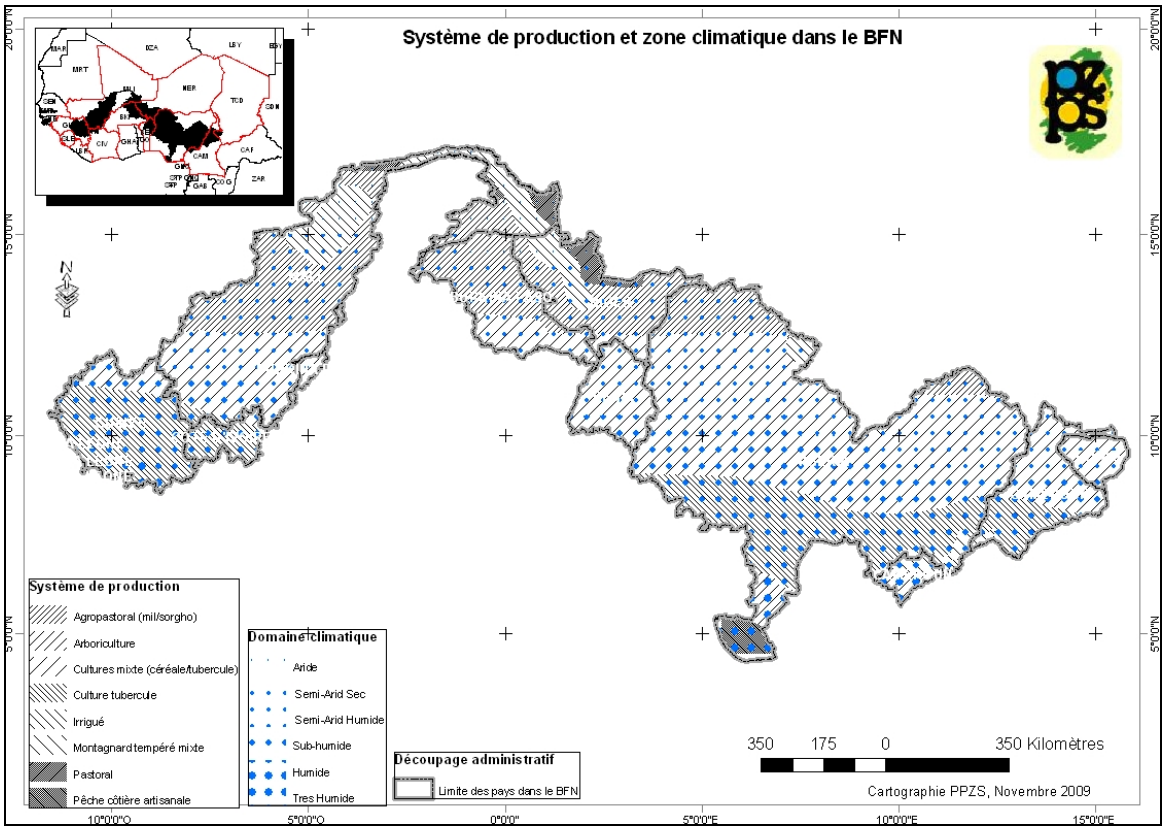

Figure 2: Niger basin climatic zones (Diop et al 2009a)

Apart from the most southern coastal areas, all climates with unimodal rainfall patterns are subject to annual spatiotemporal variations capable of affecting agriculture due to water excess or shortages. The River Niger basin suffered an important rainfall deficit in the 1970s and 1980s, which occurred over the whole basin. Rainfall-runoff graphs over the last century in the Upper Niger basin reflect well the major droughts (Figure 3). Though rainfall is on the increase again since 1993, rainfall patterns are erratic and still affected by more severe drought periods. Short dry spells of a few days provide further difficulties and uncertainties in rainy season agriculture.

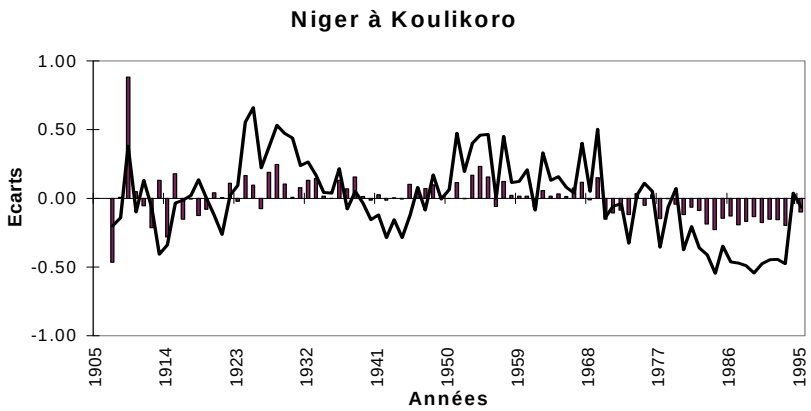

Figure 3: Rainfall-runoff in the Soudano-guinean part of the River Niger in Mali and Guinea (Mahé et al 2009)

From the fringes of the desert to the Atlantic mangroves of the Niger delta, the Niger river flows through a large diversity of biotopes. These can be categorised as follows (Table 2):

Table 2: Dominant plant association per climatic zones (adapted from White 1983)

Climatic zone	**Precipitations (mm)**	**Plant associations**
Saharan	< 300	certain plants characteristic of wadis (e.g. Tamarix) and of shady, rocky, gravely or saline faces (e.g. Cornulaca, Calligonum, Fagonia
Sahélien	300 - 750	Semi-desert grassland and thorny shrubland (north) to wooded grassland and bushland (south), with Acacia spp., Commiphora africana, Balanites aegyptiaca, Euphorbiaceae, and abundant dryland taxa
Sudanese	750 - 1200	Woodland and dry forest, with Celtis integrifolia, Hymenocardia acida, Lannea, Prosopis africana, Mytragyna inermis, etc
Guinean	1200 – 1800	Mosaic of dry, peripheral, semi-evergreen rainforest and woodland or secondary grassland
Subequatorial	1800 - 2500	Lowland rainforest and swamp forest with very diverse endemic flora including Chlorofora, Holoptelea, Uapaca, Musanga and Elaeis guineensis (oil palm); montane rainforest and grassland (above 1000 m altitude) with Olea hochstetteri, Podocarpus and Ilex
Equatorial coastal	> 3000	Secondary forest of plateau and lowland, coastal ecosystems (mangroves) and or coastal savannah

Through the combined effect of crop growing, nomadic herding, reduction of fallow period, erosion, and repeated droughts north of the 13th parallel, these ecosystems are eroding. In the tree rich fallow zones, subsist a number of large rangelands maintained by village communities (Milleville, 2007). These contain shea butter trees, parkia biglobosa (for soumbala), gum tree, silk-cotton tree, etc and offer substantial and even profitable harvesting opportunities to populations.

2.4. Demography

Population in the Active Niger River Basin is estimated at 94 million people in 2005 (calculated using SEDAC GPWv3). Due to a very high fertility rate, the current population growth rate in the basin is estimated at 3.2% (Bana and Conde, 2008, Bakiono, 2001, Guenguant, 2009) and demographers estimate that

the population could double by 2025. Populations of most countries in the basin increased by 50% between 1990 and 2005 (Tabutin et Schoumaker, 2004.) Like many parts of sub-Saharan Africa, the demographic transition has not been completed and there are concerns that fertility rates will not drop as usual, leading to fears of a population reaching 300 million by 2050 (Figure 4). The weight of this future population could well jeopardise current and future development efforts.

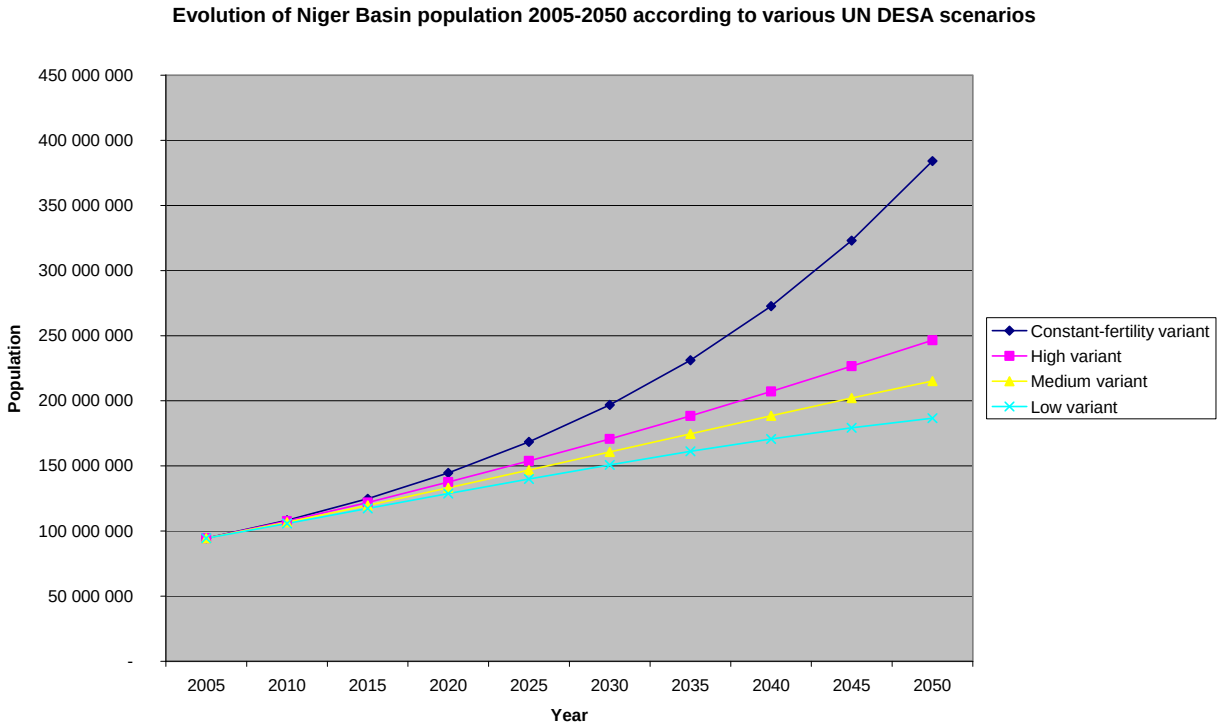

Figure 4: Evolution of Niger Basin population 2005-2050 (based on UN Population Division (2006))

Population density in the basin is high compared to national averages (up to 4 to 5 times greater), as populations gather along the Niger River, their lifeline. In Mali 70% of the population is concentrated along the river. Population densities also reproduce the distribution of humans in the past centuries. Desert fringes are lowly populated, less than 1hab/km², but between the 11 and 13th parallel, there is a band of high density, a vestige of the ancient Sahelian empires which controlled the transaharian routes until the contemporary period (Fage and Tordoff, 2002). Along the Niger river the ancient cities of Bamako (Mali) and Niamey (Niger), have become modern capitals and their populations have grown from a few thousand inhabitants to several million over the past fifty years. The second highly populated band stretches between the towns of the coastal states (Port Harcourt, Lagos), important market/export towns since centuries for all central Africa. 71% of the population lives in Nigeria.

Population is predominantly rural (64%), however this is changing rapidly and by 2025 the majority may live in the cities. The urbanisation is fuelled by a massive rural exodus, as well as a century old migrations from inland areas to coastal

areas (Pourtier, 1998) and sustained by recent political and climatic crises. This urbanisation modifies radically the relation of people to land, creating a land tenure market. Nowadays the largest divide within the basin society is the rural-urban divide. The former lack virtually everything (electricity, water, health, education) forcing them to rely on traditional mutual aid and NGOs

Population is young (44% are under 15 years of age), largely illiterate (35% literacy rates, only 18% for women) and with an average life expectancy of 50 years. (Aboubakar, 2003; Bana and Conde, 2008). Though mortality rates have reduced, they remain extremely high and up to 25% of children do not reach the age of 5 (Guenguant, 2009). After respiratory diseases, water related diseases such as malaria and diarrhoea are the major causes of mortality (UNICEF, 2008 ; OMS, 2006). Mortality rates in rural areas exceeds those in urban areas, due to lack of health infrastructures (less than one doctor for 100 000 inhabitants, against 1 for 15 000 in towns (OMS, 2006).

2.5. Sociology and institutions

The ethno-linguistic diversity in the basin is one the richest in the world with other 400 vernacular languages and five official languages. Though half of these could disappear by 2050, the sheer number of these restricts the circulation and dissemination of information and innovations.

Traditional customs, influenced by animist culture, continue to define local activities and practices, with customary assessors for instance taking part in the audience at local tribunals (Clanet, 1994; Vatican, 2009). Some continue to exert considerable influence locally, such as the sultans of Chad, of North Cameroon (Rey Bouba), Niger (Zinder), Mali (Mopti) or the animist kingdoms such as the Ngong de Léré (Tchad) or regencies Bamiléké (Cameroun), of Sokoto (Nigéria) or (North Benin). In these societies, where castes and forms of slavery persist (Amnesty International, 2008), rural areas are part of feudal powers, which do not favour innovation. The most vulnerable, such as women and children, will difficultly take initiatives to allow them to escape their condition (Barrière, 2002.).

From lack of centralised administrations implementing their directives, village and land chiefs are able to maintain considerable influence and power (Jacob, 2005). Nevertheless reforms and state decentralisation encouraged by exogenous powers from the 1960s are creating new dynamics, such as the formalisation of women's role in local assemblies which may result in modernisation. Change is notably fragilising certain traditional chief hoods which disappear unable to resolve local conflicts over resources (Schönegg and Martel, 2006; Clanet and Ogilvie, 2009), or benefit from national or NGO development programmes.

In addition to local powers, state and regional institutions (CEDEAO, UMOA, CILSS, Club du Sahel) now influence the decisional framework in the basin. They are relatively recent, dating back to the 1960s and have kept close links with the former colonising powers in the aim to promote through bilateral agreements agricultural policies. Subject to conditional aid, they cooperate with development programmes, but often remain unable to sustain or impulse them. After a period

of relative weakness, the NBA's new orientations, including disseminating the shared vision process, support to local user groups and crucially its role in allocating Niger river resources, make this institution a key player (Zwarts et al., 2005).

Furthermore, internal political tensions and peripheral rebellions undermine central powers and development efforts. In 2008 and 2009, the basin countries experienced:

Table 3: Social crises in the basin (IRIN 2008, 2009)

Country	**Contested elections**	**Food strikes**	**Rebellion**
Nigeria	X	X	Delta
Mali	-	x	North
Niger	X	x	North
Guinea	X	X	X
Burkina Faso	-	x	-
Côte d'Ivoire	X	-	Splitting of country
Benin	-	-	-
Cameroon	-	X	-
Chad	X	X	East and South

2.6. Economy and agriculture

GDP of the basin countries, just as the overall HDI indicator are amongst the lowest in the world (Table 7). Agriculture represents a large part of the Niger River basin GDP; crop production forms 25-35% of the basin GDP, livestock 10-15%, and fishery 1-4%.

Agriculturally, there are over 2.5 million ha of arable land, of which only 20% are exploited. Though the Niger basin possesses one of the largest humid areas, 27 large dams (ABN, 2008, BRL, 2008) and over 5 000 small dams (Cecchi, 2009) irrigation is poorly developed, while rainfed agriculture is carried out on 70 to 85% of cultivated areas.

Subsistence agriculture represents 78% of total agricultural production volume (OCDE, 2008) and dominates all forms of rural activities. It remains an itinerant agriculture with extensive characteristics: low mechanisation, lack of inputs (except Nigeria, which possesses fertiliser factories, thanks to its petrol, (Serpantié, 2009a)), and where much of the labour is carried out by women and children. This extensive agriculture is currently the only solution available to farmers facing climatic uncertainties, inadequate support and the absence of commercialisation strategies (Serpantié and La Machère, 1989). Statistics reveal that agriculture has succeeded in meeting the increased demand in food, as daily per capita production is stable since twenty five years (2000 kcal). However, the

projected demographic increase coupled with the increase in diets to 2500kcal/capita/day is likely to cause difficulties (CEDEAO, 2007).

Livestock and fisheries are two important livelihood strategies. There are two major livestock breeding modes: nomadic pastoralism which covers large distances annually and breed large herd of zebus, (Diop et al, 2009a) and the sedentary breeding, typically a few small ruminants and some larger bovines. South of the 8th parallel, the presence of trypanosomiasis reduces the presence of bovines, in favour of taurine and goat breeding resistant to tsetse. In total, the basin holds more than 138 000 000 LU (Diop et al., 2009a).

After independence, agricultural policies favoured export cash crops (coffee, cacao, cotton, groundnut…) developed during the colonial era. Development continued in parts, and cotton farmers now produce 2 M t of cotton fibre, grown over 3M ha against 800 000 ha 45 years ago. Yields also rose from 400kg/ha to 1t/ha today. Comparatively, cereal crops (maize, millet, sorghum) are grown on 9, 16 and 14M ha respectively. Cotton production has enabled the growers to improve their livelihoods and also become some of the major cereal growers in the region (CEDEAO, 2007). Conversely, coffee production in Côte d'Ivoire, Cameroon, Nigeria and Guinea has decreased since the 1960s to 240 000 tonnes (CEDEAO, 2008). Côte d'Ivoire is the world's largest cacao producer but production within the basin is low and confined to the southern regions due to the humid climate it requires.

The basin countries possess significant amount of mineral resources, including gold, bauxite and uranium. Nigeria is the largest petrol and gas producer in the region, and its reserves are estimated at 36M barrels, mostly situated in the Niger Delta. With Cameroon (0.7 M barrels), Chad (0.9 M barrels) and Côte d'Ivoire (0.1M barrels) they possess in 2007 3 % of the world oil reserves (CEDEAO, 2007)

Installed hydroelectric potential is estimated at 6 185 GWh, representing only 20.6% of the basin's potential. As in many parts of Africa, the Niger basin suffers from a huge deficit in transport infrastructure, which undermines economic growth and regional integration. The rail network is very poorly interlinked and countries like Niger, Chad do not have a railroad network. Surfaced roads represent less than 23 % of the total road network (CEA, 2007) Improvements are being made but important efforts remain to simplify transport, remove complicated border crossings. Alternate routes of transport (water, rail) for heavy and bulky loads (minerals, fuel…) are underused and in need of development

3. Water Availability and Access

Despite a relative increase in rainfall since 1993, the West African drought has now been lasting for nearly 40 years. It has tragic consequences in the Sahel countries, such as desertification. This drought, which is notably characterized by a decrease of rainfall, global surface-water flows and by a change in the rainy season characteristics, contributes to reduce the water availability in the Niger River Basin. This climate shift must be borne in mind if one wants to understand the present hydrology and water uses in the basin.

3.1. Water resources in the basin and their variability

Inventories of data are available by consulting the data base of the NBA and the SIEREM base from HydroSciences Montpellier Laboratory. Direct observation of surface water flow on the topographic slope of the Niger enables us to realize that some parts are not hydraulically linked to the river. These include the Algerian section of the basin (the Tassir Oua Ahaggar region) and those of Tamesna and Tahoua found in Mali and Niger. Great tributaries of the Niger which used to drain these regions at humid times, at moment can only subsist in dry valleys covered by great thickness of sand. Even the Continental Terminal aquifer found in the Iullemeden Sedimentary Basin is cut off from the hydrological system of the River Niger. It is the same situation with the Gando and the Liptako regions at the boundary between Mali and Burkina Faso.
The active hydrological section of the basin (the contributory basin) is formed by two parts linked between Dire and Tossaye by a bay in which the basin only limited to the canal formed by the river bed (Figure 5).

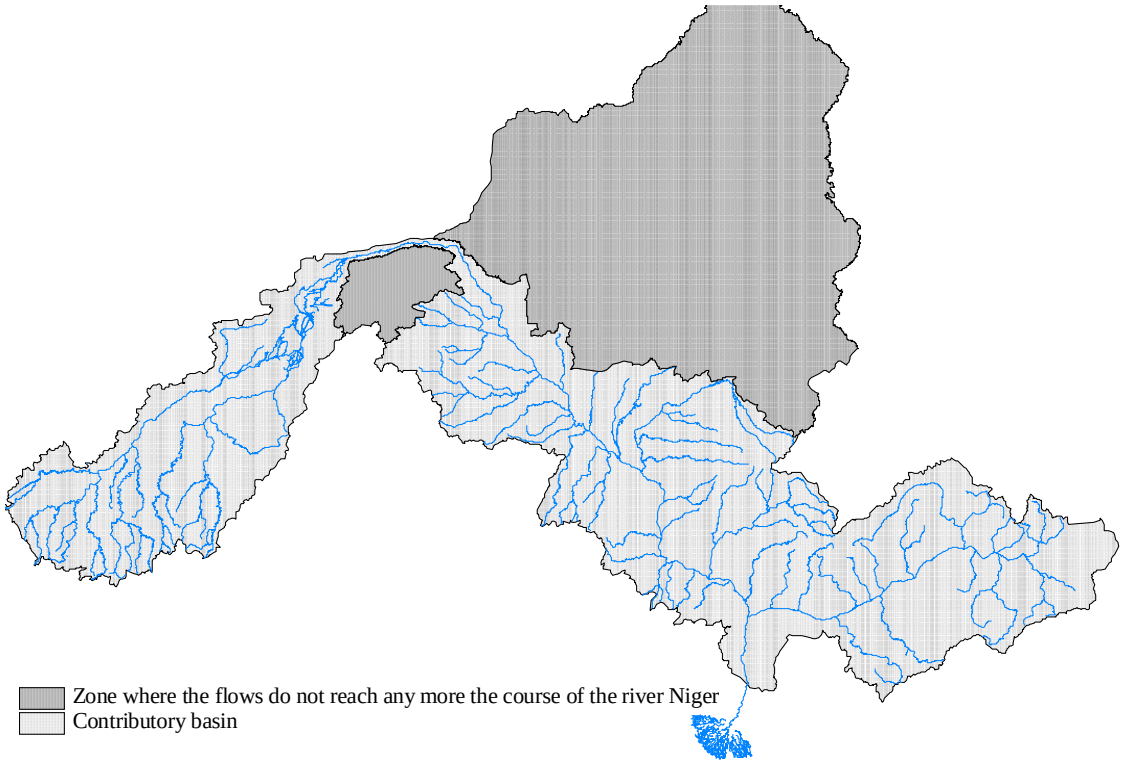

Figure 5: Contour of the Niger basin

3.1.1. Rainfall and climatology

The rainfall regime of the Niger River depends on the fluctuations of the Atlantic Monsoon which generally occurs between May and November. The intensity of the phenomenon is relatively homogeneous on the east-west axis but experiences a serious gradient in the north- south axis. There are 530 rainfall stations and 105 climatic stations with at least 20 years of observations. Data from Nigeria and Guinea are difficult to recover.

The average annual rainfall rises to 4000 mm in portions further south in the basin, while it decreases to less than 400 mm (0 mm some years) in the north under Sahelian and semi-desertic climate (Figure 6).

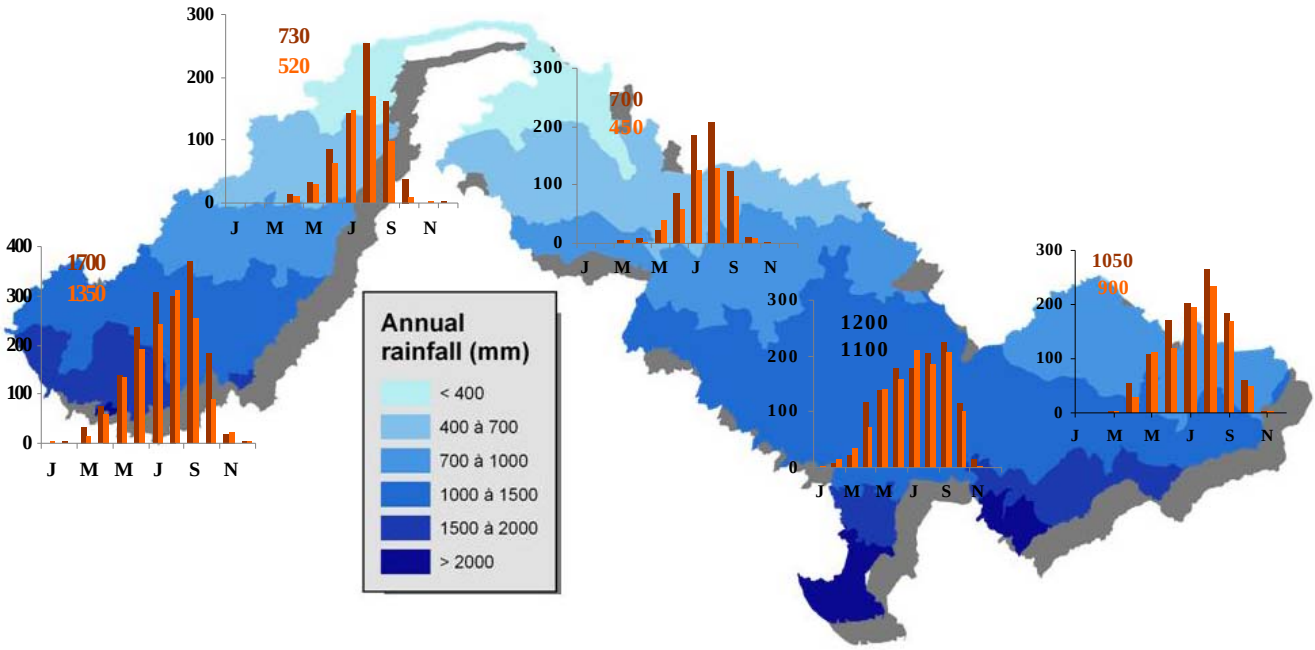

Figure 6: Niger River Basin: climatic zones and monthly rainfall illustrations

A great part of the basin experiences a high evaporation due to the vicinity of the Sahara. This has a great influence on the availability of water notably on free water plains (inland drainage and large water reservoirs). Potential evaporation is lower in the southern part of the basin and higher in the North (Figure 7). The difference between rainfall and PE determines the availability of water to infiltrate the soils towards underground layers. This monthly inventory evaluation defines the agricultural calendar (Figure 8). When rainfall is lower than ETP, (p-E.T.P<0), the water reserves in the soil are very low or even absent. In this case there is neither stream flow nor infiltration. This is the state of affairs experienced in the basin between November and April.

On the contrary when rainfall is above the ETP (P-E.T.P>0) water reserves in the soil are much more important therefore favouring agriculture. The monthly variations in the differences between rainfall and ETP will define the agricultural calendar as well as the start of stream flow which start in the humid parts of the Basin (Guinea, Cameroon and Nigeria) between May and June .The Sahel regions of the basin are only involved between July and September.

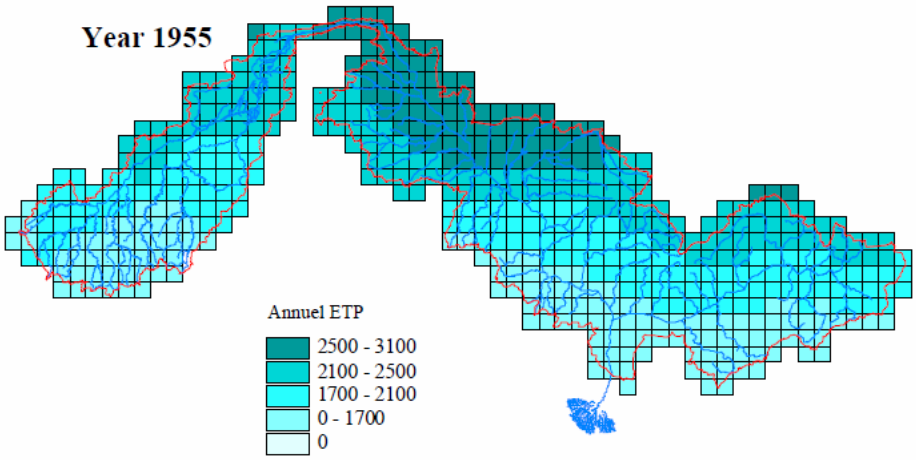

Figure 7: Annual PE: Humid year 1955, in mm.

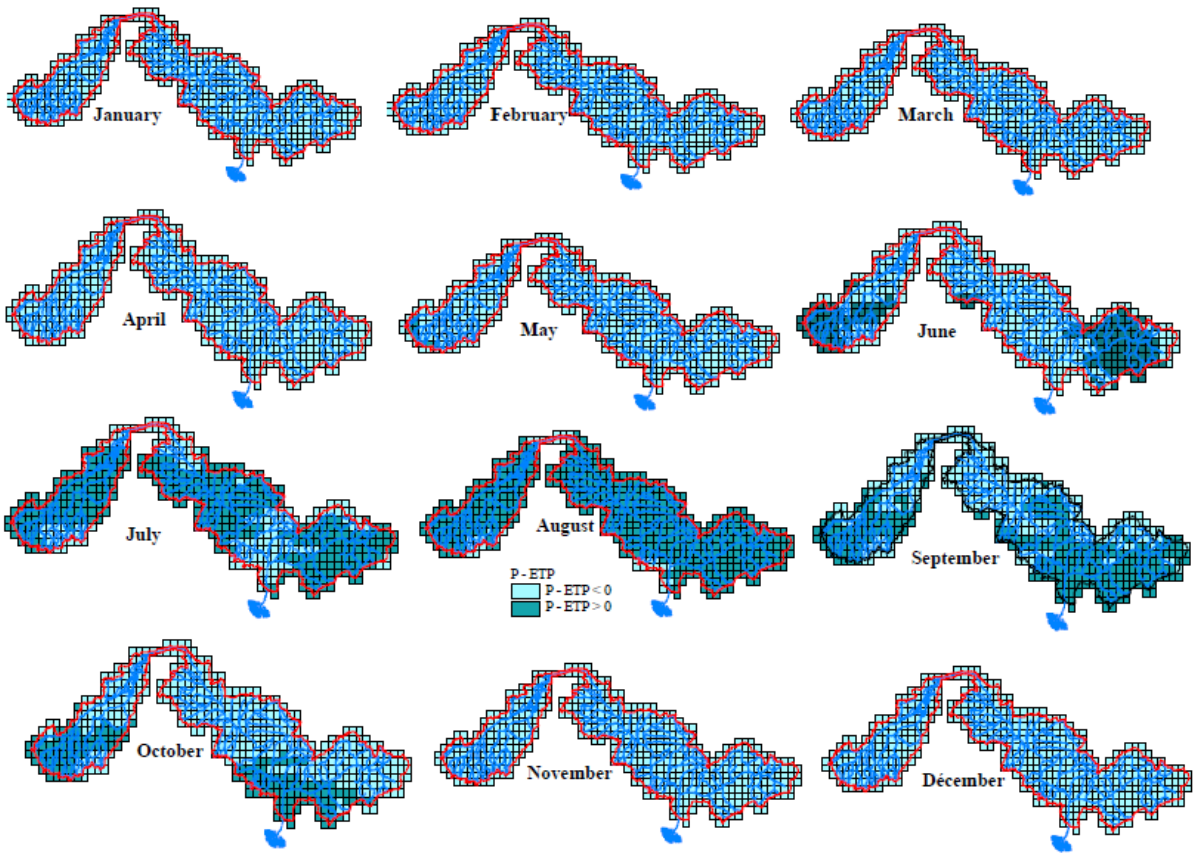

Figure 8: Monthly difference between rainfall (P) and potential evapotranspiration (ETP) in 1994, for half degree squares. Light blue: PE>P; dark blue: P>PE.

3.1.2. Flows

3.1.2.1. Rainfall-runoff variability

The hydrologic times series for the Niger began in 1907 with the installations of stations in Koulikoro (Mali) and Jebba (Nigeria). The present hydrologic observation is estimated at 250 stations including the specific network meant to check the river flow within the framework of the Hydroniger Programme. The

volumes discharged are lower in the upper basins, and increase strongly when entering Nigeria where rainfall is heavy over the Niger basin (Figure 9). The hydrological regimes strongly changes for the Upper Niger when passing through the Inland delta, where the flood is delayed by two to three months, and is reduced by 24 to 48% during extremely dry or wet years.

The River Niger basin has been submitted to a strong rainfall deficit since 1970, which occurred over the whole basin. All the sub-basins experienced a reduction of runoff. The 80s are the driest decade since the beginning of the 1900's century (Figure 10). The rainfall deficit is less strong in the southern part of the basin, mainly over the Benue river basin. The Niger basin can be divided into three main areas: the Upper basin of the River Niger in Guinea, Mali and Ivory Coast, where the runoff deficit is very strong (Figure 3); the lower River Niger basin, including the Benue river, where the runoff deficit is limited; and the Sahelian tributaries, mainly in Mali, Burkina-Faso and Niger, where the runoff has increased, due to changes in land-use (

Figure 11).

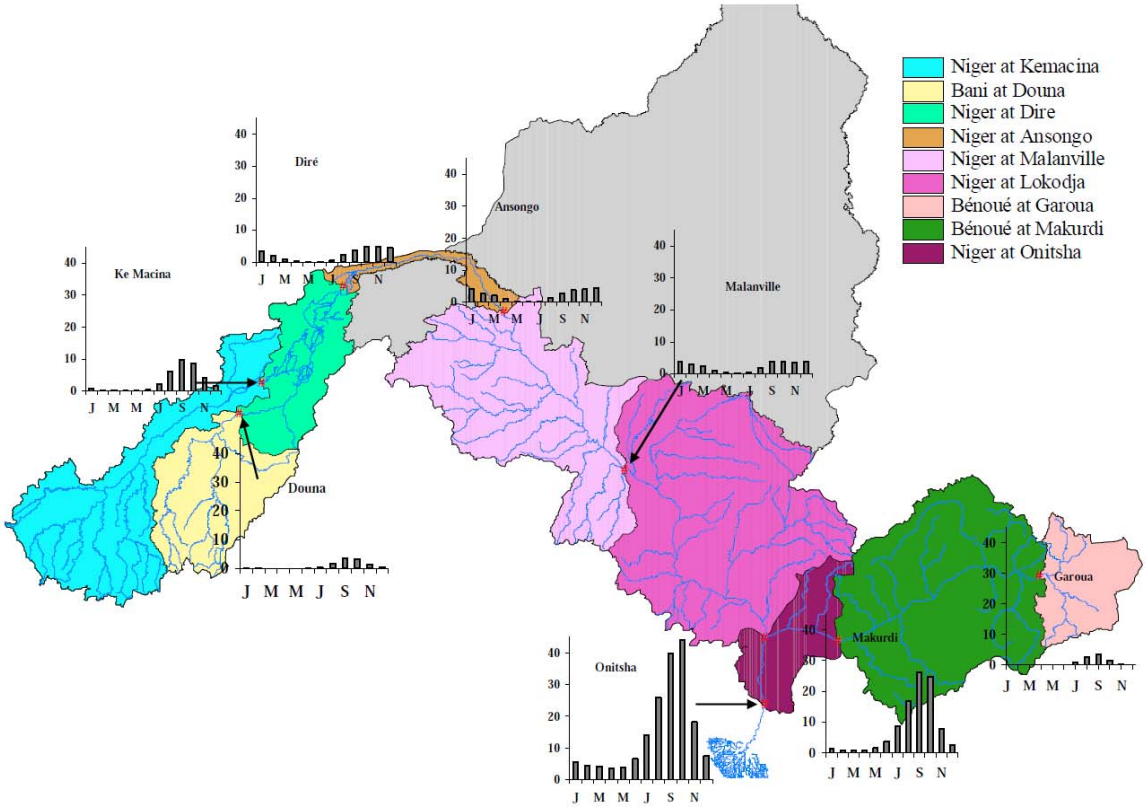

Figure 9: Monthly average volumes (in billion of m^3) (1960-1990).

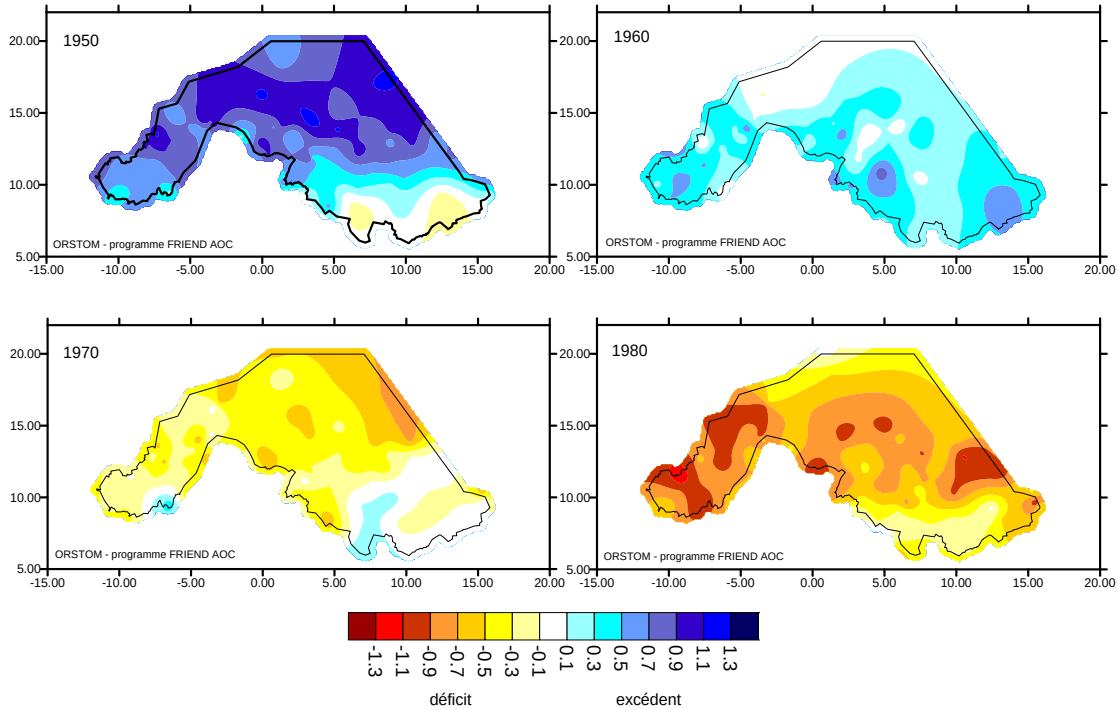

Figure 10: Rainfall index over the River Niger basin (Paturel *et al.*, 1997).

In Sahelian parts of the basin runoff coefficients have seriously increased, which lead to higher flood peaks, erosion, sediment transport and dam silting (

Figure 11). This is linked partly to the climate change-related rainfall reduction, but mainly to the increase of the cultivated surfaces, and the related disappearance of the natural vegetation. In Soudano-guinean parts of the Niger River basin, the runoff decrease has been much deeper than that of the rainfall, due to the cumulative (memory) effect of the rainfall lasting shortage on the groundwater levels.

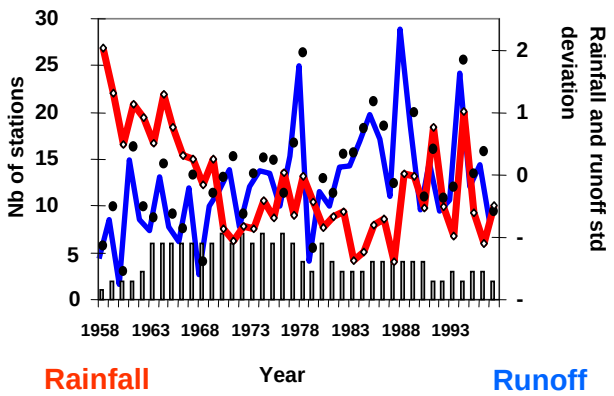

Figure 11: Rainfall-runoff relationships in Sahelian tributaries of the River Niger.

3.1.2.2. Groundwater resources

Discontinuous aquifers are mainly found on the right bank in the Niger (Guinea, Mali, Ivory Coast, Burkina Faso and Niger) in the Guineo-sudanese zones and the Sudano-sahelian zone. Pipe borne water projects in these villages make use of

such aquifers. Specific flows and the rates of failure in bore-hole realization are very unsteady (between 30 to 70%).
Generalized aquifers can be found in large sedimentary forms, especially on the right bank of the Niger River (Mali, Niger, Chad, Nigeria and Cameroon).

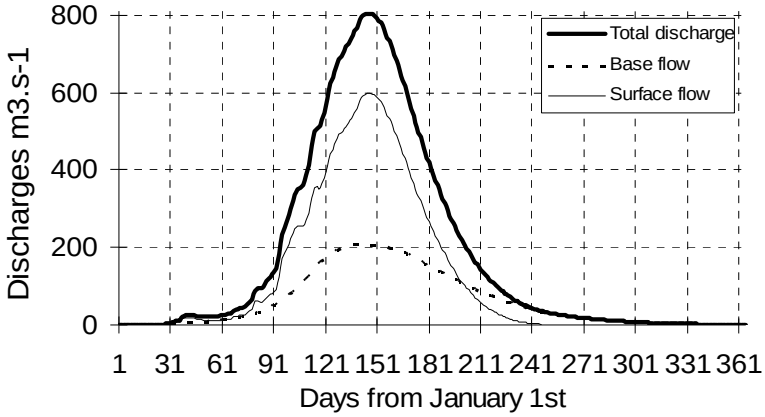

Figure 12: Annual hydrograph for the Bani River at Douna. Total Runoff (bold line) / Surface runoff (thin line) / Base flow (dashed). Average 1984-1996.

On plateau surfaces, superficial aquifers are superimposed to deeper aquifers. The outer aquifers can be partly continuous thereby forming a hydraulic link with the deeper layer or it can be discontinuous. The Figure 12 shows the importance of the baseflow in the annual runoff. This is for the Bani at Douna, but this is representative of most of the River Niger tributaries, from Guinea, Mali, Ivory Coast and Cameroon, under Soudano-guinean climate.

3.2. Accessibility to water and its uses

3.2.1. Reservoirs

3.2.1.1. The existing dams

260 dams have been identified within the Niger basin catchment (Figure 13). Their distribution is irregular and they are concentrated on some sections of the basin, notably in Burkina-Faso (mainly small dams) and in Nigeria (all sizes including large dams).

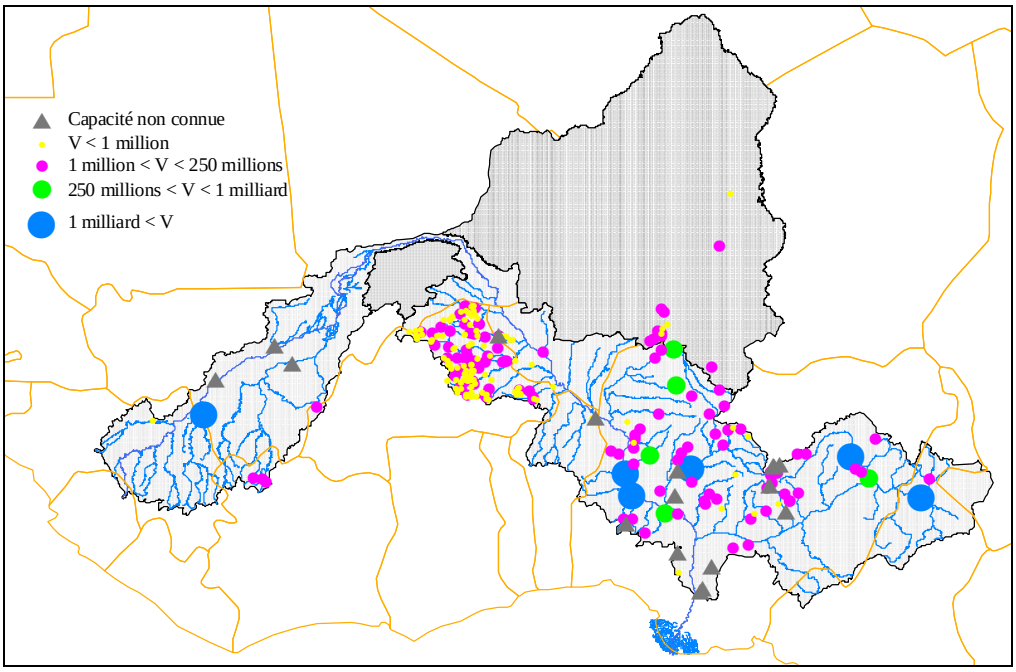

Figure 13: Niger River Basin: Situation of existing dams.

Carrying capacity varies between 25.10^{-3} million m^3 (Camp de chasse, Tapoa, Niger) to 16 billion m^3 (Kainji, Nigeria). Figure 12 shows the class distribution of the carrying capacity of all the identified dams. From this distribution 50 % of them are small dams of less than 1 million m^3, and there are only 4 "giant" dams (more than 1 billion m^3): 1 in Mali and Cameroon and 4 in Nigeria.

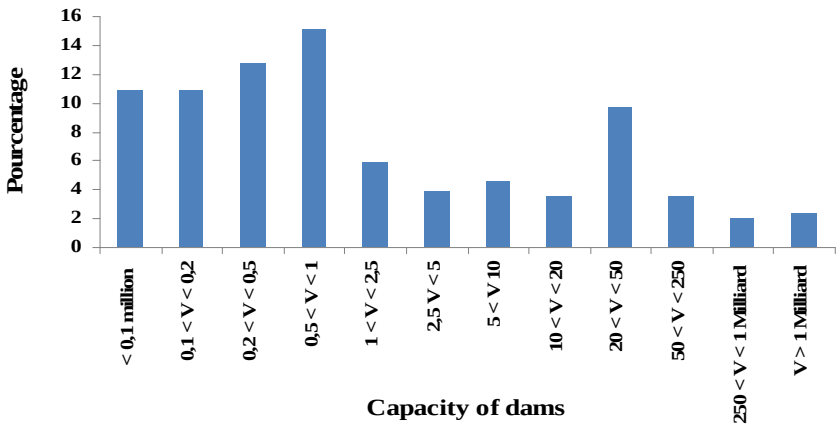

Figure 14: Class Distribution of the Capacity of Dams

An evaluation of the capacity of the existing dams places the global volume at 42 billion m^3 which represents 22% of the water influx from the Nigerian Onitsha between the dry periods of 1971 and 2001; and 27% of the same influx in the same station during the rainy seasons between 1929 and 1970. This situation reflects the poor mastery of water resources in the Niger and its tributaries.

3.2.1.2. Projected dams

Seventy dams are planned in the basin of the River Niger, mainly on the middle and upper Niger valley, in Niger, Burkina-Faso, Mali and Guinea. The only

projected sites for construction works in the lower Niger are those of Makurdi, Lokoja and Onitsha.

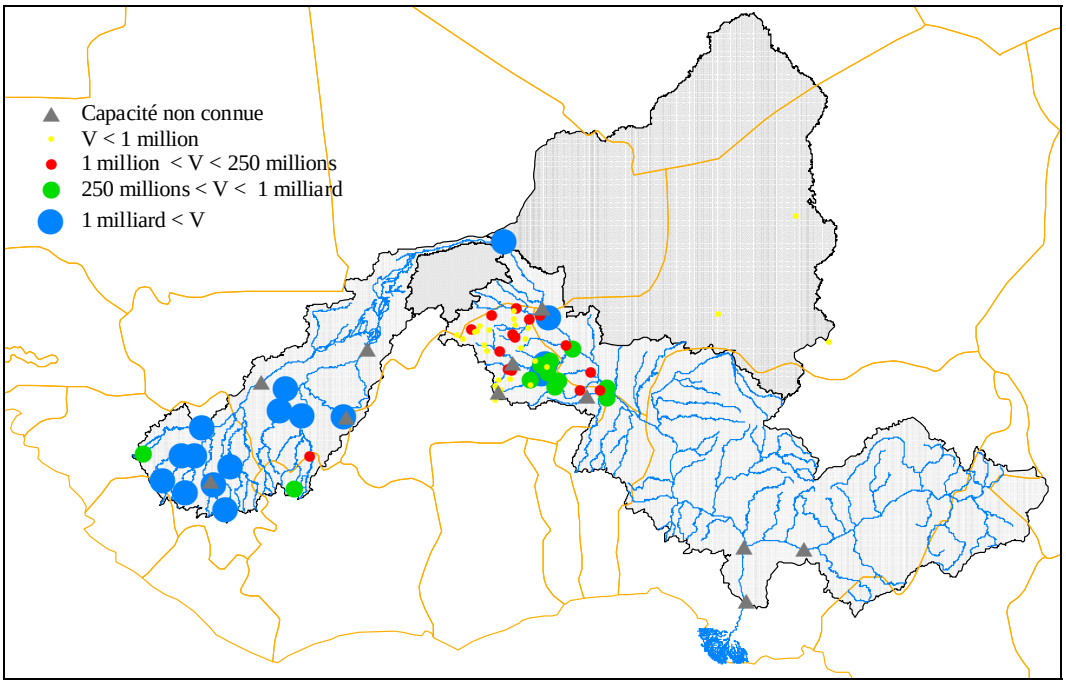

Figure 15: Niger River Basin, situation of projected dams.

Projected capacities reach 6 billion m^3 (Fomi site on the Niandan in Guinea). The total capacity on the entire basin is about 48 billion m^3 with the projected dams as against 42 billion m^3 currently. More than 80% (39 billion m^3) have been previewed to be stored in the Upper Niger and 20% only (9 billion m^3) to be kept in the Middle Niger.
Considering the existing and projected dams in the Upper Niger, the volume of water stored will be slightly above 41 billion m^3. If this figure is compared to the discharged volume at the entry point of the Inland Delta (Ke-Macina and Douna) which respectively measure 75 billion m^3 in a humid year and 21 billion m^3 in a dry year, then it means that more than 55% of all flows will be stored in a humid year and flows in the upper basin will be insufficient to fill all the reservoirs. The situation which has been worsened by drought will have drastic consequences of the Lower Delta.

3.2.2. Down-stream depletion

3.2.2.1. Depletion for purposes of irrigation

171 retention points for irrigation purposes have been identified along the Niger and its tributaries. Approximately 5412 billion m^3 are withdrawn annually to irrigate a surface area of 264550 per inhabitant, giving an average of 20 000 m^3 per inhabitant. The volume impounded by each country depends on the surface of the catchment of the country concerned (Table 4). The largest volumes kept aside are in Mali, followed by Nigeria and Niger.

3.2.2.2. Retention for potable water supply

Various water catchments areas have been set up on the Niger and its tributaries to supply many towns with potable water. These were sized based on 2005

populations and using 20 litres per inhabitant per day for the rural areas and 40 for the urban agglomerations.

3.2.2.3. Potable Water Retentions for Livestock Breeding

The estimate of volumes impounded for livestock is difficult due to their diffuse nature. Calculation of water needs associated with livestock is based on a need in 30 units per day. Estimates show that in 2005, about 223.6 million m^3 of water was used for about 2 771 000 LU. The largest reserved volumes are found in those countries with the largest areas of land within the basin (Nigeria, Niger). Mali is noted for its livestock numbering 8 640 000 U.B.T. However, reserved water for livestock is small (14.2 million m^3).

Table 4: Retained volumes and irrigated surface area per country

	Number of uptakes	Total surface irrigated in 2005 (ha)	Annual total volume taken in 2005 (Million of m^3)
Benin	2	1006	23
Burkina Faso	3	1482	9
Cameroon	3	5300	107
Ivory Coast	10	2495	46
Guinea	8	8984	104
Mali	8	117348	3825
Niger	43	43315	454
Nigeria	94	82620	847
Total	171	264550	5412

It should be noted that part of the riparian population gets its water from the water-bearing beds of the river. The results of the many estimates, represents the maximum level of uptake without taking into account other sources of water.

3.2.3. Water use account

Figure 16 (after Mainuddin et al, 2009) shows the major water uses over the River Niger basin. This approach, combined with the WEAP model, could be useful to determine areas where water can be reallocated to benefit the poor.

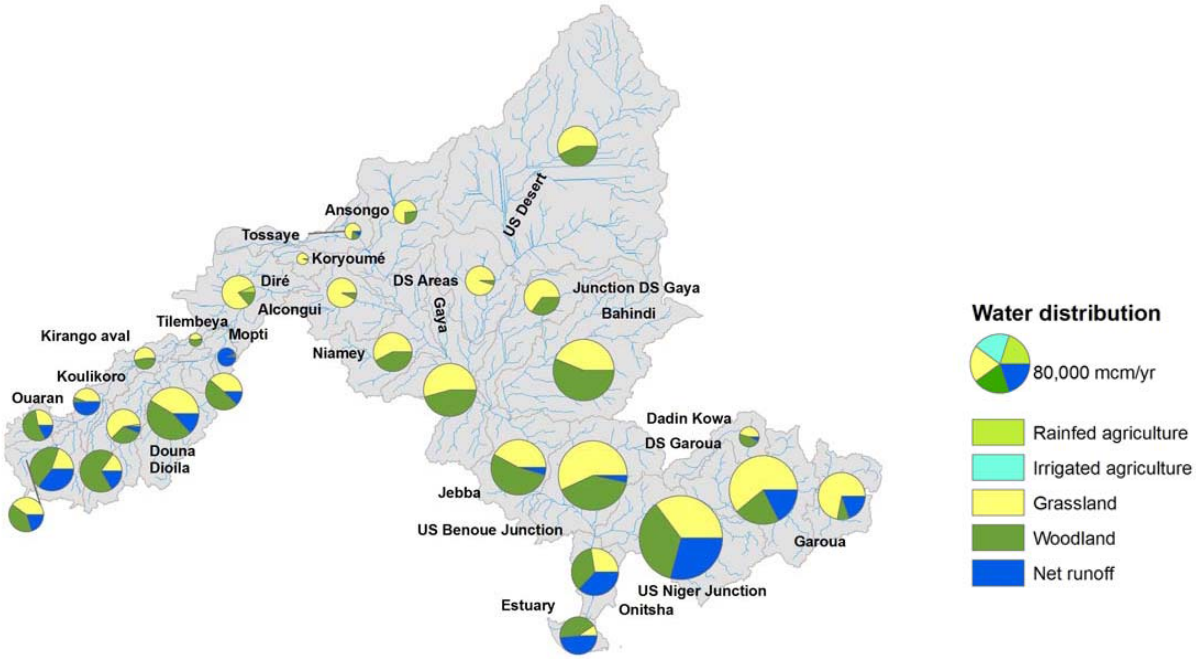

Figure 16: Summary of major water uses in Niger Basin catchments (Mainuddin et al, 2009)

At the whole basin scale, and looking at it very schematically, we can make an estimate of total water evapotranspired. Using the water balance $P = E + Q + \Delta S$ and an average rainfall of 690mm over the total basin, this corresponds to 1500 km^3/year of water across the whole basin. We know that blue water at the outflow equals around 200 km^3 (183 km^3 at the confluence of the Benue and the Niger at Lokodja, Nigeria); consumptive withdrawals for humans, livestock, industry are estimated around 15%, hence 22.5 km3; groundwater infiltration represents 1 to 10% of annual rainfall (Leduc, 2009). These numbers vary from year to year and depend notably on the land cover. As baseflow also contributes to flows, we will consider annual changes in GW storage equal to 0. Green water evapotranspired represents therefore approximately 1200-1300 km^3.

3.3. Changes in water availability

3.3.1. Application of climatic scenarios

Simulations have been carried out for the horizon 2050 with the HadCM3 model and A2 scenario. Figure 17 shows the changes in runoff in 2050 compared to the 1966-1995 average in West Africa. According to this GCM/scenario, there would be a slight increase in runoff over most of the upper Niger river basins in West Africa, but not over the upper Benue river basins. The situation would worsen in 2080 following a general rainfall reduction over West Africa. This is only one model and one scenario. After a comparison of several GCM outputs for the region, Ardoin *et al.* (2009) conclude that most of the recent GCM outputs for the

region show lower rainfall predictions than the HadCM3 model.

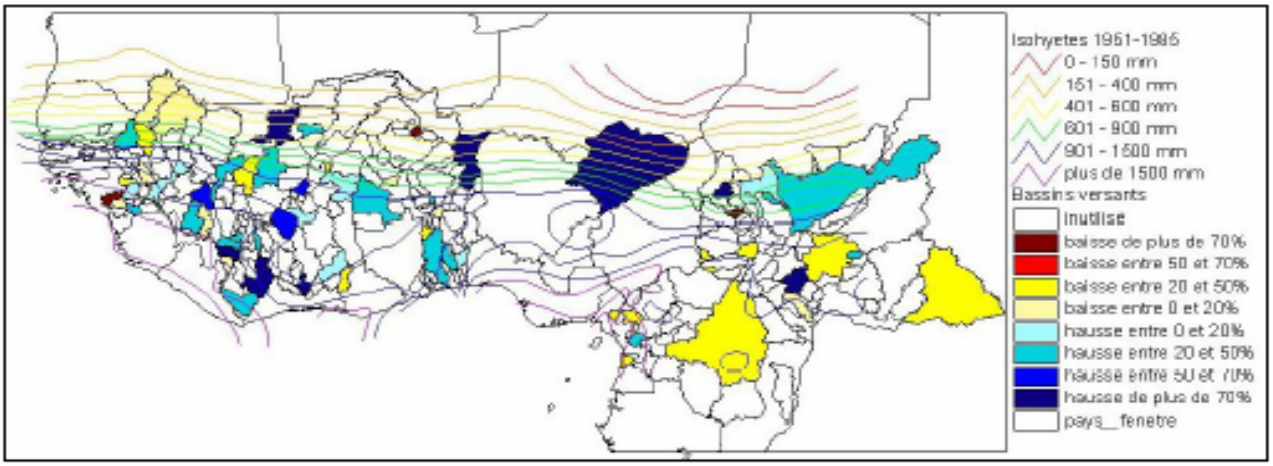

Figure 17: Percentage of variation in runoff in West Africa between (1966-1995) and 2050, using the IPCC HadCM3 A2 scenario.

3.3.2. The case of the Niger River inner delta in Mali

For the Niger Inner Delta (a key focus for the BFP Niger), an integrated model of the Niger inner delta called MIDIN has been developed. It integrates several relationships between water, biology and human activities along the different hydrological entities like channels, lakes and floodplains. The Figure 18 shows the correlation between the flooded surfaces, as depicted by NOAA images between 1990 and 2000, and the water heights at the main gauging station of Mopti in the delta. This correlation allows the determination of the flooded area of the upper delta area according to the Mopti water level. This will result for instance in being able to predict one month in advance from the water height at Mopti the water height in the Northern part of the delta (North of the central lakes).

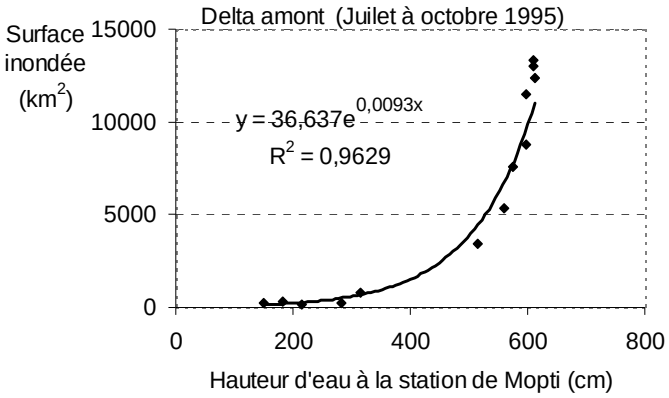

Figure 18: Correlation between water height and flooded area in the upper inner delta, Mali

3.4. Conclusion

Nigeria currently holds the majority of dams, including large dams and there are currently only a few dams in the upstream section of the Niger river in Mali, Guinea and Côte d'Ivoire. There are however plans to build a number of dams (including some very large dams like Fomi in Guinea) in the coming years. It is

very important before building them to take into account the past years variability of climate and river regime. It is particularly important to take into account the very deep runoff decrease in the tropical humid sub-basins, and the runoff increase in the Sahelian ones. It is also noticeable that most of the GCM outputs predict a rainfall reduction during the next decades of the 21st century. Several tools such as WEAP, MIDIN and rainfall/runoff modelling should be implemented by stakeholders such as the NBA to be used as predicting tools.

4. Agricultural water productivity

4.1. Introduction

Physical agricultural WP is defined as the ratio of agricultural output (kg, ton) per m3 of water consumed, while economic WP is the value derived per unit of water used (Molden et al 2009, Seckler et al 2003). The Water Productivity concept was popularised by Molden 1997 and evolved from water use efficiency, which De Wit 1958 already expressed as kg of crop per m3 of water transpired. Molden developed WP into a broader indicator, capable of looking at the range of benefits associated with water use (Bessembinder et al 2005, Hussain et al 2007).

The reasoning behind Water productivity evolved from the premise that water resources are becoming increasingly scarce due to anthropogenic (demographic increase, rising industry demand, dietary changes, land use changes, ecosystem demand) and climatic influences and therefore it is essential to maximize the value of water consumed. Studies published in the late 1990s estimate that by 2025, one third of the population in developing countries may live in conditions of physical water scarcity (insufficient water to meet agric, domestic, industrial and environmental needs) (Seckler et al 1998; Rijsberman 2006; IWMI, 2000). While actual predictions of water scarcity may be difficult[1], there is nevertheless little doubt that the strain on water resources will continue to increase as population numbers and water demand rise.

In water scarce regions or irrigated systems where water is a rare, valuable input, increasing water productivity or the value per unit water appears as a necessity. Where water is currently not limited, streamlining water productivity considerations into water management policies appears advisable, in light of projected increased strain on water resources. At the basin level, within the context of IWRM, it appears sensible to assess the various uses of the available water resources and maximise the value from each drop. In closed basins, this need becomes greater, as disputes over resources require reasoned allocation of water and reduction of non beneficial losses.

However, what are the implications of seeking to improve water productivity? In terms of agriculture, what decisions does privileging WP lead to? Especially in rainfed agriculture, where water may not be limited or disputed, is WP actually relevant? Currently this indicator is only exceptionally questioned and only its actual translation is discussed, but as with all indicators, its use, value and interpretation at various scales must be considered.

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[1] Water scarcity is complex to define (Noemdoe et al 2006, Rijsberman 2006), as it requires a comprehensive understanding of how much water is needed, how it can be accessed (taking into account spatio temporal variations) and must be combined to predictions of climate change, demographic increase, dietary changes, land use changes, etc. Furthermore predictions of water scarcity do not account for future technological advances that may enable countries to capture, transport or desalinise water efficiently and cheaply; however a growing reliance on technological innovations would inevitably put strain on other resources, such as fuel, labour etc (Zoebl, 2006).

4.2. Water productivity calculation

There is currently no accepted definition for the numerator or denominator in Water productivity. In terms of production, one may use dry yield, fresh yield or even total dry matter since crop residues are used as animal feed, house building, handicraft weaving etc. Similarly, at the denominator one may use applied water (rain, irrigation inflow etc) or depleted water, typically ET but also water that flows to a location where it can't be readily used or where it becomes heavily polluted (Seckler 1996, Molden et al 2003). Furthermore, with rainfall one could consider annual rainfall, or only sowing to harvest period, or decide to include fallow years. Again with ET, one could calculate ET annually or from emergence to maturity. Molden et al 2003 recognise that the WP concept leads to an infinite number of practical translations of water productivity. The choice of the researcher will be guided by the discipline, the focus of the study, the scale, however the absence of a standard definition reduces the ability of WP to allow comparisons and formulate recommendations (Bessembinder et al 2005), and its value as an indicator for decision makers.

4.3. Rainfed water productivity

4.3.1. Methodology

In this study, we calculate Water productivity using dry yield cereal production over total rainfall and dry yield cereal production over evapotranspirable water. Total rainfall, used in previous research in ecology on Rain Use Efficiency (Le Houérou, 1984, Snyman et Fouché, 1991), provides a measure of total water supplied to rainfed agriculture on a given area. However in strictly rainfed agriculture, the available water resource is not total rainfall. Rain that falls when the plant can not exploit it or in excess of the demand is not an exploitable resource and it could be argued that it should not be taken into account. The available resource is that fraction of rainfall susceptible to be evapotranspired by a plant ("evapotranspirable rainfall"). The rest is always drained. This criteria, allows better than total rainfall, a comparison of water productivities under different climates, as only the water useful to rainfed agriculture is taken into account and the resource is defined not simply by the climatic supply but also by the plant demand ETM[2] which is related to climatic demand ET_0.

Evapotranspirable water for a given soil, climate, year can be calculated on monthly aggregated climatic data, using the Cochémé and Franquin (1967) method (intersection method, Figure 19) adapted to semi arid and savannah regions of Africa with one rainy season.

[2] ETM : Maximal evapotranspiration; ETR : Real evapotranspiration ; ET_0 : reference evapotranspiration

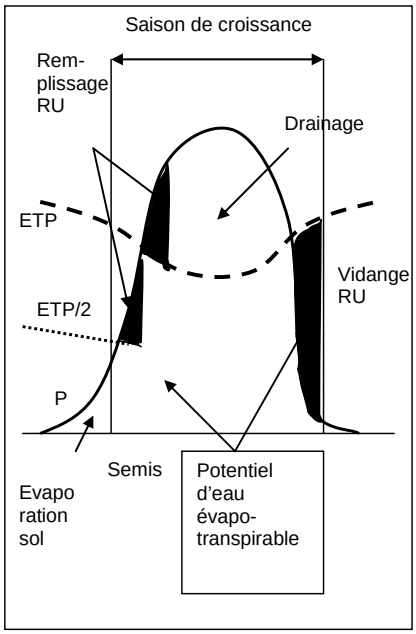

Figure 19: Intersection method, adapted from Cochémé and Franquin, 1967

The year 1999, a year of above average humidity was taken as reference. Average Penman ET_0 over the 1984-1995 (Ardoin-Bardin et al., 2009) period was used. A detailed methodology is provided in BFP report (Serpantié 2009a) and results are presented in Figure 20 and Figure 21. Cereal yields in comparison are provided in Figure 22.

4.3.2. Results

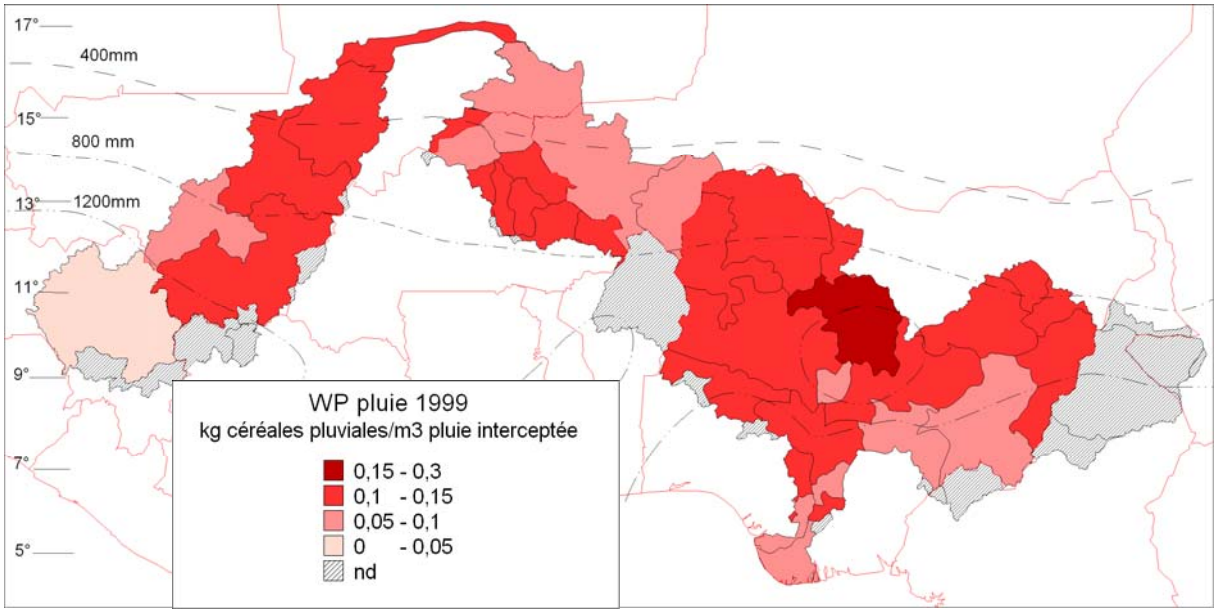

Figure 20: « Water productivity of rain intercepted by crops ». Ratio of annual average provincial yield for rainfed cereals in kg/ha over annual average rainfall per province in t/ha for 1999.

In 1999, rainfed agriculture (using total rainfall) is globally homogeneous and close to 0.1 kg/m^3 over zones as different as the Sahel, the cotton savannahs,

humid parts of Nigeria. The highest WP is found in Kaduna state, Nigeria, where population density and yields are high and rainfall averages 1200mm. Where rainfall is very high such as in South-East Nigeria (delta zone), WP falls despite excellent yields. North of 800mm, the Niger stands out with its low WP due to its low yields.

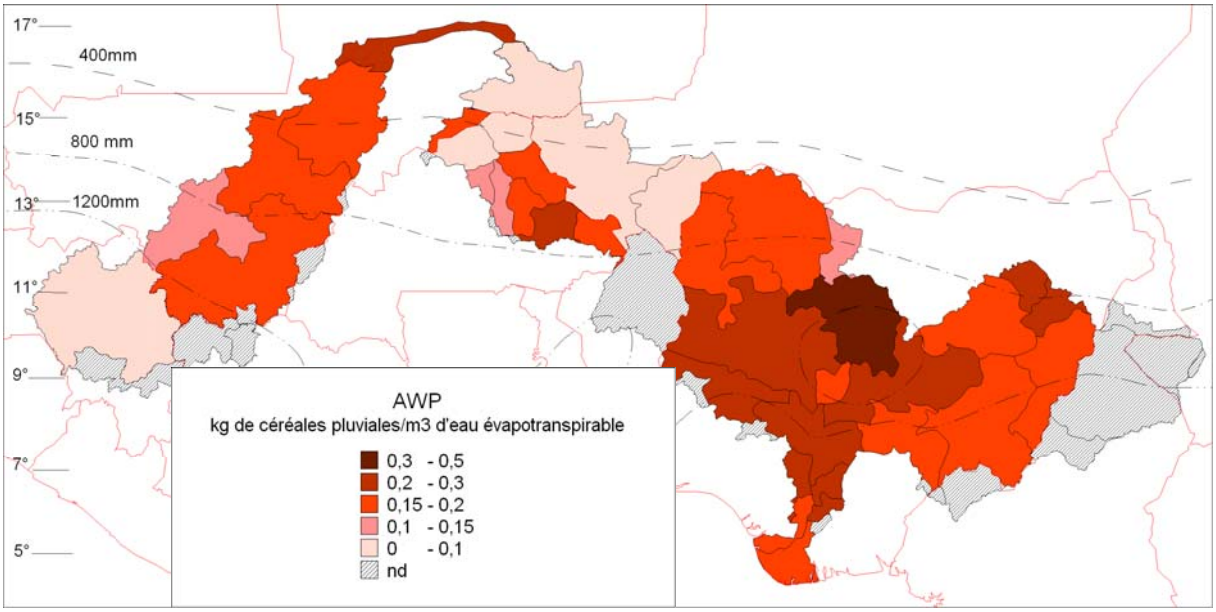

Figure 21: « Available rainwater productivity » Ratio of annual average provincial yield for rainfed cereals over average annual evapotranspirable water for 1999.

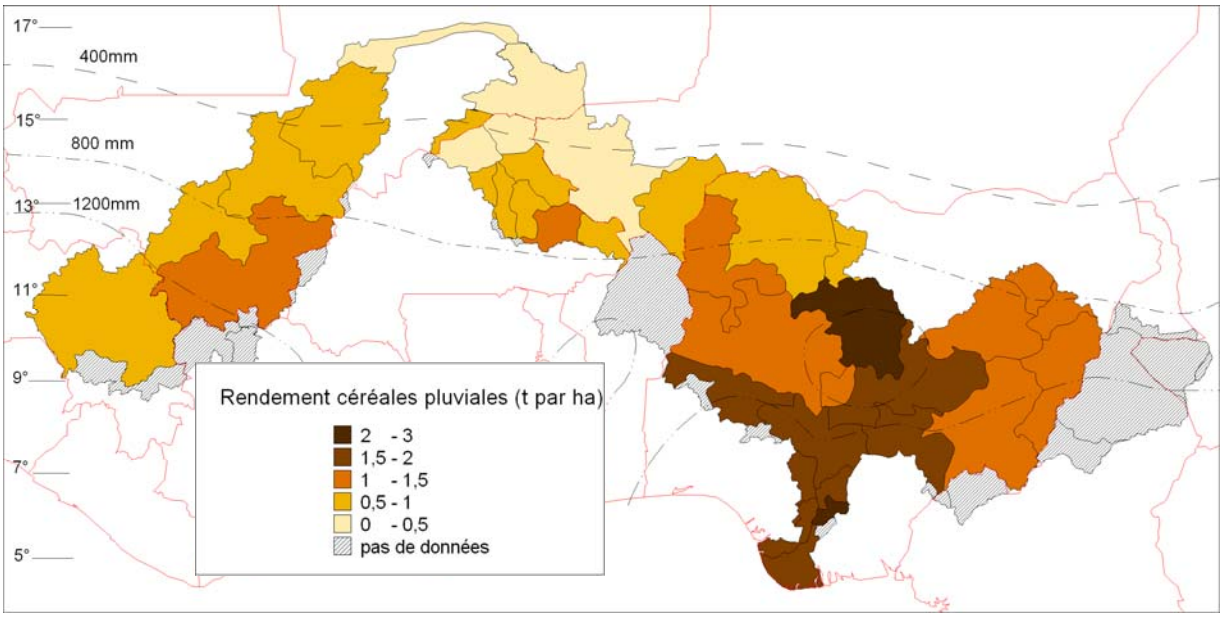

Figure 22: Average annual provincial yield for rainfed cereals

Using evapotranspirable water, differences are more contrasted. In terms of high WP, Nigeria stands out from other countries, advantaged by its fertilised and more intensive agriculture. The result appears closer to the yield maps, except under extreme climates, very dry or very humid. The most northern region which exploits a minimal quantity of water in extensive millet agriculture produces a high WP, due to the very low denominator. In Nigeria, despite high yields, AWP

also decreases in the Niger Delta, where evapotranspirable water is high (long rainy season). Also in this humid zone, cereals are replaced by more adapted crops (taro, yam, cassava).

4.3.3. Discussion

Looking at one year, such as 1999, only allows a limited view and interpretation of WP. This study would need to be developed further over several years (dry, average rainfall etc).

4.3.3.1. Low WP

Though 1999 was a year with high rainfall, we note that the order of magnitude of WP is around 10 times lower than under temperate climates (winter wheat in Beauce, France: 1kg/m^3 of annual rainfall): one must indeed account for longer cultural cycles, a lower ET_0 which allows us to valorise low rainfall (600 mm in Beauce), longer day length during flowering season, fertile and deep soils, intensive crop systems in terms of inputs and soil labour, and varieties that respond well to fertiliser.

4.3.3.2. Interpretation and paradoxes

We also note the marked difference between the two variants of WP (fig 2a et 2b), and the significant divergence with yields (fig 2c). Within a narrow isohyet band, WP naturally vary accordingly to yields. In interclimatic comparisons, the AWP (*available water productivity*), which does not take into account dry season evaporation and drainage, provides a more accurate picture of the agricultural performance. It reflects better agric performance as we now only look at the way the plant exploits water during crop growth, but does not consider the water available outside cropping season which could potentially be harnessed differently (rainwater harvesting).

Nevertheless, in interclimatic comparisons, interpretation of agricultural WP is complex and leads to paradoxes. From the WP maps, two areas appear to use this water most efficiently. These are North Mali and part of North Nigeria. However does this mean that planners should concentrate agriculture in these water efficient areas, as water resources become scarcer. When one looks at yields, clearly in Northern Nigeria this seems viable, but in Northern Mali yields are very low, and high WP occurs only because of the very low rainfall. Clearly in the latter, high WP does not imply a good investment in agriculture to reduce poverty and food insecurity. Conversely, in southern Nigeria, WP appears low implying that water is underused. However rainfed agriculture performs well and it is the excess of water that is responsible for low WP. In Guinea where WP is low, one could assume we should invest in techniques to improve rainfed WP, however Guinean farmer strategies are to invest in lowland rice, due to the natural benefits of humid zones and the heavy constraints of leached rainfed soils of humid zone in an under industrialised country.
Interpretation is therefore highly complex and requires referring to both numerator and denominator, i.e. yield and rainfall maps.

4.3.3.3. Water as limiting factor in agriculture

In agricultural terms, low WP does not necessarily indicate that agriculture is not exploiting water well. Indeed in many cases, low WP is due to low yields which may be increased only thanks to fertiliser inputs and not better water use, and in other cases, low WP is due to excess water. This difficulty is inherent to the formula, as it considers a certain quantity of water (gross or evapotranspirable) to be a factor of production in all parts of the study zone. Productivity is defined as a production over the means, inputs, resources allocated to the production process. Productivity therefore requires water to be a production factor, but in parts it is not.

Rainfall is a specific water input: portion contributes to the maintaining of a hydric condition necessary for production (hence potentially a production portion), another is in excess. Within the latter, a portion is even counterproductive. Furthermore, one can not consider rain water, even limited to its evapotranspirable portion systematically represents a quantitative production factor, as would be labour or fertiliser. In fact, where rainfall is sufficient or in excess, (>800mm for maize, >700mm for sorghum and millet; large parts of the basin), water ceases to become a production factor and improvements in yields result only from better use of other factors than rain. Intensifying agriculture increases the utility of the rainfed area, but not of rainfall. As a result in agricultural terms, WP for rainfed production basin ceases to have much relevance in the wetter parts of the basin. However it may still be useful to water planners, who need to know that there is excess water and how it can/should be used by agriculture or other sectors. Nevertheless in humid zones, low WP may be due to a poor performing agriculture, excessive rainfall or a combination of both and WP does not differentiate this. Low WP does not tell us whether that water can be used to advantage in agriculture.

In certain cases, water related problems occur despite sufficient rainfall, due to variations in rainfall. Indeed problems in rainfed agriculture are often due to the large spatiotemporal variations in rainfall rather than low cumulative volumes of rainfall (Mahoo et al in Rockstrom et al 2002). As a result, measures to reduce exposure to drought or dry spells are to be recommended, which require farmers to move away from strictly rainfed agriculture along the rainfed-irrigation continuum. This for instance may mean rainwater harvesting measures and supplementary irrigation. Water harvesting aims to divert and concentrate surface runoff but SSA farmers, due to lack of funds or experience, tend to privilege water conservation measures (SIWI 2000 in Rockstrom et al 2002). Experiments show that supplemental irrigation can increase WP but especially "if combined with soil fertility management" (Barron, Fox in Rockstrom et al 2002). It is not explicit which between water or soil is more important.

4.3.3.4. Other uses of water

Where there is excess water, basin planners could recommend solutions to harvest the excess water either in agriculture (rainwater harvesting to use in dry season) or for other uses (industry, hydropower etc). Moving rainfed agriculture to adopt irrigation techniques requires investment and capacity building, but one also needs to consider the current uses of the supposed excess water. Indeed, excess water implies that the excess is not correctly/sufficiently exploited. In

rainfed production, the proportion of rainfall actually transpired and therefore directly used by the plant can be inferior to 10% (Rockstrom et al 2002). Rockstrom considered the rest to be lost from the cropping system. Clearly this water is not used up by the plant, but this water may be crucial for other uses, including GW recharge, downstream users and local climate regulation. Indeed actual ET is an environmental function which controls the moisture and rain parameters (Monteny and Casenave, 1989). This is what Seckler et al 2003 refer to as the water efficiency paradox: "Indeed while every part of the system may be at low levels of water use efficiency, the system as a whole may be at high levels of efficiency".

4.3.4. Conclusion

Overall, WP does show where water is used/exploited best but interpretation is very complex, notably in interclimatic analysis. Interpretation requires referring to both numerator and denominator, i.e. yield and rainfall maps. In these conditions, the WP indicator even improved as AWP, remains delicate to use.

It remains therefore difficult to derive general recommendation directly from the WP map, without making mistakes or without bettering conclusions made from yield maps. While one recommends taking care when interpreting (Molden et al 2009) WP, the actual value of it is rarely questioned.
While a m3 of water in an arid zone is 100% evapotranspirable, and therefore a true production factor, another m3 in a sector characterised by excess water, may be in part non productive water or actually counter productive. In agricultural terms, the WP concept seems most applicable where water is scarce and truly a production factor. In wetter parts (>700/800mm), rain ceases to be a production factor (improving water supply doesn't change yield) and therefore it is no longer a water efficiency / WP problem; one should talk of increasing rainwater utility. Low WP implies water is under used in rainfed agric, but in some cases yields are high and using rain more will not improve yields. Solutions such as increased fertiliser, longer grain crops or rainwater harvesting to develop irrigation activities/extend the cropping season may be advocated. For basin planners, WP can still provide interesting insight/diagnostic of the way water is used or more importantly unused in the basin. However, issuing recommendations on how to exploit this water requires a complete understanding of the agricultural limitations as well as an assessment of the current uses and value of this drained water.

Currently agric strategies attempt to reduce risk and depend as little as possible on water quantity, hence extensive not intensive. Therefore increased WP goes by improving reliance and strategies such as rainwater harvesting have a role to play. Otherwise four main strategies exist: increase the rainfed production area (by rehabilitating ecosystems where it has disappeared/damaged, increase land productivity of the rainfed agriculture (independently of water), develop water efficiency where it is scarce (essentially north of 700 mm for millet and sorghum), increase plant tolerance to water excess. Research should continue as much on the resistance to drought in all key development phases, than on reducing drainage sensitivity. The too rare references available concerning crop systems as practiced by farmers reveals the need to develop research in this direction.

4.4. Water productivity in irrigated agriculture

Irrigated surface area represents less than 3% of agric land. There is only one significant hydroelectric dam in the Sahel on the Niger. The number of farmers concerned by the river's water management is difficult to estimate but is much greater than the amount of areas under full control irrigation would imply, once one includes farmers with plots in lowlands, free flooding or controlled flooding. The amount of irrigable land is huge and can not all be irrigated, at least not from surface waters. Certainly without dams, it is not possible to extend agriculture in dry season. With Fomi dam alone, it is possible to develop new perimeters. According to the NBA, the building of Fomi, Taoussa and Kandadji dams offer significant opportunities to triple the irrigated surface area, up to 400 000 hectares in Sahelian countries, essentially in Mali and Niger. Maximal expansion would increase withdrawals from the river to 14%, compared to 1.5% currently.

However the investment plan will impact heavily on wetlands and their biodiversity, the environmental services and the livelihoods of a million herders, fisherman and traditional rice growers in the Inner Delta. Current agricultural withdrawals already have an impact on the Inner Delta wetlands of Mali (De Noray 2003; Zwarts et al 2005), on the Niger delta in Nigeria (NDES 1999; Uyigue et Agho 2007) and on production of hydroelectricity of the Kainji dam in Nigeria. The river Niger has already run dry during low flows and in dry season withdrawals in irrigation are reaching their maximum (ABN and BRL 2007). As a result, irrigated agriculture will need to improve its water efficiency and the economic gain derived from each cubic metre of water used in order to justify the heavy investments it demands. Maintaining reserve flows are important to maintain rare species such as hippos or "lamantins" in the river and Inner Delta.

4.4.1. Presentation

The three major irrigation countries in the basin are Mali, Niger and Nigeria. Mali has mostly invested in the development of large perimeters such as the Office du Niger and the "Operations Riz" of Mopti and Ségou. Niger has invested in a number of small and medium perimeters along the river, while Nigeria possesses a number of large dams with full control irrigation.

Perimeters equipped for partial and especially control irrigation have increased greatly in the last decades but traditional systems such as recession flooding, lowland and free flooding still dominate in terms of surface area. Partial control irrigation, i.e. controlled flooding and lowland development also occupy significant surface areas. However traditional systems, recession and free flooding are dwindling, due to recent droughts, but also because farmers, NGOs and governments attempt to control water supply better. If the NBA development/investment plan favours large scale developments, the CILSS, FAO and WB currently favour small irrigation, preferably individual and private. Small scale irrigation is notably developing in Burkina Faso and Ivory Coast and is on the increase in Mali.

4.4.2. Agricultural performance

According to official statistics, rice yields in Mali and Niger are increasing while those in Nigeria are falling. In perimeters under full control irrigation, the objective of 7t/ha is feasible. Yield differences are mostly due to fertiliser input. Well off farmers can achieve such yields.

Mali is about to realise a small agricultural revolution. Surface areas are increasing fast, and yields are improving. Malian farmers are adapting to the urban demand and rice importations remain limited. In Niger, however the contribution of rice growing to food security in Niger is low because the irrigable areas are very limited and distant from major population centres. Nigeria suffers from the dysfunction of the public sector which has resulted in the near total abandon of perimeters equipped for full control irrigation. Nigerians now privilege the expansion of production into lowland, which does not favour yields but does not mean they are not profitable.

4.4.3. Large withdrawals

Withdrawals are important in Mali, especially at the Office du Niger and the perimeters under partial control which divert water and don't return much to the river, from lack of drainage. At the ON, part of the water withdrawn is returned to the river by the Macina canal, but the amount returned from the perimeters remains unknown. Withdrawals are lower in Nigeria because the more humid climate requires less water. The Nigerian fadamas systems essentially withdraw water from groundwater, in unknown quantities but probably less than in the large perimeters.

4.4.4. Large fluctuations in WP

We summarise in the table below the WP results. These were obtained by averaging yields obtained by the APPIA project and dividing by withdrawals found in NBA documents (which consist in a mixture of expert views and field measurements) (Figure 24). WP for rice in full control irrigation is relatively low in the basin. It is typically between 0.2 et 0.3 kilograms per metre cube. A few rare perimeters obtain higher results in Niger

Table 5: Water productivities in irrigation

			Productivité sur le BFN (kg/m3)			
Pays	Année	Périmètres	Using water entering the plot		Using water withdrawn at source	
	Tout l'office du Niger					
Mali			SH	SS	SH	SS
	94/95	ON	0,36		0,19	
	95/96		0,38		0,2	
	96/97		0,39		0,204	
	97/98		0,41		0,216	
	98/99		0,46		0,24	
	99/2000		0,46		0,24	

	2000/01		0,46		0,244	
	2001/02		0,46		0,244	
	2002/03		0,46		0,244	
	2003/04		0,44	0,16	0,2292	0,05
	2004/05		0,45	0,16	0,2372	0,05
	2005/06		0,46	0,17	0,2428	0,06
	2006/2007		0,45	0,18	0,2344	0,06
	Office du Niger par zone de production					
	2006/2007	Macina	0,36	0,15	0,21	0,05
	2006/2007	Niono	0,41	0,18	0,24	0,06
	2006/2007	Molodo	0,38	0,17	0,22	0,06
	2006/2007	N'debougou	0,41	0,16	0,24	0,05
	2006/2007	Kouroumari	0,38	0,17	0,21	0,06
	2006/2007	M'bewani	0,36	0,16	0,22	0,05
Périmètres APPIA						
Mali	2004	Kamaka	0,18		0,18	
	2004	Sinah	0,36		0,35	
	2004	Saba 1	0,7		0,67	
	2004	B1	0,14		0,14	
	2004	Djidian	0,53		0,2	
Niger	2004	Lata	0,64		1,04	
IIMI Niger						
Niger	1997	Kourani Baria I	0,59		0,3	
	1997	Kourani Baria II	1,22		0,53	
	Moyenne					
Tous les pays	Toutes les années	Tous les périmètres	0,45	0,17	0,3	0,06

The performance of production zones in the ON are below reference/optimal values. This is due in part to the original dimensioning of the perimeters as well as to the state of the irrigation canals. Initially planned for several hundred thousands hectares, there are actually only around 65 000 ha of perimeters equipped for irrigation. With gravity irrigation as in the ON, it is difficult to confine water volumes withdrawn to the desired equipped areas. The extension of the ON to several hundred thousand hectares by 2025 could improve WP.

The data from the APPIA database suggest that WP of rice in the Mali and Niger perimeters are also low. Results vary between 0.14 and 0.67 kg/m3 confirming other studies (0.05 to 0.6 kg/m^3) (FAO, 2003). The reasons behind these results are excessive withdrawals, water wastages and low yields. Market gardening activities in dry season have a much greater WP than rice, thanks to a high value crop and less water wastages, to the point that certain perimeters actually don't have sufficient water inflow.

Overall, WP in the basin is relatively low because yields are low and withdrawals high especially at the ON in the Sahel zone. WP should increase with the extension of ON surfaces, the continued rise in rice yields and expansion of market gardening activities. The regulation of the river by 3 planned dams should however reduce overall WP by promoting dry season rice production, which consumes more water.

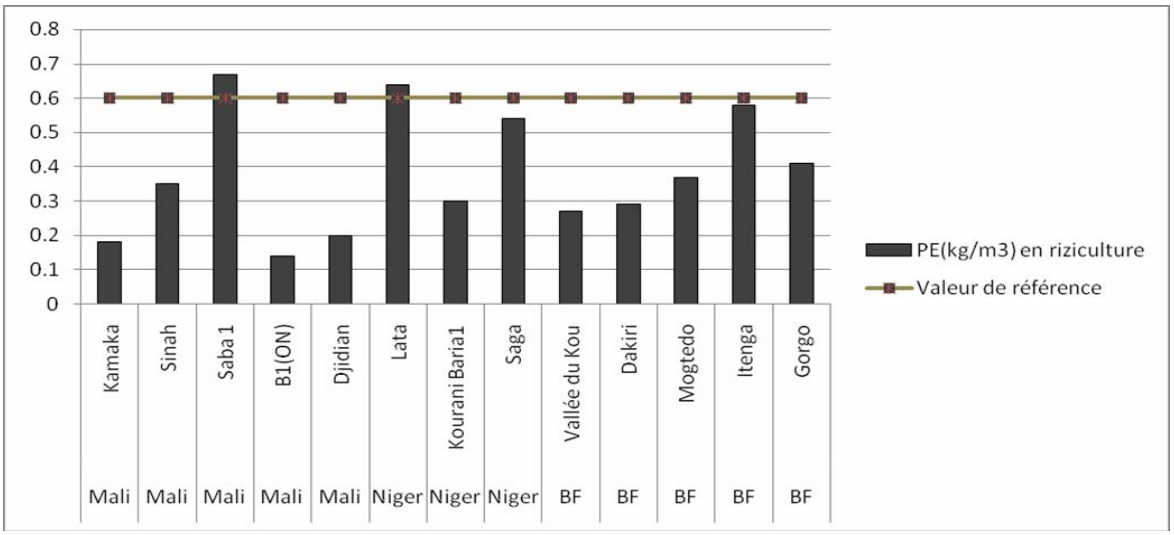

Figure 23: Water productivity (APPIA + perimeters studied by IIMI)

4.4.5. WP uncertainties

Many experts suspect crop yield statistics to be inflated by statistical services. It is necessary to carry out control surveys by independent organisms. Furthermore, the measurement of withdrawals is rare. Results obtained are very variable and numbers on efficiency, necessary for the calculation are very uncertain. Finally, returns to GW or the river have not been studied extensively, except at the Office du Niger. Scientific studies must be carried out on return flows in the principal types of irrigated perimeters. Water wasted goes to drains or percolates in aquifers under plots. The water which goes to drains can follow different routes. Ideally, it returns to the river. In practice, drainage canals fill up and develop grasses or are cropped. As a result, numbers for WP are variable and doubtful.

Furthermore, economic gains of perimeters are poorly estimated. The grass in canals is sometimes harvested by herders and drains are planted with banana plants, which reduces losses. At the Office du Niger, supply is so great that a large part refills GW reserves. This superficial aquifer in turn refills partly deep aquifers which can serve to supply deep well of villages situated outside perimeters.

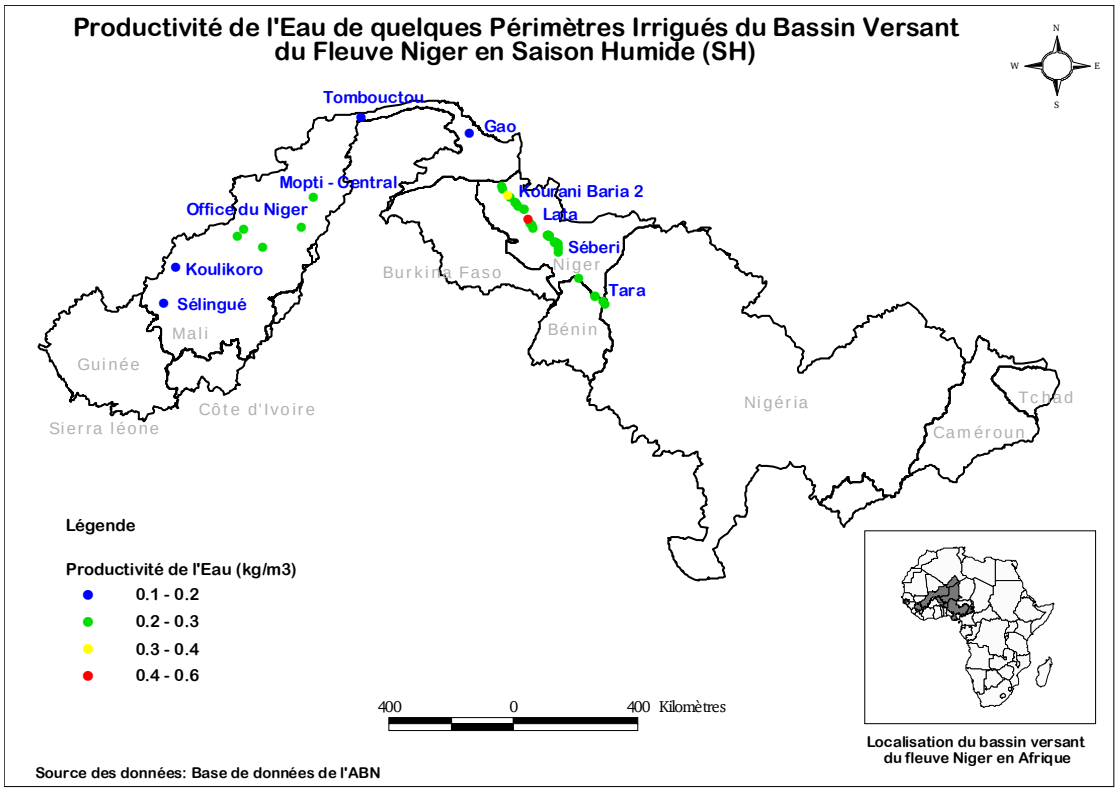

Figure 24: Water productivity in irrigation in Mali and Niger (data from NBA and APPIA project)

4.4.6. Improvement strategies

4.4.6.1. Reduce water consumption

Large perimeters

Overall water consumption levels will increase rapidly in the basin, be it from the expansion of formal irrigation perimeters or from informal small scale irrigation. Reducing the efficiency of perimeters appears difficult because it is not a priority for irrigating farmers, agricultural groups or even the states. Instead priority is a better satisfaction of crop water needs to obtain maximum yields, guarantee food security and create jobs. The awareness raising work is in its infancy and measures such as making producers pay for water is difficult to implement in the current context. As the river no longer dry up, thanks to the Selingué dam and a return of the rainfall, the sense of urgency has gone. Large dams which will contribute to low flows, are planned, further reducing the sense of urgency in economising water and promoting dry season production, more water consuming. However, the expansion of the ON could increase WP as the greater density of perimeters will reduce losses due to the distance/dispersion of irrigated areas.

As part of awareness raising, withdrawals of large perimeters must be subject to a precise and regular following, as well as an annual reporting. Objectives must be fixed and discussed regularly. Agronomists must then propose production plans including dry periods, respect of "water turns" and respect of calendars. The results of these withdrawals must be published regularly and discussed annually at the NBA level. Sanctions against large wasters could be considered.

It is also possible to consider finding funds from hydroelectric production to finance actions to reduce wastages in the upstream part of a dam.

Small scale irrigation
Large perimeters such as the Office du Niger or the Office Riz in Mali are at the heart of political stakes, but are not efficient in terms of withdrawals and WP. Even though doubts exist on the actual volume returned and reused, such investments remain difficult to manage, notably in terms of water supply.
Even public perimeters in Niger which pump water from the river don't seem inclined to reducing their consumption. They benefit from cheap electricity from Nigeria and subsidised by the Niger state. In individual small scale irrigation, farmers have more facility to reduce withdrawals and economise energy from their pumps which reduces water consumption. If the expansion of small scale private irrigation is probably a guarantee of less wastage, it also implies more dry season withdrawals.

4.4.6.2. Changing crops

Rice growing is largely dominant in the basin and will be for a long time. The choice of rice growing is an ancient priority difficult to question for food security reasons. Beyond Senegal and Mauritania which dispose of a limited potential and import more and more Asian rice, Sahelian states have chosen to produce rice to reduce imports and provide jobs. Even elsewhere on the planet, the development of irrigation has rarely been a question of immediate profitability. This is a food security question, sovereignty and risk reduction, reinforced by the actual food crisis and climate change context. West Africa has no interest to depend on Asian rice. Rice is less perishable than the majority of alternatives and production sells easily while the risk of unsold fruit & vegetables is high. Rice production in the basin contributes substantially to local/regional demand, in part thanks to the contribution of the ON in Mali.

4.4.6.3. Improving yields

The increase of WP must also come from the increase in rice yields. Agronomists privilege the concept of intensification, i.e. the increased use of production factors, labour and capital per unit area. However they mostly promote an intelligent intensification which activates synergies between biology and chemistry. Intensive systems have an ambivalent environmental impact. On one hand they tend to pollute the environment with synthetic fertiliser and on the other they consume less surface area than traditional systems, which tends to reduce the pressure on neighbouring ecosystems. Whatever type of irrigation, substantial yield increases are accessible without excessive investments. In certain areas, 2 growing cycles are possible, either 2 of rice or one market gardening or even forage after a rice cycle. Rice and market gardening yields which can increase substantially, should improve as farmers and farmer groups gain in experience.

4.4.6.4. Wider capacity building/support

Support to agricultural groups should help improve the functioning of collective perimeters. To increase the performance of outputs, groups can improve transformation, stocking, provision of inputs and seeds. To reduce wastages, groups can play a role in the respect of water allocations, the maintenance of

distribution and drainage networks as well as accompanying dry season decisions.

Support to farmer groups is important in terms of training & capacity building but results are currently disappointing. The distribution of small plots to farmers that privilege rainfed agriculture raises a problem as to their time investment on irrigated plots. The land tenure uncertainties are another important debate which has led to attempts to secure land tenure. The professionalisation of water professions has not led to the desired improvements of the industry. In any case, the disorganisation of the industry remains one of the principal handicaps in irrigated agriculture.

4.4.7. Conclusion

According to the NBA, 265 000 ha are irrigated, of which 135 000 ha in Mali, 46 000 in Niger and 84 000 ha in Nigeria. The NBA will reach 1,5M ha in 2025 of which nearly 1M in Nigeria and less than half a million in Mali. Controlled flooding agric will go from 170 000ha to 311 000ha, while free flooding/recession flooding could remain around 100 000ha, all between Mali and Niger. Even in 2025 withdrawals will mostly take place in Mali as Nigeria consumes less per unit surface. Agric withdrawals are actually a little over 9 billion m3, essentially in Mali. In 2025, they could triple to nearly 30 Billion m3. Drinking water supply withdraws actually less than billion cubic metres, essentially in Nigeria. In 2025 it could exceed 2 billion. For now these are supplied from aquifers but it is not unlikely that in the future rural areas are supplied by water from the rivers, which would increase this figure.

Eventhough irrigation performances are below potential, donors seem ready to continue its expansion. The arguments provided are: probable aggravation of climatic variability, repeated food crises, change in diets, the relative competitivity of Sahelian rice, considerations over non durability of rainfed agriculture.

WP is relatively low in the basin because yields remain below potential and water wastages are important, notably at the Office du Niger and in the rice operation Mopti. Reducing these wastages will demand important efforts as water is not yet rare and these withdrawals are globally considered minimal. However, the measurement of WP (yield statistics), withdrawals but also return flows must be improved. Of the expression “More crop per drop”, the basin population will focus mostly on the “more crop”. The reduction of “drops” requires a collective awareness of the importance and an array of measures.

4.5. Water productivity in Fisheries

4.5.1. Distribution

The fishers in the basin may be divided between full time fishers, mostly belonging to ethnic groups recognized as fishers, and agrofishers, who spend a part of the year growing crops, and occasional or part-time fishers for whom fishing is a secondary activity.

Different sources provide estimates on the number and distribution of fishers in the Niger basin. Although there are some strong different between sources, it appears that the fishing activity is mainly concentrated around the large floodplains (Inner Delta) or reservoirs (Selingue, Kainji, Jebba, Lagdo). A more diffuse activity occurs along the main river stretches, and also along smaller water courses on which no surveys have been implemented.

The order of magnitude of the total number of professional fishers in the basin is 100,000, of which 62,500 in the Niger Inner Delta and 13,000 in the large reservoirs. If the activity of one fisher on the water induces one full time job on the ground, and if each active person provides the living for 3.5 other persons, the total population depending directly on the fisheries activity is 900,000, out of a total population in the basin of 95 million people.

4.5.2. Living standards

Although fishing may in some cases be a last resort activity for the poorest, the standard of living in the fishers population may not be regarded as much different to the rest of the rural population. When they have access to land, the "full time" fishers also practice rain fed or flood recession cultivation.

According to recent surveys (CP 72 on the Inner Niger Delta and Lake Kainji, surveys on Lagdo and Sélingué), the fishers community share with the rest of the rural populations the same constraints on their living: they rank first food shortage, and second the lack of access to health care, to good quality household water, to school or to credit. The lack of production means (nets, canoes), the variability of the hydrology and the poor strength of their fishers associations come second. Lack of access to land occurs specifically in some regions where the fishers are considered as new settlers.

4.5.3. The fisheries production

According to Neiland and Béné (2008), the total fish catch in the basin is about 240,000 tonnes per year (estuarine delta not included), with a value of almost 100 million US dollars.

It has been estimated that fish represents a significant fraction of the animal protein in Africa, with 40% in Nigeria and 49 % in Cameroon (FAO, 2005). If the mean figure for fish consumption in Africa of 7.7 kg/capita/year is applied to the Niger basin, the total demand for marine and inland fish is 730,000 tonnes.

4.5.4. Water productivity in fisheries

To our understanding, it is not possible to give figures for Water Productivity (WP) in fisheries, as fishing is a non water consumptive activity.

However, a marginal WP can be estimated when a change in the water management, and in the water volume associated with a fishery, can be related to a change in fish catch.
This is the case for floodplains in which the fish catch is usually related to the importance of the river discharge or flood. Previous relationships have indicated that a decrease of 1 m3/s or a total of 13 Mm3 in the flood discharge (from July to September) to the Inner Delta would induce a decrease of 27.8 tonnes in the fish catch of the region (Laë, 1992). More recent observations lead to a similar result (Morand et al. in press).

4.5.5. Threats and opportunities

The main threats and opportunities have been well identified by the fishers communities in their answers to the surveys (Béné et al., 2009). They are very similar to those of the farmers, and in accordance with the global socioeconomic context of the poor countries in the basin.

Threats and weaknesses

At the basin scale, the main threats are related with the drivers of change now in action:

- The demographic increase leads to an increase in the number of fishers, with a number of consequences:
    - Competition for space and conflicts with the other activities (herders, farmers),
    - Competition for the resource, with the use of destructive gears and a threat to the sustainability of the fish stock,
    - Poor enforcement of both traditional and modern (legal) fisheries regulations because of the large number of newcomers, and of the inability of the legal state to enforce the regulations. This also leads to a threat on fish stock sustainability,
    - Increase of the number of fishers and decrease of their individual income.

- Although the demand for fish is sustained, the difficult access to markets in some regions of the basin, and the competition from marine fish trade leads to low prices.

- The natural aquatic ecosystems are being modified by the construction of dams, by water abstraction for large and small scale irrigation. These modifications have a large impact on the downstream fish communities that are not always fully compensated for by the increase in production in the newly created reservoirs upstream. Some fishing communities have to migrate to new fishing grounds where they will not have the same rights (especially for access to land).

- To these man-made modifications must be added the uncertainty about climate change with a change on the rainfall regime and its amplified impact on the hydrologic regime (IPCC, 2007). If an increase in rainfall would be rather beneficial, a decrease of the rainfall would translate into a large increase of the water demand for irrigation and thus an increased threat on the fish resource.

- In their every day's life, the fishers depend on a variable resource, and are thus vulnerable. They face the same constraints as the other rural populations, with the lack of access to drinking water, to health services, to school for the children, to food in some periods, to productions means or to a fair credit. National or pro-poor policies have not, up to now, taken into account the fisheries sector, partly because their importance has not properly been evaluated. Some policies would benefit from the participation of fishers association to the decision making (ABN, 2007).

Opportunities and strength

The data available indicate a high fishery potential in the existing water bodies. The development of new dams may contribute to gather the fishers communities in a reduced number of sites, and thus to a better access to markets and also to a better visibility. As shown above, the construction of dams has also drawbacks for the fishers communities and also on some fish communities. However, by shifting from hydrologically highly variable natural systems to regulated systems the fishers communities may somehow escape the natural variability of the resource.

The increase in fish demand (FAO, 2002), the creation of new infrastructures (ice plants) and fishing harbours around new water bodies, may help to a better access to market with better prices, and to better living conditions for the families. This transition should benefit from new policies (NEPAD, 2006).

Fish culture in ponds, around irrigated perimeters, along rivers and mostly in cages in reservoirs has been described as a complement or an alternative to the fishing activity when the fishery is perturbed by new developments or water management. Although fish culture is technically a good solution, the communities presently involved in fishing are poorly prepared to manage this new activity.

Nigeria is one of the few African countries, with Zimbabwe, Ghana and Egypt where some fish culture has developed, mostly as small and medium scale enterprises. It has been estimated that about 2000 fish farms, covering 60,000 ha, produce 80,000 tons of fish per year, a figure rapidly increasing (Brummett et al., 2008; FAO, 2009). Elsewhere in the basin, fish culture is of much smaller importance.

4.6. Livestock water productivity

4.6.1. Introduction

With 138 000 000 livestock unit in 2008, the Niger river basin offers a variety of livestock productions, whose demand will increase with the projected rise of population. Since centuries, countries in the interior (4 out of 9 countries in the basin) supply the demand from coastal countries centred around two large economic basins (Duteurtre, 2004): Nigeria with its large towns (Abuja, Port Harcourt and Lagos) and the Ivorian basin and the towns of Abidjan, Yamassoukro and Bouaké. As in the West part of the Basin, there is only one train line leaving the Bobo Dioulasso refrigerated slaughterhouse, the majority of meat exports is on the hoof. These are poorly controlled by official services but conserve enough flexibility to survive political crises which periodically close borders.

There are two major livestock breeding modes: nomadic pastoralism which covers large distances annually and breed large herd of zebus, (Diop et al, 2009a) and the sedentary breeding, typically a few small ruminants and some larger bovines. South of the 8th parallel, the presence of trypanosomiasis reduces the presence of bovines, in favour of taurine and goat breeding resistant to tsetse. In total, the basin holds more than 138 000 000 LU (Diop et al., 2009a). In West Africa, the Niger Basin plays an important role in livestock productions which will increase with the demand in animal production of the Ivorian and Nigerian economic poles.

To this day, animal production remains largely extensive and exploits natural rangelands. As a result, they remain largely dependant on 1) access to water which determines the management of the animals and herd performance; 2) the amount of rainfall and its distribution (water points flow and/or seasonal accessibility of certain regions); 3) developments/dams that influence the volume of agricultural by products; 4) animal losses due to water related diseases (and therefore of the sanitary/health cover)

4.6.2. Background

Scattered over more than 1 500 000 km² distributed over nearly 13° latitude, the 50 000 000 herders of the basin breed several animal species. Their North-South distribution is function of their resistance to drought and their aptitude to exploit natural rangelands.

Camels constitute the dominant form of breeding/herding north of the 11th parallel, below which they seldom venture (Figure 25).

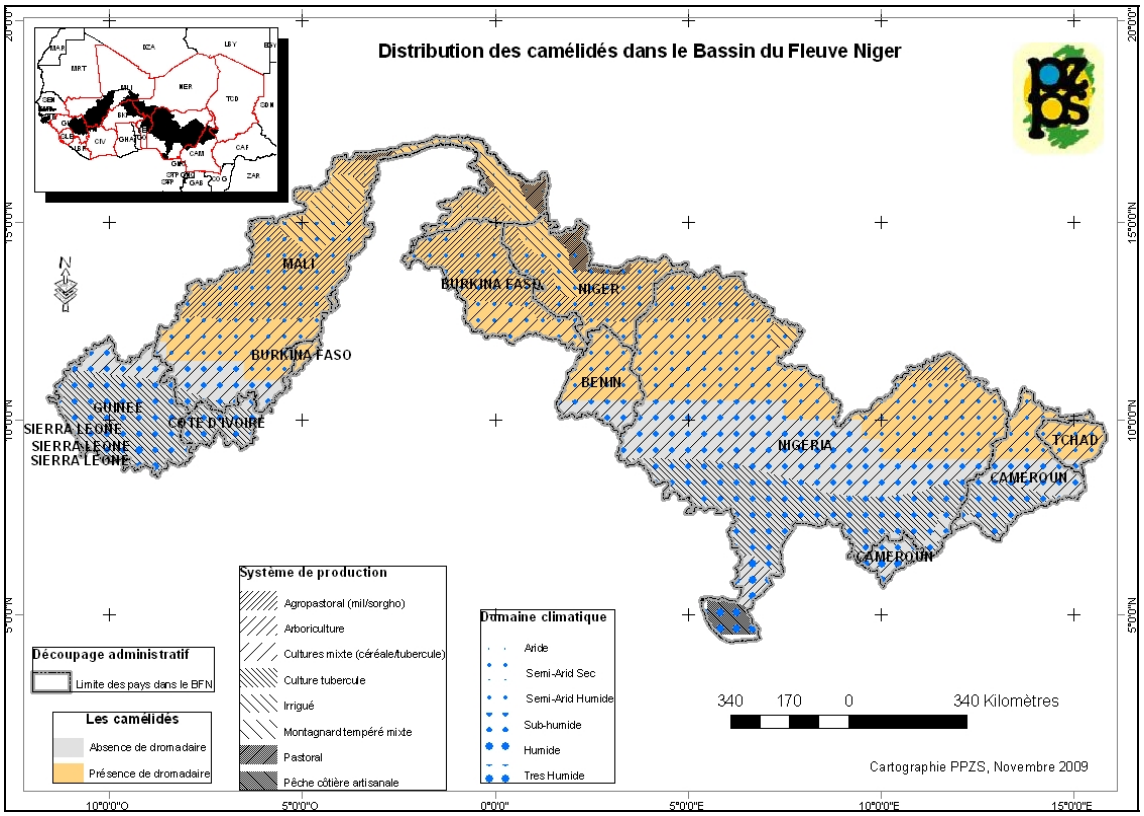

Figure 25: Camel distribution in Niger basin

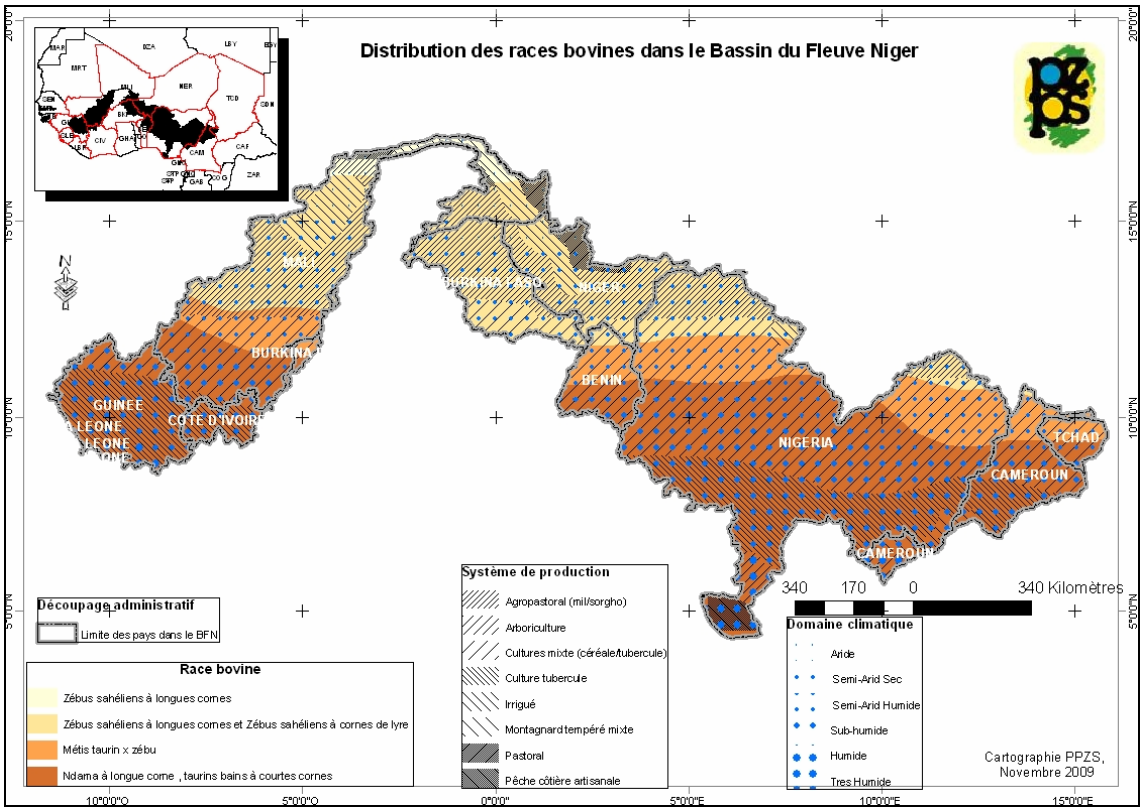

Figure 26: Bovine distribution in the basin

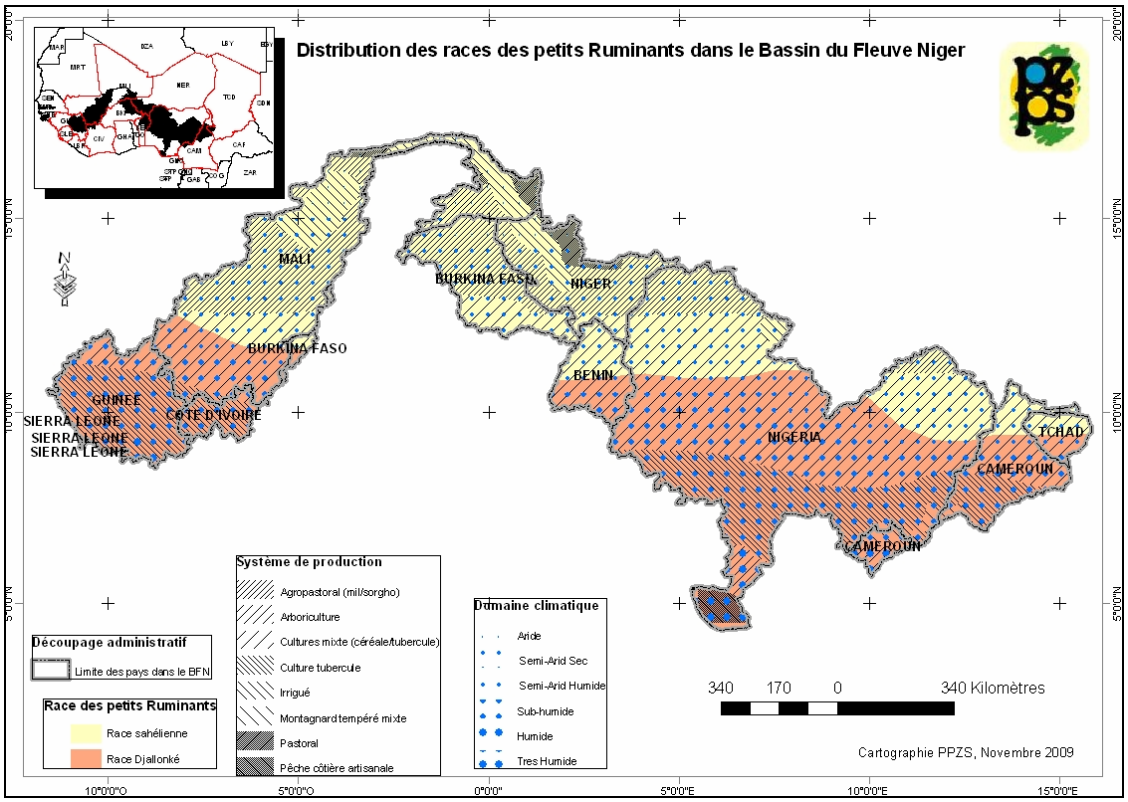

Figure 27: Distribution of small ruminants in basin

The area of zebus (bovines) follows and extends to the 7°N (Figure 26), limit of prevalence of trypanosomiases, where only taurines tolerant to this endemic survive. Zebus and taurines are heavily mixed in this intermediary zone.
In this zone, farmers attempt to cross breed to privilege the physical aspects of the former and tolerance to epizooties of the latter. Movements specific to these regions supply multiple occasion to cross breed. Beyond daily and seasonal movements which village herds undertake, 5 to 15% of breeders are pastoralists living on Sahelo-Saharan fringes (Diop et al 2009a), whose annual movements can exceed 800km (Figure 28)

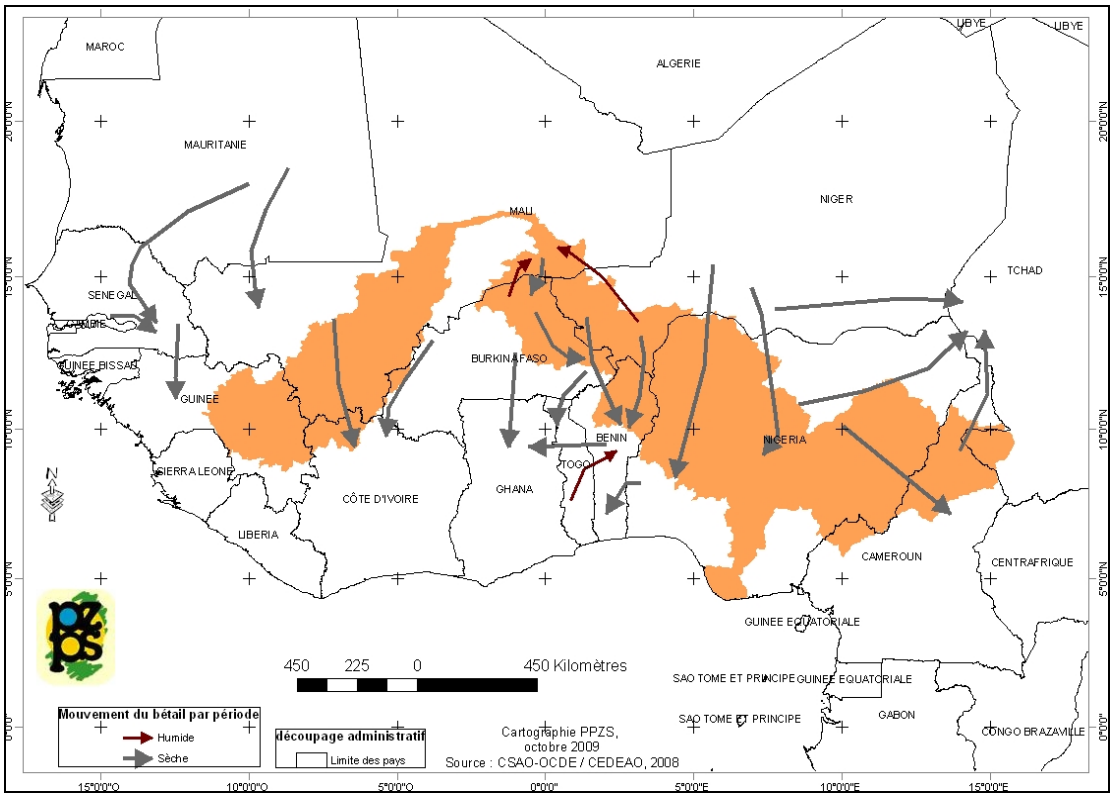

Figure 28: Major pastoral movements

As Figure 27 indicates, there are small ruminants in all the basin, of different sizes according to the species, but maintained in small herds of a few units (<10), typically containing 2 to 3 bovines.

Despite the natural and socio-political crises which stir countries (apart from Benin and Burkina Faso), all livestock categories are increasing, having practically doubled since 1978. Besides from Nigeria and Côte d'Ivoire, where the increase in LU appears more regular (better sanitary/health coverage), the graphs depicting growth in national herds reflect clearly the impact of various disruptions (1980s drought, conflict…) (Figure 29,

Figure 30 and

Figure 31)

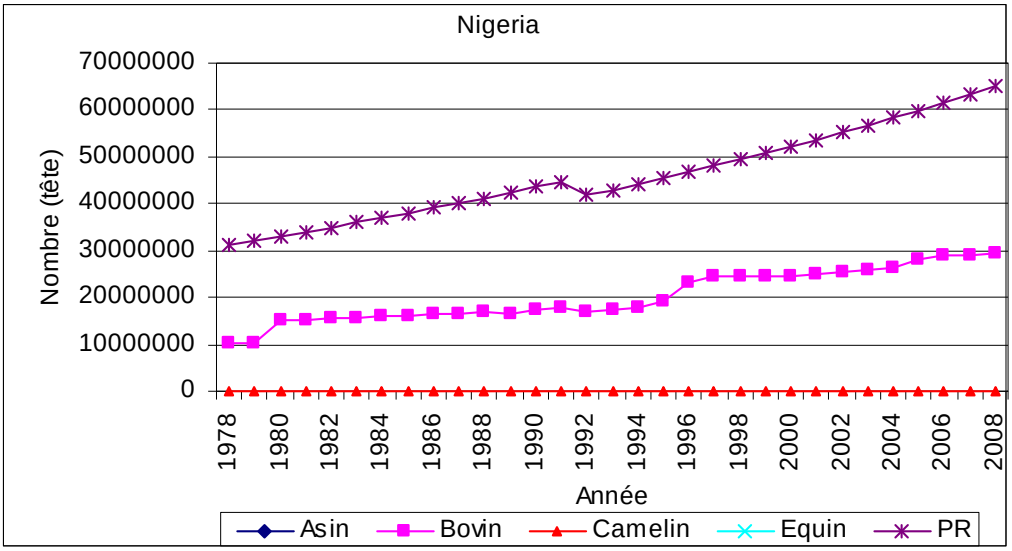

Figure 29: Growth of national livestock in Nigeria

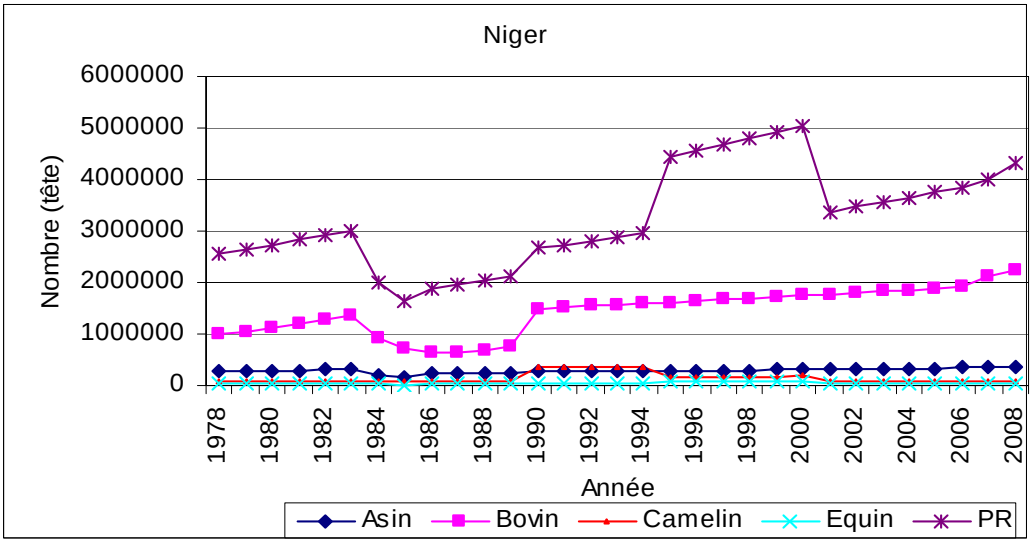

Figure 30: Growth of national livestock in Niger

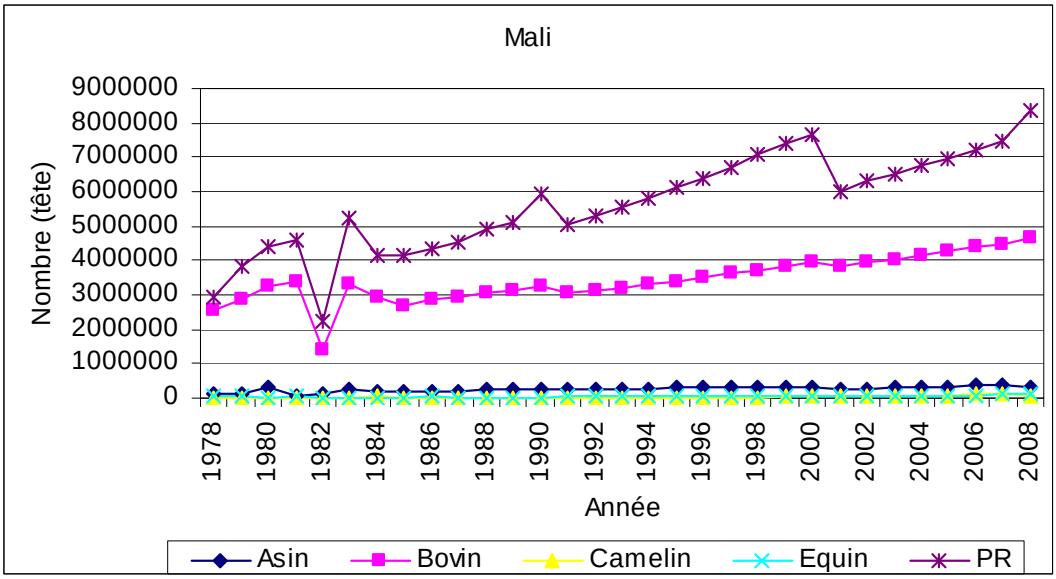

Figure 31: Growth of national livestock in Mali

The various growth rates vary from 3.6% (Burkina Faso) to 2.7% (Mali and Nigeria), and even 2 to 1.5 %(Benin, Niger, Cameroon and Côte d'Ivoire). In 2008, Nigeria remains the country with the largest concentration of livestock (68 %), then Mali (9.7 %) and Niger.

4.6.3. LWP calculation

Livestock water productivity in the Niger basin (LWP) can be calculated:

LWP = Erreur ! Des objets ne peuvent pas être créés à partir des codes de champs de mise en forme. Erreur ! Des objets ne peuvent pas être créés à partir des codes de champs de mise en forme. = Erreur ! Des objets ne peuvent pas être créés à partir des codes de champs de mise en forme.

Where:

Vi *(Value of productions and services)* ***; v*** *(meat)****; l*** *(milk);* ***f*** *(fertiliser)****; ta*** *(animal traction);* ***cp*** *(leather and skins);* ***Qe*** *(water necessary for production and services);* ***fnh*** *(natural fodder);* ***rr*** *(crop residues);* ***cm*** *(drinking water).*

The detailed methodology required to calculate LWP according to this formula is provided in Diop et al 2009b. Unfortunately, homogeneous data at same spatial scales was not available across the basin. Instead to calculate LWP we used: kg of livestock (not taking into account milk, traction etc) for 1999 over water consumed by livestock and used to produce the annual feed.

W applied in m3 = LU * 6, 25 Kg DM/ day / LU* 365 / RUE en kg DM/ m3).
There is no average Rain Use efficiency data but it is possible to provide interval of RUE per climatic zones (Serpantié, 2009b). The following RUE data was used.

Kg MS/ m3	Sahelian	Soudanese	Guinean
Rainfall	- 500 mm	500 – 1000 mm	> 1000 mm

RUE max	1	1	0.57
RUE min	0.2	0.4	0.25

However RUE is very variable per year (when rainfall is low, RUE is higher) and there will be differences between data in a research station and field data (affected by the type of ecosystem)

We also present below the number of LU/ha.

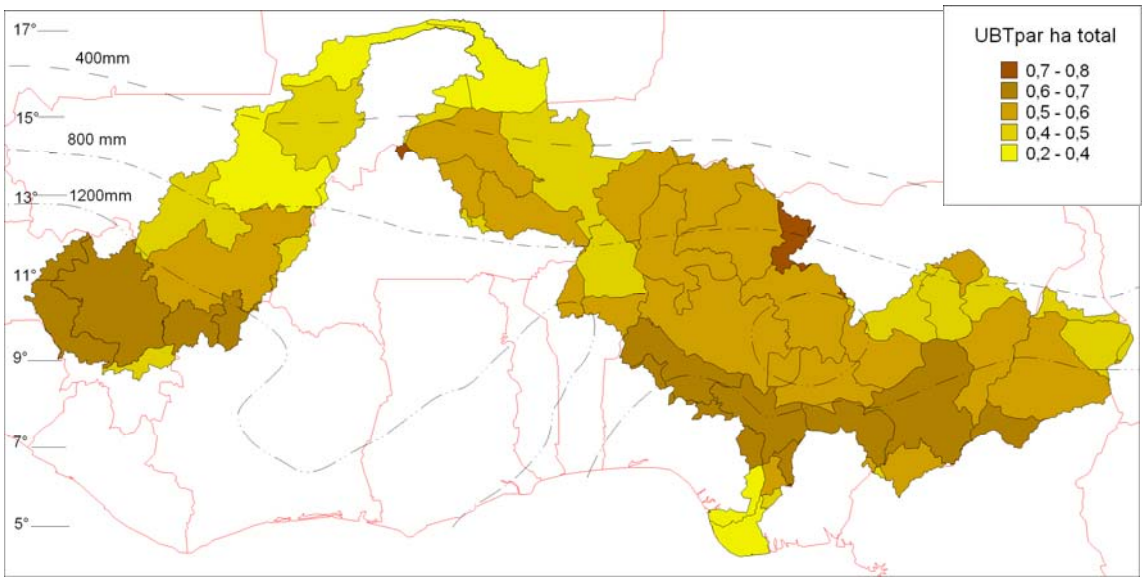

Figure 32: Number of LU per ha in the basin

High densities are concentrated in the zones between 1100-2000mm. Burkina Faso stands out relatively to Mali and Niger, perhaps due to the higher density of population.

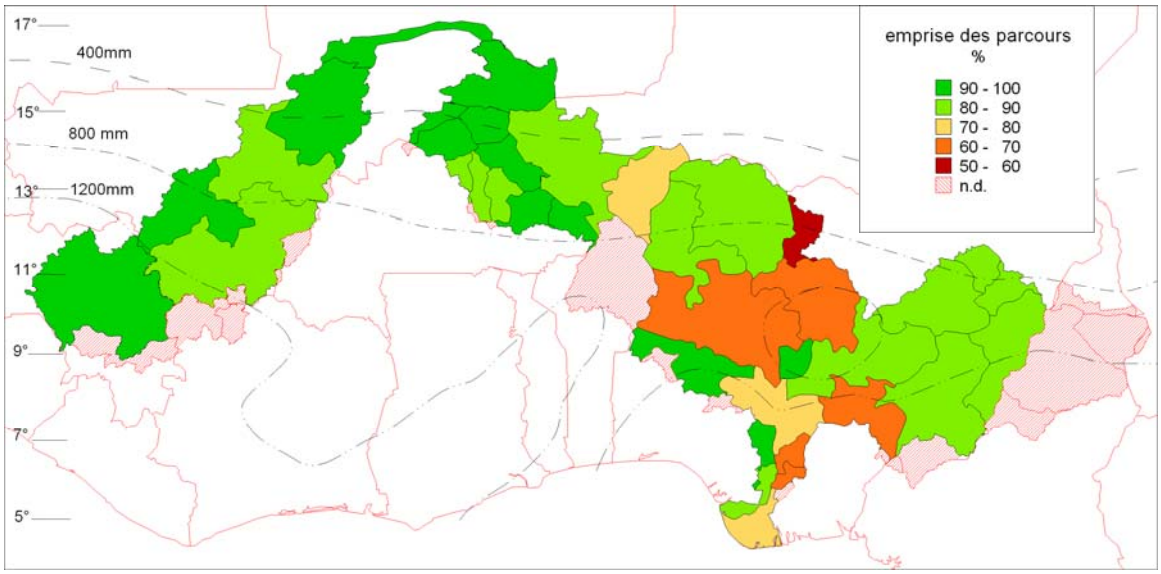

Figure 33: Amount of rangeland (total area-cultivated area) over total area.

The upper basin (where investments concentrate on lowland rice growing), the Sahelian zones, the Inner Delta (bourgou) and the less populated eastern part of Burkina appear as the regions with most available rangeland. However it reveals the relative rarity of rangeland in central Nigeria due to the high population density, but where 50 to 70% remain available and therefore not cropped.

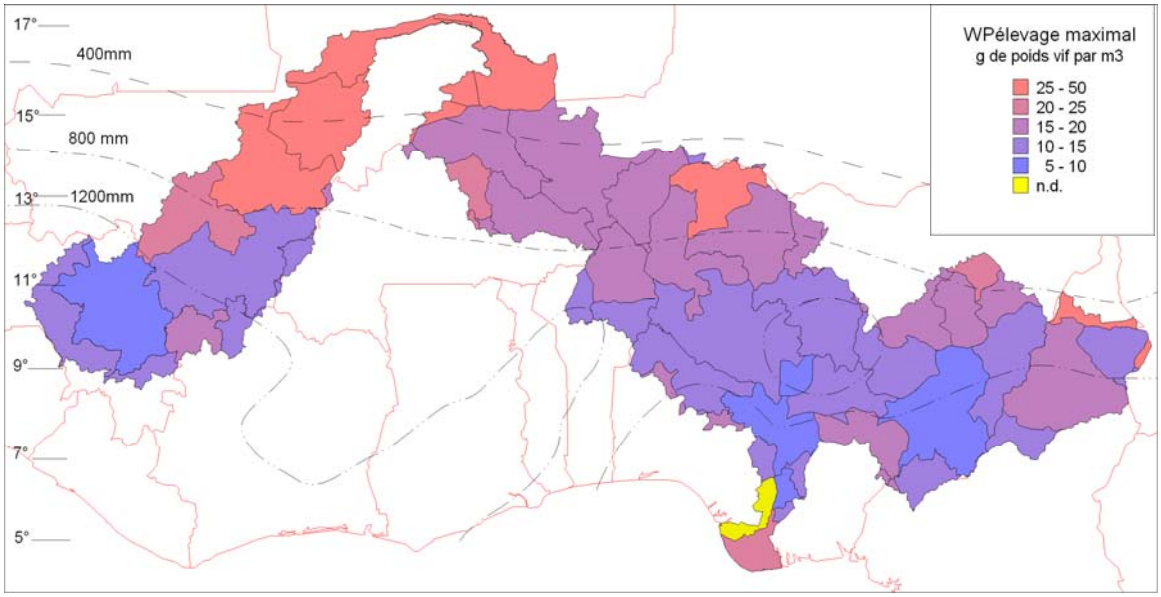

Figure 34: Livestock water productivity (maximal values using RUE range)

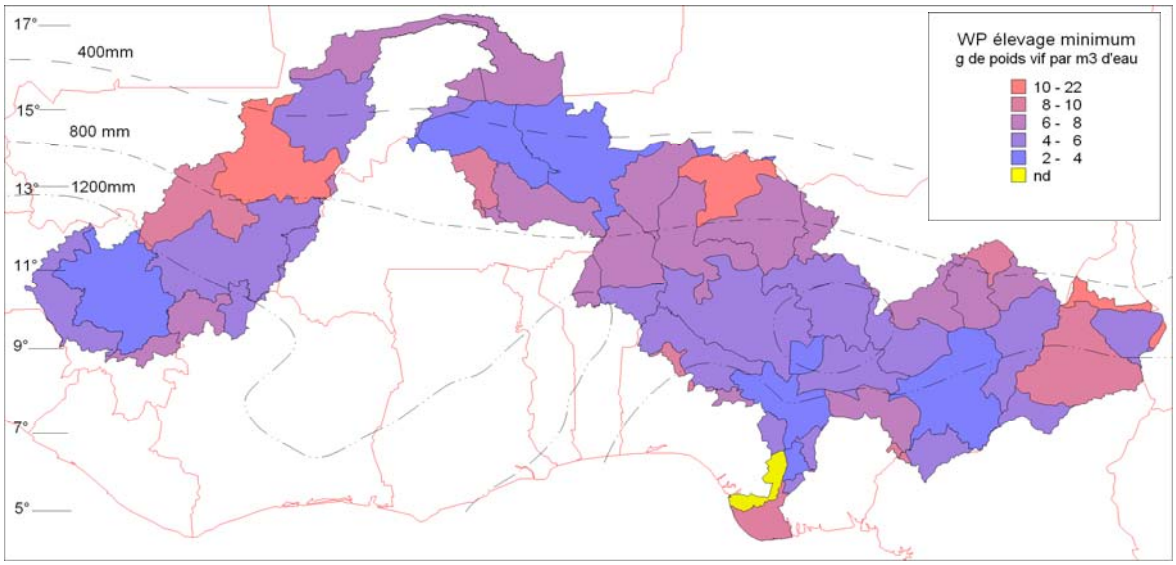

Figure 35: Livestock Water Productivity (minimal values using RUE range)

The order of magnitude of LWP is relatively low (0.002 to 0.05 kg per m3 water). This seems logical considering the place of herbivores in the trophic chain. It would be interesting to assess WP using kJ or $ in order to reflect the increased value of meat over certain crops. At northern latitudes, there is often no other uses of the biomass and hence no other use of the available water. The low water productivity values may therefore not necessarily be representative of a poor performance or productivity. At lower latitudes, low WP does infer issues of

tradeoffs and wiser uses of water, due to the competition between pastoral, agricultural or forestry (wood, biodiversity) based uses of water.

The best productivities are situated in the Sahel. Conversely, the worst LWP are situated in the zones where there is more than 1200 mm rainfall. The differences in LWP between the Inner Delta and North East Burkina Faso and West Niger can be explained by the high productivity of bourgou.

4.6.4. Conclusions

There is everywhere a great availability in natural rangeland, contrary to what is often reported. Regions offering the most natural rangelands are either those where agriculture is focused on lowlands (Upper Niger in Guinea or Kwara and Kogi, Nigeria), leaving interfluves free, or areas like the Inner Delta in Mali which provide seasonal pastures, but where herders don't reside.

The remarks made over LWP are similar to those made for rainfed agriculture. Above 1500mm rainfall and below 400mm, the values are less intuitive and more complex to interpret. Indeed low LWP in southern latitudes does not reflect poor performance, but simply excess water, which when looking at livestock in isolation appears wasted. In northern latitudes, relation to water is complex as though WP may be low, livestock may be the only organism capable of exploiting this water. Eitherway, to interpret water productivity it is necessary to go back to the maps spatialising the numerator and denominator.

Productivity issues in livestock relate to traditional aspects of the industry (vaccination/health coverage, food constraints), and the ability of animals to support local environmental constraints (heat, transform low nutrient, acidic food, ability to move over large distances to get food/water, frugality (low consumption).

Recommendations to improve livestock productivity and water productivity include:

- A better use of bush and tree browse as fodder for livestock. Applied research is needed to select the plant species and practical methodologies for their use.
- For all herders (sedentary and nomadic pastoralists):
    - Better health/sanitary coverage
    - the commercialisation of crop residues and animal by products
    - with animals consuming only 40% of the biomass they roam (60% is lost), develop the commercialisation of fodder, and limit the divagation of animals
    - Introduce laws/policies to restrict bushfires
- For village/less mobile herds/breeders
    - multiply the tree and shrubs plantation to increase year round available green fodder
    - Develop hedging to multiply the sciaphilic effect
- For pastoral systems

- ensure through an applied/implemented/respected agropastoral legislation, a true passage from nomadic agriculture to transhumance
- Limit and support/regulate adequately the routes and displacement seasons, including for transboundary commercial passages/movements
- Support through adequate legislation and agro-pastoral codes, the respective domains of activities at the three scales (local, national and regional)

5. Institutional analysis

5.1. Introduction

5.1.1. Background, Object, Scope, why institutions matter?

Institutions include policies, laws, regulations, organisational arrangements and structures, norms, values systems, traditions, customs and practices. Increasing competition over water resources and greater water conflict risks largely depend on institutions that determine incentive structure of the stakeholders and affect their behaviour (Ostrom 1990, North 2005, Runge 1992). A better knowledge of the complex Niger Basin institutional context appears as an essential challenge, to provide a better comprehension of the multi-scale interactions and dynamics affecting water availability and productivity, poverty alleviation and gender issues. To reach this objective, we first aim to identify the different scales within the Niger Basin institutional framework; secondly analyse the key role played by local institutional frameworks regarding water availability and productivity, poverty alleviation and gender issues and thirdly undertake statistical analysis of institutional data and indicators mapping.

5.2. Identification of the different scales of the Niger Basin institutional framework

5.2.1. Institutions at the inter-regional level :

The Niger Basin Authority (NBA) was created in November 1980 and brings together the nine riparian countries of the basin (Burkina Faso, Benin, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria). It replaced the Niger River Commission formed in 1963. In 1987 several objectives were assigned to the NBA such as harmonizing national policies, promoting development projects, controlling forms of navigation in the river and participating in the formulation of funds' requests. After a crisis period, the NBA engaged in the "Shared Vision" process in 2002 – largely funded by the Agence Française de Développement (AFD) - in order to promote a coordinated and equitable development of water resources in the Niger Basin (according to the IWRM requirements). An Action Plan for Sustainable Development (PADD) that is linked to an Investments Program plan (IP) was adopted as well as a project of legal and regulatory framework -Water Charter project 2008.

As part of the Shared Vision process, a reflection was initiated on the strengthening of civil society involvement at the regional level. After a diagnostic phase (Bazie, 2006) an initiative to support water users' effective participation in the countries' appropriation of the shared vision process was implemented. This initiative was entrusted by the NBA to a tripartite consortium gathering the NGO Eau Vive, the GWP WAWP (Global Water Partnership – West Africa Water Partnership) and the SIE (Secrétariat International de l'Eau) and national coordinating bodies in six NBA's member countries were created (Benin, Burkina-Faso, Ivory Coast, Guinea, Mali, and Niger; Koné, 2008). However the first meeting of the constitutive assembly of the River Niger Basin's users Regional Coordination held in August 2008 raised protests notably from the ROPPA

(Réseau des Organisations Paysannes et de Producteurs d'Afrique de l'Ouest/ Network of West Africa small farmers and producers' organisations), who contested the legitimacy of the composition of the regional coordination. The Eau Vive NGO and the NBA Executive Secretariat were accused of favouring NGOs representatives to the detriment of water users' organisations ones. ROPPA was created in 2000 by local and national organisations of small farmers and producers' in order to enforce their capacity to influence national and regional political reforms in the fields of agriculture and development (Coulibaly, 2007).

An involvement of customary authorities in the shared vision process and the implementation of the NBA projects is also seen as a strategic issue (Bazie, 2006). Stakeholders' participation and organisation remains very low in all the NB riparian countries (Bazie, 2006). Despite the ambition to improve their involvement by the NBA, financing intended to improve their capacity building is considered to be insufficient (5% of the IP - ABN, 2008), and adequate ways to institutionalise such an involvement at both the regional and national level remains unclear.

ECOWAS which gathers all West African states (and therefore all NBA member countries except Chad and Cameroon) plays a major role in the regional process towards IWRM implementation that was launched in 1998 (Ouagadougou Declaration). It was followed by the adoption of a regional IWRM action plan in 2000 (RAP- IWRM/WA) and the institutional setup of the Permanent Framework for Coordination and Monitoring of IWRM in West Africa (PFCM WA). Activities of the PFCM aim to improve the water management framework at regional and national levels in order to favour the implementation of an IWRM approach guaranteeing the sustainability of water uses. According to such objectives, PFCM directly supports River basin management structures established in all the trans-boundary Basins (among them the NBA) and states in implementing IWRM at trans-boundary basin and national scales (elaboration of IWRM national plans). A convention has been adopted between NBA and WRCU (the ECOWAS executive body of PFCM) to promote and facilitate the implementing of participation and gender issues principles in the "Shared Vision" process.

5.2.2. Institutions at the national level (9 NBA's countries)

An inventory and analysis of the national legal and political water management frameworks was carried out. The results along with the status of IWRM implementation, protection of customary water or land tenure rights, and gender issues are also presented in Table 6.

The role of the states remains essential in the management of natural resources in the Niger Basin. Contrasting with the trend towards private ownership and private rights in the land tenure sector, reforms to water legislation - largely driven by international exogenous forces - have seen the assertion of state control over water resources and the introduction of complex mechanisms for the allocation of administrative water rights (Hodgson 2004). The profound reforms aiming to decentralize and liberalise the economy have consequence on agriculture-related policy. They notably confer to new institutional actors (public:

local government and authorities, and private operators: notably village association created and funded through international remittances) a main role in bringing the water debate close to the levels where actual problems have to be addressed. According to IWRM principles, this decentralization process is supposed to bring a greater participation from the civil society and more transparency in public affairs (WRCU, 2007), but such reforms will also introduce changes and potential clashes between customary institutions and the new elected local governments.

Table 6: Synthesis of the legal and political national institutional framework *(main sources : Faolex Data Bank, Aquastat Data Bank, ECOWAS)*

	Benin	**Burkina Faso**	**Cameroon**	**Chad**	**Ivory Coast**	**Guinea**	**Mali**	**Niger**	**Nigeria**
Water law or act (Modern Right)	Code de l'eau 1982 (revision process)	Code de l'eau 1987 Loi d'orientation relative à la gestion de l'eau 2001	Code de l'eau 1998	Code de l'eau 1999	Code de l'eau 1998	Code de l'eau 1994	Code de l'eau 2002	Code rural 2003	Water Act 1993 - National Water Resources Bill (draft 2008)
Land act (Modern Right) Customary land and eventually water rights recognition	Loi sur le régime foncier rural 2008 Concession on land state-owned, land titling registration (oral languages) Customary law recognition (user right)	Loi portant sur la réorganisation agraire et foncière 1996 – 2008 (revision) Occupation permits on land state-owned Customary chiefs consultation (Code de l'eau)	Décret fixant les conditions d'obtention d'un titre foncier (2005 revision) Land titling on customary land – registration	Loi sur la propriété foncière et les droits coutumiers 1967 (collective or individual land titling registration)	Loi relative au domaine foncier rural 1998 Concession on land state-owned Customary law recognition IC nationality conditionality	Code foncier domanial 1992 Land titling registration Customary water uses recognition (Code de l'eau)	Code domanial et foncier 2000 Recognition of Customary right on non registered land (Loi d'orientation agricole 2005)	Code rural 2003 Customary law recognition – titling registration (Commissions foncières –CoFo-experimentation 1993)	Land Act Use 1978 (State Governor land control + customary law recognition)
Decentralization	1999 : 12 Départements	1998-2001 - 13 Régions, 45 Provinces	1998-2004-2008 : 10 Régions, 58 Départements	22 Régions, 61 Départements, sous-préfectures	2001-2009 : 19 Régions, 2 Districts, 81 Départements, 390 sous Préfectures	1990 : 8 Régions, 33 Préfectures, 33 Communes urbaines, 303 Collectivités Rurales de Développement	1996-2005 : 9 Régions 49 Cercles), 703 communes	1996-2001 - : 8 régions 35 départements et 213 communes rurales et 52 communes urbaines	Federation - 36 States - 789 Local Governments Areas

IWRM National Plan	Non ECOWAS member Pilot project	IWRM National Plan 2003 (Conseil national de l'Eau 2002, Commissions locales de l'eau, Projet Pilote du Nakambé)	Non ECOWAS member Recognition of IWRM principles – Comité National de l'Eau 2001- (signature of the « Convention portant creation de l'Autorité de Gestion Intégrée des Eaux de l'Afrique Centrale »)	Non ECOWAS member	IWRM Director Plan -1999		IWRM National Plan 2007	Recognition of the IWRM principles	Recognition of IWRM principles (adoption of NWR bill under way)
Gender Issues	Protocole sur les droits de la Femme en Afrique	Protocole sur les droits de la Femme en Afrique	Centres de Promotion de la femme		Plan national d'action de la femme	Protocole sur les droits de la Femme en Afrique Politique nationale de promotion de la femme 1996	Protocole sur les droits de la Femme en Afrique Loi d'orientation agricole (formal reservation to land access for women in public funding land development areas)	-	Protocole sur les droits de la Femme en Afrique – Woman Commissions /LGA

Stage of implementation: active, underway, lacking

5.2.3. Institutions at the local level

Partly due to the slow decentralization process and absence of implementation of modern water law, customary rights continue to play a central role in water management. Traditional law varies per ethnic group and requires case by case analysis but customary rights notably affect water through land issues, as water and land remain closely tied (Ramazzoti, 1996, Caron, 2009). The recognition of customary land tenure rights (Table 6) appears as a critical issue in modern water legislation, though its recognition remains rare (Cotula, 2006). Land tenure reforms of the past 15 years (influenced by the IFI and donors commitment to free and open land markets) have favoured individualized tenure and land titles, thereby affecting the legal formalization of customary rights (McAuslan, 2006).

5.3. The key role of the local institutional framework

5.3.1. Legal pluralism and changes in customary land and water management systems

The fact that customary laws remain dominant despite the progressive introduction of new legislation and structures creates a legal pluralism. This "legal pluralism" refers to the co-existence of systems of rules based on different or even contradictory principles privileging opportunistic behaviours. New structures are created by decentralization reforms and other state interventions and policies but also through participatory governance requirements (IWRM principles) and development projects (grassroots NGO's Developments programs) who create their own authorities and committees (e.g. to manage wells etc). This plurality of standards also results from economic and social changes (demography and economic ones) that bring about certain stakeholders to contest the legitimacy of local and traditional norms and encourage the emergency of new practices, more legitimate even if not official (Lund, 2000).

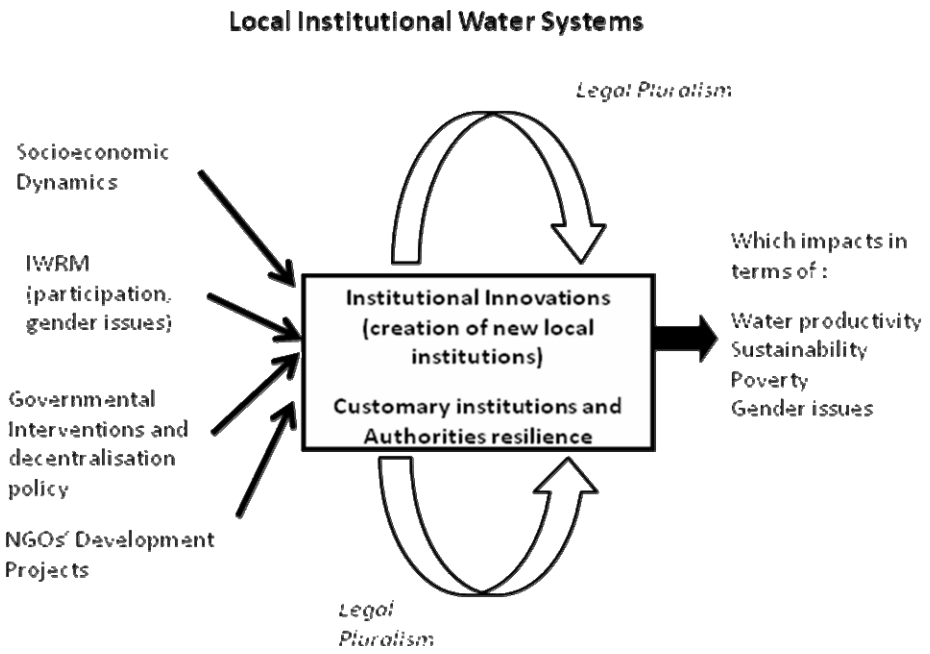

Figure 36: Influence of legal pluralism on Water productivity (Caron, 2009)

The dynamics between these structures create a change dynamic, which is susceptible to weaken traditional authorities and institutions. Such dynamics are not unequivocal. While in some cases customary law regulation systems are resilient in others they have been undermined by these profound changes and/or have lost their legitimacy (Laville Delvigne, 2006). Legal pluralism also makes local systems of authority and arbitration more complex (Figure 36), and can lead to land and water governance problems and conflicts (Lavigne Delville, 2006; Cotula, 2006).

Accordingly, the legal pluralism strengthened by currently local institutional changes is seen as one of the main cause of agriculture productivity stagnation and rural poverty in NBA's countries rural areas, due to the insecurity it creates in terms of definition, allocation and enforcement of land rights and consequently for the dependant water rights. (Figure 36)

5.3.2. Dynamics of change in local institutional water management systems and its potential

The major factors impacting agricultural water productivity in rural areas that are identified in academic literature are summed up in Figure 37

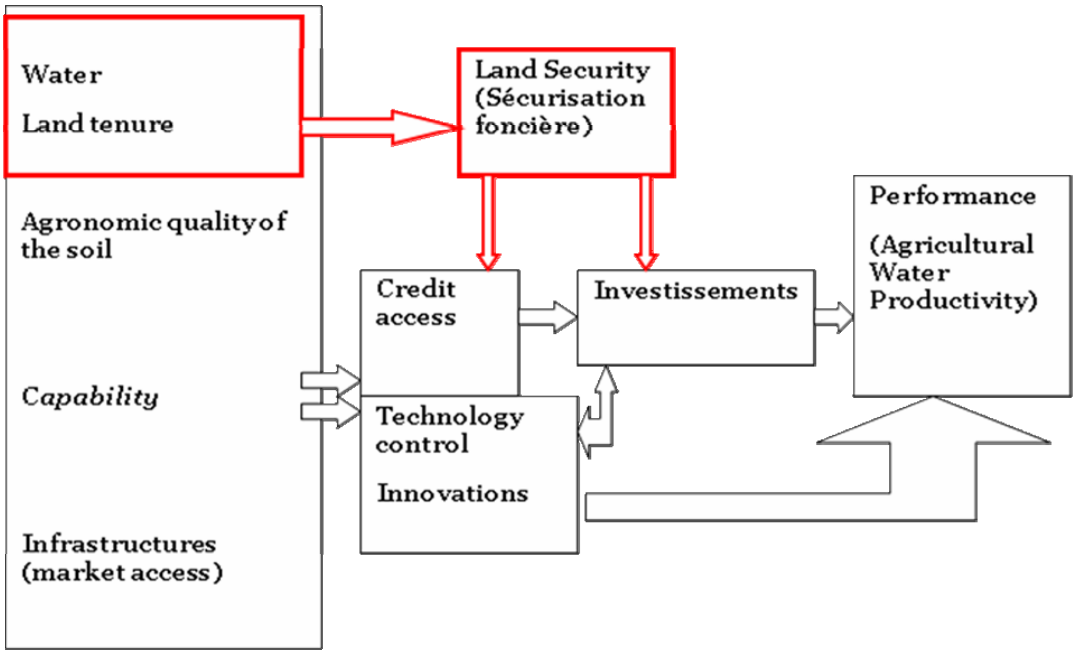

Figure 37: Factors affecting Agricultural Water Productivity (Caron 2009)

The governance of water and land resources has the potential to play an important role on agricultural water productivity and must be considered when analysing the institutional dimension of agriculture water productivity. Water rights are greatly embedded in the land rights in most of the customary tenure systems, hence land tenure security also conditions the secure access to water resources. Indeed land tenure security is presented as a decisive condition to encourage necessary investments for increasing agricultural productivity in the literature.

The legal pluralism that results from the duality of the system of land tenure experimented by all the NB states is considered as the main source of land tenure insecurity. Indeed, the enactment of formal land legislation largely influenced by European conception has often created a dual and separate system (Hodgson, 2004; McAuslan, 2006). But, the specificity of the rules and practices of customary tenure has been denied (McAulsan, 2006). The development of a "common law" of tenure that fuses the best of the multiple systems remains under consideration in national policy reform agenda. Nevertheless there are signs of growing awareness of this issue, like the introduction of customary tenure in code for pastoral land rights in Francophone countries (McAulsan, 2006).

Despite the promotion of individualisation and privatisation of land rights by IFI, most Governments have been reluctant to transfer full property rights to their citizens and the majority of rural land remains as a State domain.
However, recent land tenure legislation reforms have introduced procedures to secure land rights and transactions through the creation of registration systems (Table 6). Various ways to register rights to land have been enacted (Toulmin, 2008). The capacity of these registration procedures in effectively improving land rights security, particularly for the poor rural small holders (and women and young people), is largely debated (McAulsan, 2006; Toulmin, 2008). Indeed, in

practice, the implementation of these large scale national formal land titling programs have been very weak and source of exclusions because they are too costly (and corrupted) and non-adapted for poor rural population. However, new approach to land registration based on the involvement of the community and local institutions and on local and simple registration systems have been experimented. Such "bottom up" and participative land titling systems, in line with the commitment to decentralisation, may help to protect the tenure rights of the poor (McAulsan, 2006; Toulmin, 2008).

A strategic analysis of land tenure securing policies has been conducted in Mali, Niger and Nigeria with three priority foci: gender issues, dispute or conflicts resolution procedures, and experimentation or innovation that aim to securing claims based on locally recognized tenure systems.

5.3.3. Case study: Talo Dam project (irrigated rice production, on the Bani River, Mali).

5.3.3.1. Context

The expansion of irrigated agriculture constitutes one of the national priorities of the basin countries. Bani valley in the Upper Niger Basin is identified as one of the priority Development Zone of the Niger Basin (ABN et al., 2007). The Talo Dam is part of the "National Program of middle Bani's Plain Development", PMB, coordinated by the Malian Ministry of Agriculture within the Strategic framework for growth and the fight against poverty (PRSP-I- 2002-2006). The program encompasses 20320 ha of land development (1603 ha to rice culture, 4290 ha for Bourgou grazing, 490 ha for fish-farming).

The project was stopped in May 2001 due to protests led by population located downstream of the dam and the NGO Cultural Survival. A mediation process in 2002 resulted in the creation of the "Comité des Bons Offices" within which the NGO World Vision was civil society interest representative, complementary impacts studies were undertaken, modifications to the project were made and the "Comité de Bassin du Bani" provided for by the Water Act ("Code de l'eau" – 2002) was set up.

5.3.3.2. Methodology

Preliminary identification and analysis of the Malian water and land governance institutional framework and the stage of implementation of the decentralization policy were done before the fieldwork. The implemented methodology combined desk review and stakeholders' interviews (both at national, regional and local scale). The analysis of the collected data was done according to the analytical grids created (Socio-ecosystem resilience analysis). As the Dam only came into service one year before the study, results must be cautiously interpreted and the timeframe was too short to assess its impacts in terms of agricultural productivity (an increase in rice productivity was observed for 2007 – 3.5 t/ha for irrigated culture from 1t/ha under rainfed agriculture).

Fieldwork was carried out during August 2008 in major villages of the 4 communes, in the Woloni plain nearby the dam. The work studied more particularly: (1) the process of developed land allocation (focus on the customary authorities involvement -Bambara is the majority ethnic group- and on women and young people land access) (2) the agricultural technical improvement's support.

5.3.3.3. Main results

The main results of the study are:

- Limited positive impacts for women and young people from the PMB decentralized land allocation process, despite the enactment of such objectives through recent law reforms – particularly the Malian "Loi d'Orientation Agricole" (2005);
- Existence of collective women strategies to assert their claims to land and secure women's access to land. Notably involvement of the 8 ASPROFER "Association pour la promotion des femmes rurales" in the land allocation process and proposition to claim land collectively and redistributing individual access to plot internally
- Breeder marginalization: lack of implementation of actions to secure access to water and land for cattle, notably no lack of compensatory grazing areas, potential source of conflicts with migrants;
- Lack of establishment of a PMB dedicated management organization
- Women's access to micro-credit via collective organization (CANEF) supported by the PMB;
- Risk of negative impacts on ecosystem dynamics and on Human health (water diseases, pollutions …).

5.3.4. Conclusion: Implications for policy and practices:

Clear property rights and management rule for water and water infrastructures are crucial legal and institutional factors to promote efficient equitable and sustainable water use (Cotula, 2006). Interaction between the statutory and customary law is expected to continue in all the NB riparian states. What type of Government action is precisely needed varies from context to context and also depends on the governmental vision of agricultural development –balance between agribusiness and smallholder farming and relative importance of objectives like efficiency and equity. Specific policy recommendations can not be made here, but issues to be taken into account for policy and practices may be formulated:

- Legal pluralism should not be univocally viewed as a threats and a problem -it allows rights to adapt to changes in economic and power relations –in some places, multiple institutions find ways to cooperate and coordinate, creating hybrid new regulation frameworks;
- Need for land and water legislation built according to local systems rather than attempting to replace it with systems "imported" from elsewhere (innovation is needed in terms of design of local systems to secure water and land access and property rights);
- Temptation to idealize the "local" should be resisted due to the many customary systems inequity as regards social status, age, gender and other

aspects. Governmental intervention must raise the challenge of finding ways of recognizing and securing local water and land rights, on the one hand, while avoiding entrenching inequitable power relations and unaccountable local institutions, on the other. There is no universal solution emphasis should be on the process to design and implement context-specific approaches**;**

The NBA organization –according to its prior engagement in promoting stakeholders participation and involvement of traditional authorities (ABN, 2007) - should be used as institutionalized forum for debating these common issues. Recommendations in terms of land tenure and water rights reforms blending the best of customary and Western law in order to give primacy of place to the land and water concerns of the poor should be elaborated and their implementation supported -for example via their explicit introduction in the Niger Basin.

5.4. Institutional data and indicators mapping

5.4.1. Identification and gathering of institutional indicators at the Niger Basin countries scale

Due to the recognition of the main role played by institutions in both development and poverty dynamics (Meisel and Ould Aoudia, 2007), institutional data banks have been developed. This part presents a specific institutional database from the gathering of suitable and comparable indicators for eight of the nine Niger countries (excluding Guinea). A statistical analysis has been carried out in order to (1) give an insight in each national institutional configuration, (2) make a typology of these institutional contexts and eventually, (3) identify major blocking institutional factors regarding BFP Niger issues.

The main databases and sources exploited are:

i) IPD 2006 (Institutional Profiles Database 2006 – MINEFE and AFD – France - http://www.cepii.fr/ProfilsinstitutionnelsDatabase.htm);
ii) Human Development Indices 2007-2008 (PNUD - http:// hdrstats.undp.org/buildtables/#);
iii) AQUASTAT (FAO - http://www.fao.org/nr/water/aquastat/ main/indexfra.stm).

Other pertinent Database have been identified but not exploited due to technical (heterogeneity in the referent level of definition) and logistic reasons (great number and redundancy of variables): Gender and Institution Database (GID – ODCE), African and Development Index (AGDI), Uppsala Conflict Data Program (UCDP – PRIO), Program Minorities at Risk –MAR- from the Center for International Development and Conflict Management (CIDCM – Maryland University.

These provided a set of 139 selected indicators (428 variables) (Caron 2009) - that can be arranged in the 8 following themes or dimensions -Cf. Annexes Table 5: (1) External pressures; (2) Internal and external Safety; (3) Political Institutions and Public governance; (4) Stakeholders weight influence; (5) institutional reforms; (6) Legal environment; (7) Rural areas and agricultural sector; (8) Gender issues.

Limits due to i) according to the lack of homogenous available data at the sub-national scale, this level has been discarded; ii) the IPD data base does not encompass data for Guinea; iii) the qualitative and subjective nature of institutional indicators must be underlined.

5.4.2. Institutional profiles of the basin countries

Statistical analysis of the gathered institutional data (Component Multiple Analysis) was carried out. It consisted in exploring all the qualitative data gathered to bring out the most significant institutional characteristics of the 8 NB riparian countries covered.

First statistical treatment's results

The first two axes of variables dispersion revealed by the MCA form the first factorial plane on which all the countries are projected – Figure 38 (two axes capture 37.8% of total variance, that is to say the information contained in the entire database).

On the first axis F1 (19.9% of total variance)*:* the principal variables allow to differentiate and to characterize some specificity of the institutional configuration of Nigeria in contrast with a good internal security and strong exogenous pressures (Niger, Benin, Burkina Faso, Cameroon).

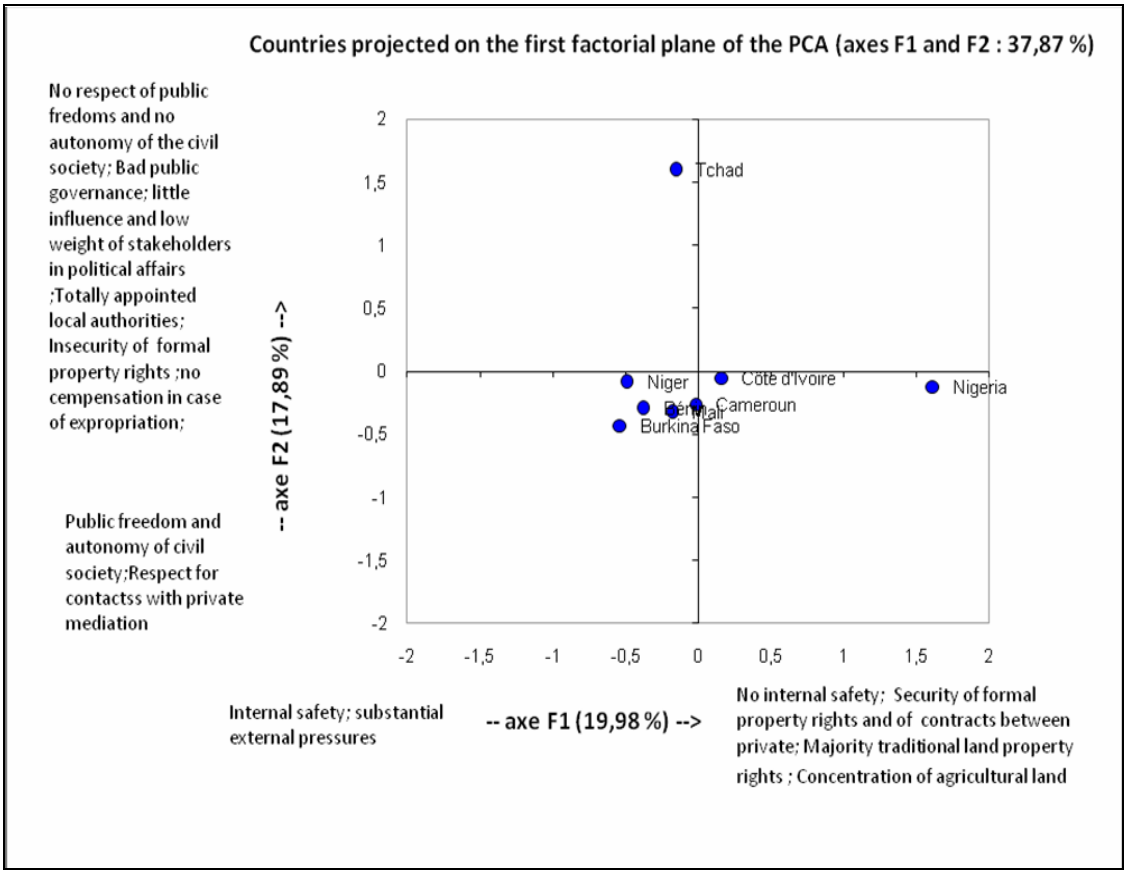

Figure 38: Individuals Projection on the first factorial plane (F1, F2) - 8 countries, 428 variables

The second axis F2 (17.9% of total variance) is strongly correlated with the indicator "guarantee of Public freedoms and the autonomy of the civil society". The position of Chad contrasts with others countries.

According to the results of a primary illustrative statistical exploitation of the IPD that has been carried out by its authors (51 countries where included, 79 stock variables), the NBA's members belongs to the same institutional profile group of "informal-fragmented" (Meiser and al., 2007). Our results put in light that institutional profiles of the NBA's countries are not so homogenous, and would need to go beyond this first classification. Such encouraging first results prove the quality and the pertinence of the IPD sources that provides the main part of institutional indicators.

5.4.3. Institutional factors affecting water productivity

The IPDB data provide complementary, comparable information on land tenure security issues that are summed up in Figure 39. Except in Cameroon and Ivory Coast the scale of traditional collectively owned land (traditional rights, religious rights and others) is high or very high. Agricultural land property rights are mainly traditional and informal in all the eight considered Niger Basin states. The security of traditional land property rights and transaction is low or medium (except in Chad, Nigeria and Niger). The security of formal land property rights and transaction is far from maximal but better assured than for the traditional rights except in Burkina Faso and Chad. In Cameroon, Ivory Coast, Mali, Niger and Nigeria (good security for the two latter) the level of security of formal and traditional property rights and transaction is identical. The security of traditional property rights (that encompass existence and importance of traditional system not only in agricultural matters and its capacity to ensure security of property rights) is high in Burkina Faso, Chad, Cameroon and Nigeria but medium in Niger and Mali.

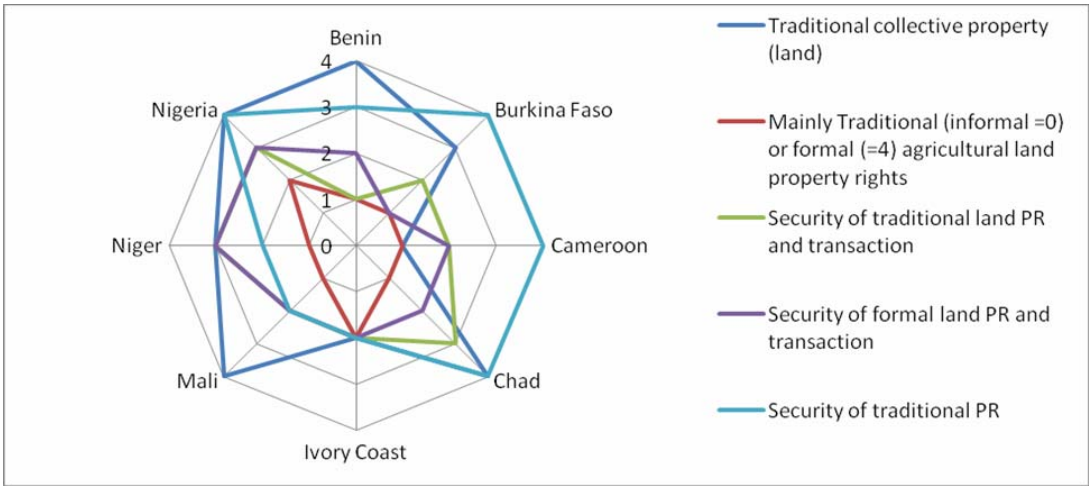

Figure 39: Traditional property and security of rights transactions in agricultural sector. From 0 (very low) to 4 (very high). Sources : Institutional Profiles DataBase 2006 – http://cepii.fr/ProfilsInstiutionnelsDatabase.htm)

Access to financial services (formal or informal ones) constitutes an important water productivity factor (Figure 37). The data gathered in the IPDB put in light that traditional credit systems are particularly highly developed in Benin, Cameroon and Niger but with important variations in terms of guarantees - reimbursement rate- that are very high in Ivory Coast but low in Niger (Figure 40). The micro-lending (informal or institutional one when it is backed up by NGOs or banks) plays an important role notably in Benin, Cameroon, Niger, Nigeria (with a very low reimbursement rate) and even more important than traditional credit systems in Burkina Faso and Mali. The underdevelopment of both traditional credit system and micro-lending in Chad must be underlined.

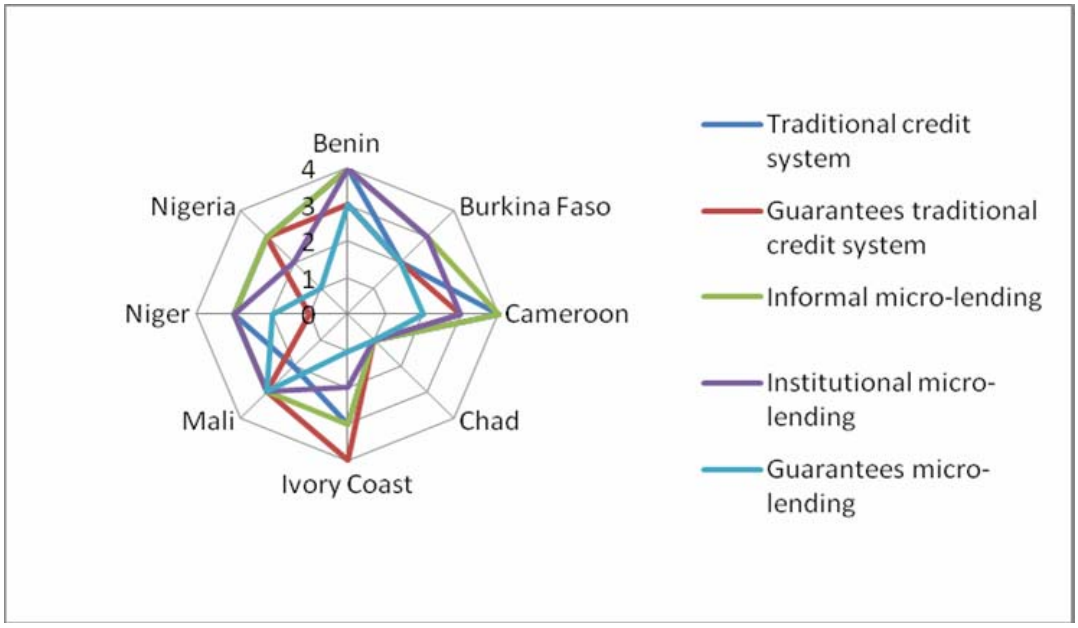

Figure 40: Role of traditional credit system and micro-lending and quality of guarantees (reimbursement rate) From 0 (no or very low reimbursement rate) to 4 (highly developed or very high reimbursement rate) - Sources : Institutional Profiles DataBase 2006 – http://cepii.fr/ProfilsInstiutionnelsDatabase.htm

5.4.4. Interest and limits

The first results of the statistical analyse of our qualitative institutional data originated from various institutional databases are partial –because no variable has been excluded. Another limit of our results lies in the fact that assessment of institutional characteristics are by construction subjective.

In spite of such limits, this complementary methodology allows a more rigorous comparative approach that allows identifying some specificity of the national institutional characteristics of each of the NB riparian countries covered. The development of such an institutional water focusing database could become one of the objectives of the Niger Basin Observatory.

5.5. Conclusion

The WP4 results give first insights into the current functioning of the Niger Basin complex multi scale institutional framework. If the effective assessment of impacts (or performance) of its multi scale interactions in terms of water availability and productivity, poverty alleviation and gender issues, was beyond the objectives and the forces of the WP4, major blocking factors have been identified.

According to the BFP Niger issues we focused on poor rural small land holder situation. From this point of view, one of the prior challenges to improve water agricultural productivity, poverty alleviation and gender considerations appears to be the recurrent question of security of land tenure (and women's rights to land). Such a crucial institutional issue is shared by all the French-speaking Niger basin riparian states. The legal pluralism that all these countries experimented is the result of a deeply historically path-dependent process. A colonialism period explains it in major part, current legal reforms are still driven by exogenous norms that do not correspond to the specific needs of the rural poor and fail to recognise the communal tenure as viable and economically efficient.

Land governance issues that still encompass water governance in NB rural areas (except in certain large irrigating schemes) is one illustration of our general observation on the major role played by exogenous norms and external pressures – that comes from international institutions requirements - on the formal Niger Basin water institutional framework that is currently set up. As we have underlined, such exogenous norms also impact informal or customary norms and rules, originating harmful competition and conflicts as well as institutional innovations -some time desirable notably in terms of gender concerns - via hybridization processes.

Thus, such exogenous driven institutional dynamics that are expected to be reinforced must also be viewed as a source of opportunities. The NBA is a good example of such opportunities. According to the agenda of its "shared vision" process, this latter should play a crucial role in favouring the development of innovations in terms of design of pertinent and culturally and context-adapted institutional solutions responding to the needs of rural poor both men and women who are the majority of land holders in all the member countries.

6. Poverty analysis of the Niger Basin

The primary research focus of Work Package 1 was the evaluation of methods to quantify the extent, magnitude, location and potential water related causes of poverty in the Niger Basin, West Africa. Water poverty occurs as the combined effect of multiple factors such as increasing and competing water demand, changes in hydrological regimes due in part to climate change and impoundments, increasing population, environmental degradation, reduced water quality, impediments to water access, regional conflict and corruption, and changing levels of water productivity. These relationships are dynamic and likely to vary spatially and temporally. Past policy responses have relied on poverty assessments that are generally not spatially explicit; and hydrological models based on historical flows that may be redundant under changing climate regimes. Hence policy initiatives that are able to account for the different causal relationships of spatially differentiated poverty are likely to be more effective that those that rely solely on hydrologic probabilities.

Sustainable water management requires institutional and governance arrangements that can be adapted to dynamic social and biophysical systems, can operate at multiple scales and respond to changing levels of river modification. Effective water policies consist of three key features: generally-agreed and achievable targets; appropriate and adaptive instruments capable of steering towards those targets; and monitoring mechanisms to provide feedback on progress towards targets (Hilborn and Walters 1976). The performance of effective water policy can be measured by the ability to sustain the functioning ecology of the water system, the potential for the efficient allocation of water resources and capacity to meet the conventional tests of equitable distribution and fairness through time.

We hypothesise that water policy design, and ultimately performance, are sensitive to spatial scale effects and initiatives to reduce poverty will need to account for spatial variation.

Institutional arrangements for poverty alleviation and the unit of analysis where decisions are made and implemented can occur at the Whole of Basin, National, administrative district and community scale. The first research objective was to identify methodologies capable of integrating impact analysis and policy formulation that reliably differentiates poverty at these multiple scales. A second research objective was to map poverty at a unit of analysis that aligns water productivity and water access with poverty data, revealing opportunities for politically feasible water policy formulation. A final objective was to provide evidence based analysis that guides effective policy development in the direction of the causes of poverty at scales that reflect the most exposed communities.

Details of the original Niger Basin research including GIS constructs, spatial referencing and spatial regression methods can be found in Ward et al. (2009).

6.1. Poverty profile in Niger Basin

There is a general, enduring consensus as to the magnitude and distribution of West Africa's poverty, both acute and chronic. Economic development in West African nations has been either slow or static for the past fifty years. When ranked by gross domestic product (purchasing power parity, per capita), all nine countries of the Niger Basin fall in the bottom quarter of national incomes. The United Nations Human Development Index, a composite ranking based on national income, life expectancy and adult literacy rate, ranks all of the Niger Basin countries in the lowest quintile of countries (Table 7) (UNDP 2007). The proportion of people living below the poverty line (US$1.25 per day) is high throughout the Niger basin countries and especially acute in Burkina Faso (70.3 %), Guinea (70.1%) and Niger (65.9%) (World Bank 2009). This amounts to an estimated 138 million poor in the Basin countries, of which a disproportionate number live in rural areas.

Life expectancies are in the bottom 15% of all countries worldwide. Niger Basin childhood mortality rates (death prior to the age of five) of up to 250 per 1000 live births are approximately two to three times higher than those in neighbouring countries in northern and southern Africa (Balk *et al.* 2003). The region is characterized by a high prevalence of endemic and epidemic communicable diseases. Respiratory diseases, malaria and diarrhoeal diseases are the largest causes of child mortality (ECOWAS-SWAC/OECD 2008). HIV infection rates are considered high (between 1.1 and 7.1%); though less severe than those in southern Africa.

Table 7 provides a snapshot of the development status for these countries according to an array of commonly applied poverty metrics. Such indicators have become increasingly widespread and favoured by decision makers, as they provide a more legible, though often simplified view of the reality on the ground (Molle and Mollinga 2003). Reducing complexity facilitates communication and comparison; however these indicators present several limitations, including aggregating data into national or yearly averages which mask spatio-temporal differences. Poverty, traditionally measured as individual or household income, often fails to reflect the many dimensions of poverty, notably when considering the mostly cashless, subsistence farming society of West Africa (*inter alia* Cook & Gichucki 2007; World Bank 2009). Index measures of poverty attempt to capture the multi-dimensional nature of poverty by aggregating a range of selected social-economic indicators, however they rely on subjective or even arbitrary construction of composite indices and attribution of weights weightings (often assigned by the analyst). Indicators which measure a relatively mono-dimensional and objective situation (Molle and Mollinga 2003) (e.g. childhood mortality rate) may offer the closest depiction of the situation in these communities.

Table 7 Poverty and water situation indicators for countries of the Niger Basin.

	GDP (PPP, per capita)	Population below poverty line (US $1.25/day)	Life expectancy at Birth	Under 5 mortality rate	Total Available Renewable Water Resources	Water Poverty Index	Basic Human Needs Index	Social Vulnerability Index	HDI	Gini Co-efficient
	2007	2007	2007	2007	2005	2002	2000	2004	2007-8	2007
	$US/capita	%	Years	%	m3/yr/capita	100-lowest poverty 0-highest poverty	50L-minimum basic needs	Index value (higher – more vulnerable)	Index value (higher – more developed) (rank in brackets)	100-complete inequality, 0-complete equality
Benin	1,500	47.3	55.4	19.1	3,820	39.3	15	0.584	0.437 (163)	36.5
Burkina Faso	1,200	70.3	51.4	15.0	930	41.5	17	0.658	0.370 (176)	39.5
Cameroon	2,300	32.8	49.8	14.9	17,520	53.6	33	0.640	0.532 (144)	44.6
Chad	1600	61.9	50	20.8	4,860	38.5	11	0.618	0.388 (170)	-
Cote d'Ivoire	1,800	23.3	47.4	19.5	4,790	45.7	28	0.584	0.432 (166)	44.6
Guinea	1,000	70.1	54.8	15.0	26,220	51.7	26	0.562	0.456 (160)	38.1
Mali	1,200	51.4	53.1	21.8	7,460	40.6	6	0.585	0.380 (173)	40.1
Niger	700	65.9	55.8	25.6	2,710	35.2	20	0.725	0.374 (174)	50.5
Nigeria	2,200	64.4	46.4	19.4	2,250	43.9	24	0.621	0.470 (158)	43.7
OECD* mean	37, 496	n/a	78.3	0.52	39,085	39.7	n/a	n/a	0.939	10.39
Non OECD* mean	10 898	n/a	66.1	6.76	26,802	23.6	n/a	n/a	0.686	18.65

Compiled from Gleick, 1999; Lawrence *et al.*, 2002; Vincent, 2004; UNESCO, 2006; UNDP, 2007; CIA, 2008; World Bank, 2009;*OECD mean based on the 27 high income countries as defined by the World Bank (2009)

6.2. Water poverty in the Niger Basin

Water poverty occurs when people are either denied dependable water resources or lack the capacity to use them. Water may be insufficient for basic needs, for food production or for wider economic and environmental services. Water scarcity is commonly thought to arise due to physical or economic constraints, though Molle and Mollinga (2003) distinguish three further causes of scarcity: managerial, institutional and political scarcity. This distinction reflects the complex nature of water poverty and points to the need to look beyond technical and financial means alone to reduce water poverty.

There exist a number of indicators designed to measure or characterise water poverty (see Table 7). Just like poverty indicators, these require moving from raw data towards a composite aggregated indicator and as a result often gain in simplicity what they lose in accuracy. The widely used Falkenmark "water stress index" (Falkenmark et al. 1989) defines a threshold of 1700m^3 of renewable water resources per capita per year, under which a country is deemed to suffer from water scarcity. All countries except Burkina Faso exceed this threshold; however the indicator fails to capture spatio-temporal variations, crucial in a country such as Mali which spans from a sub humid to a hyper arid climate. A more comprehensive measurement of water poverty is the Water Poverty Index, which notably takes into account communities' abilities to access and use water but suffers from the use of arbitrary weights and must ideally be generated at a local rather than national or regional scale (Sullivan and Meigh 2003).

6.3. Relations between water and poverty

Though indices provide an overview of the poverty and water situations faced in the basin, they do not intend to reflect the linkages between water and poverty. Composite indices intrinsically mask the importance of each factor, making interpretation of the potential causes behind water poverty and formulation of subsequent interventions difficult. Furthermore, identifying a state of water poverty (i.e. low level of water resource, access or use) may not necessarily tell us about the associated level of poverty, i.e. reduced livelihood, well being or economic poverty.

To address the question of a hypothetical relationship between water and poverty at the national scale, we estimated statistical relationships, using poverty maps and correlation coefficients. Significant correlations do not imply causality but point towards water resource factors which may influence poverty. At the national scale, weak correlations between widely used water and poverty metrics of between 0.02 and 0.47 are characteristic for all African nations (excluding small island states). Table 8 summarises the correlation matrix between the Falkenmark Index of water availability and widely used poverty indices; the Water Poverty Index (WPI), the Headcount Ratio (proportion of people living under US$1 per day, PPP), the Human Development Index (HDI), the Genuine Savings Indicator (GSI) and the Social Vulnerability Index (SVI). Note that data were not available for Libya, Liberia and Somalia and the table does not include small island states. Thus at a national level, there is little evidence for a strong association between a country's water situation and its development performance

on the African continent. Note that the TARWR correlation with the WPI is to be expected given that the latter incorporates a form of the total water resources statistic.

Table 8: Correlation matrix of poverty indices and the Falkenmark index of water availability, based on 48 African countries (2001-2002 data)

	Falkenmark	WPI	Headcount Ratio	HDI	GSI
Falkenmark[1]	-	-	-	-	-
WPI[1]	0.30*	-	-	-	-
Headcount Ratio[2]	0.26	-0.34*	-	-	-
HDI[3]	-0.21	0.67*	-0.58*	-	-
GSI[4]	-0.18	-0.08	-0.17	0.16	-
SVI[5]	0.07	-0.47*	0.48*	-0.48*	-0.02

* - statistically significant correlation ($p < 0.05$)

[1] Lawrence, *et al.* (2002); [2] World Bank (2009); [3] UNDP (2007); [4] Hamilton and Clemens (1999); [5] Vincent (2004).

In this analysis we hypothesised that variables associated with water access and productivity would significantly affect observed levels of poverty. We therefore decomposed poverty indices as individual variables and an expanded array of water and non water poverty determinants at high resolution spatial scales to detect statistical relationships.

For this study we relied on three common poverty variables and assessed the role of water related variables in explaining the observed distribution in each for the countries of the Niger River basin. The basin is socially and economically heterogeneous, has a high proportion of subsistence livelihoods and a relatively large non-market, hybrid economy. A singular monetary measure of poverty (for instance, household income) is unlikely to capture either the full magnitude or distribution of poverty. We therefore used two health variables: child mortality and child stunting (height for age ratios) and a composite relative wealth index. The singular dimension of the first two variables avoids the problem of subjective weighting of composite indices and provides evidence based poverty measures that intersect cultural, economic and policy boundaries (Setboonsarng, 2005). Note that the wealth index is country specific and cannot be compared internationally (Rutstein and Johnson, 2004). Data was taken from the Demographic and Health Surveys (Measure DHS, 2008) and interpolated to estimate values in non-sampled regions. Figure 41, Figure 42 and Figure 43 illustrate the spatial distribution of child mortality, child morbidity and relative wealth respectively, in 630 administrative districts across the basin.

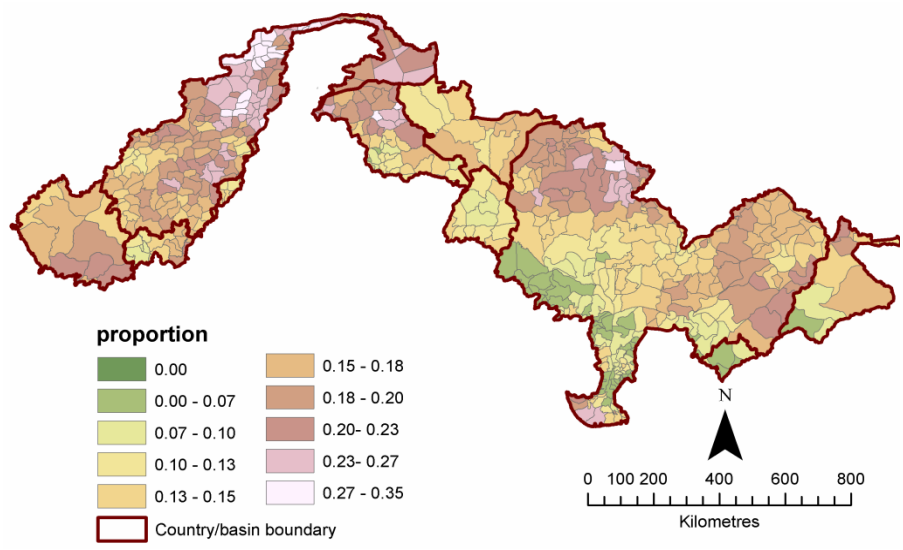

Figure 41: Estimated child mortality (percentage of children who die before age 5) across the active Niger Basin (based on births recorded since 1980).

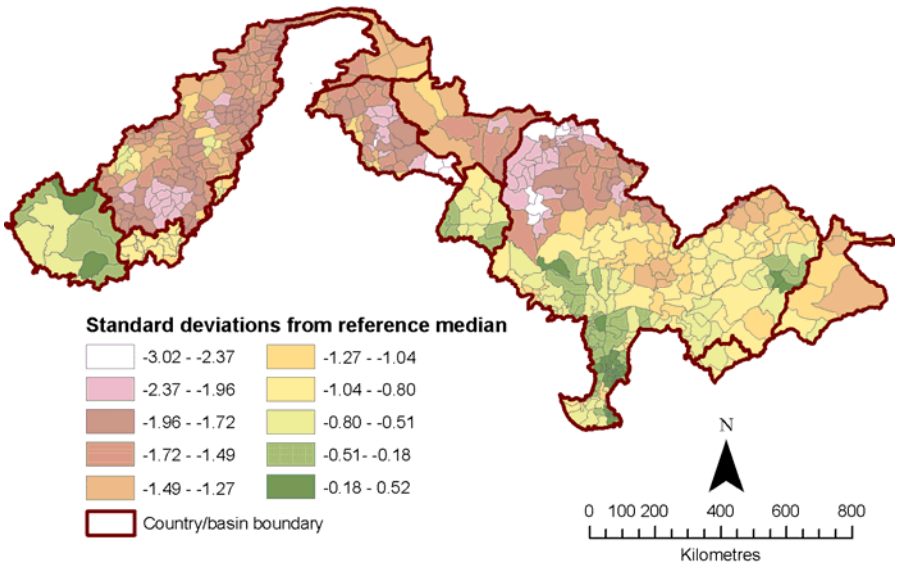

Figure 42: Estimated child morbidity (height–age ratios) across the active Niger basin

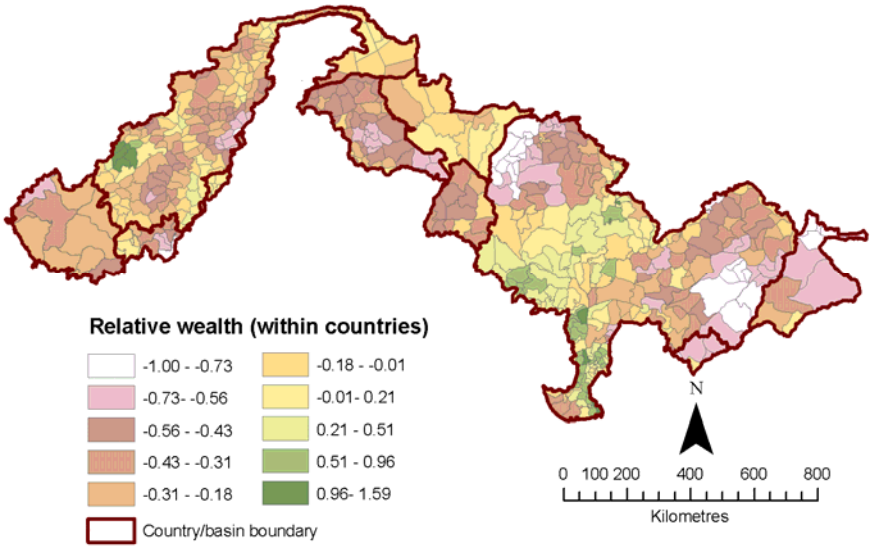

Figure 43: Estimated relative wealth across the active Niger basin, as indicated by possessions, land ownership, housing material, employees. Values are relative within countries, not between countries.

6.3.1. Whole of basin assessment (Geographically Weighted Regression)

The poverty estimates were assessed for statistical correlation with possible poverty determinants, both water and non-water related, and was undertaken in the first instance at a Basin scale using Geographically Weighted Regression (GWR). The explanatory variables employed in the analysis are detailed in Annex 1. GWR formally accounts for significant spatial correlations or spatial patterning, which can bias regression results and lead to misinterpretation. This demonstrated that the influence of different poverty determinants (such as geographical isolation, education levels and availability of water for instance) is variable over the Niger Basin; unsurprising given the socio-economic and biophysical diversity of this large study area.

Furthermore, considerable disparity between results analysed for child mortality and child stunting was found despite the widely accepted relationship between these variables. This highlights the need for poverty analysis that incorporates a number of alternative poverty metrics for cross validation, as is used here. At the whole of basin scale, we considered robust only those results that were supported by both the mortality and morbidity analyses.

The total quantity of available water resources (TARWR, cf. Figure 44 and Figure 45) was significant ($p<0.05$ for all statistical tests, unless noted otherwise) in North West Nigeria, East Nigeria and central Mali. In Figure 45 (and Figure 47), districts where TARWR (5A=unprotected water) is not significant (at $\alpha=0.1$) are coloured blue; districts where TARWR is associated with a significant increase in child mortality are coloured yellow and orange, and districts where TARWR is associated with a significant reduction in child mortality are coloured green. TARWR was only occasionally associated with poverty, suggesting that social or

institutional factors of water use are more important than water availability. The quality of water used by households appears to be as important, or more so, than the total quantity of water available in the environment. The use of unprotected well or surface water is generally positively correlated with increased child mortality and increased stunting. In North West Nigeria and east Nigeria, a 1% decrease in the number of people using unprotected water is correlated with an up to 2.4% decrease in child mortality. Increased irrigation development is correlated with reductions in child stunting in central Mali, North West Nigeria, central and eastern Nigeria and North Burkina Faso. Increased time spent in education is significantly correlated with a decrease in child mortality and child stunting. In much of the Mali Inner Delta, a one year increase in the average level of education is associated with an approximate 3% decrease in child mortality.

The variables demonstrated to be statistically non-stationary (i.e. their influence varies across the landscape) may be more appropriately addressed using a geographically targeted policy approach. The differences in coefficient estimates are likely to be symptomatic of the ways in which a variable influences communities subject to local conditions.

Education and access to improved water quality (see Figure 46 and Figure 47) are variables that are significant and relatively stationary across the study area. They can therefore be addressed with whole of catchment scale policies with less attention to regional differences. Certainly, a variable as important as education will require its own nuances due to cultural factors, however its importance is relatively spatially consistent.

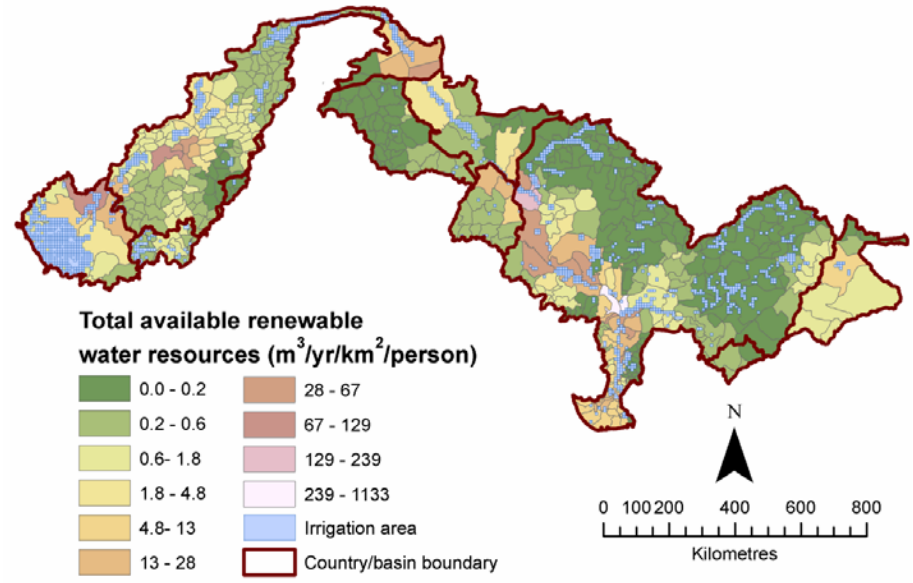

Figure 44: Total available renewable water resources and irrigation areas within the active Niger Basin (source: FAO, 2007; FAO, 2000)

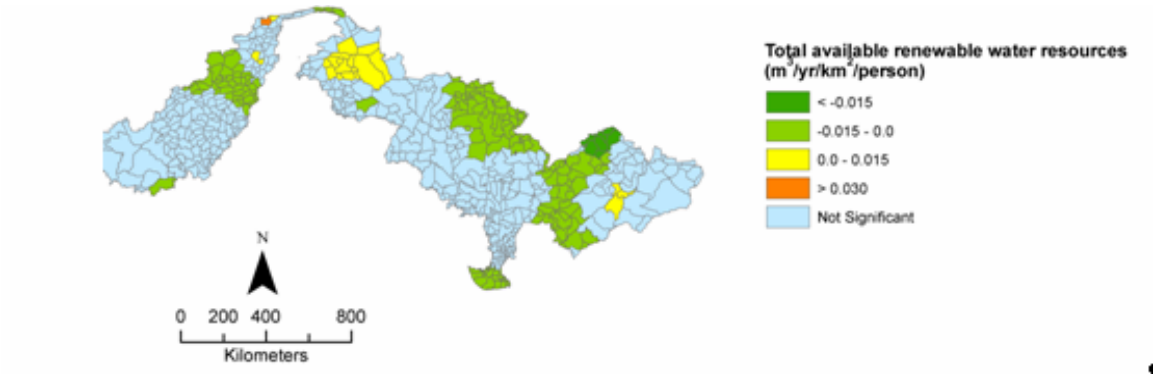

Figure 45: Map of total available water resources and associated change in child mortality estimated with GWR

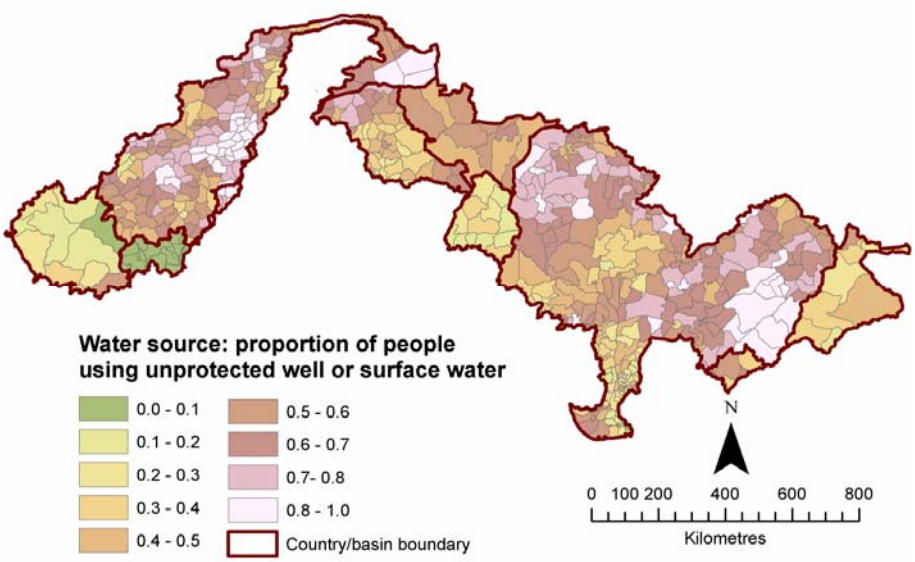

Figure 46: Water source: proportion of people using unprotected well or surface water. Note: Guinea is not comparable to rest of active basin due to omission of some data (data source: Measure DHS, 2008)

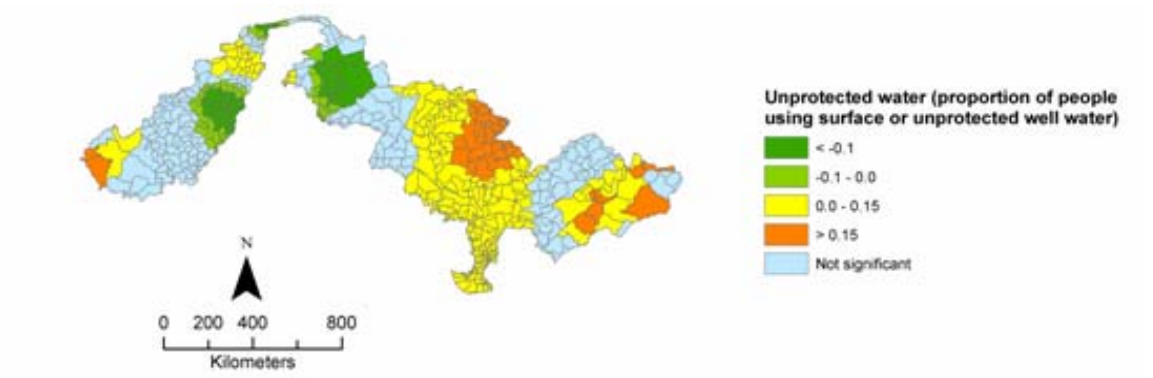

Figure 47: Map of unprotected water and association with child mortality estimated using GWR

6.3.2. National and sub-national poverty analysis (LISA clusters)

Policy decisions are often made at the state or national level, and regional perspectives of poverty cannot be presumed to be aligned or concordant with the differentiation of poverty, livelihood vulnerability or institutional diversity across the entire Niger basin (Hyman *et al*. 2005). A finer resolution of poverty analysis was used as an alternative to a whole of basin analysis, enabling the identification of poverty hotspots at a sub-national scale. Anselin (2005) has developed localized indicators of spatial correlation (LISA) to account for spatial clustering at defined local scales. These clusters represent areas that have significantly elevated poverty levels ($P<0.05$), referred to as 'hotspots.'

There is broad convergence in the hotspots found using different poverty measures. Figure 50 (A) shows child mortality hotspots (coloured red) in central Mali and the inner Niger delta, north Burkina Faso and North West Nigeria. Figure 50(B) shows hotspots of child stunting (coloured red) clustered in Southern Mali, North Eastern Burkina Faso, North West Nigeria and South West Nigeria (stunting is measured by a height for age ratio hence low values indicate worse conditions). A hotspot indicates those regions where the height to age ratio is spatially correlated and significantly less than the basin median. Figure 50(C) shows hotspots of low relative wealth or asset value (coloured red). Because the wealth index cannot be compared internationally (Rutstein and Johnson, 2004) this map provides less robust evidence; however it shows very similar results to the other metrics. Poverty hotspots occur in South Mali, east Burkina Faso and North West Nigeria.

Potential causative factors of each poverty hotspot were explored using spatially explicit regression analysis. As indicated by the 'whole of basin' approach, this sub-basin scale assessment also found considerable differences in the way poverty manifests in different regions. Table 4 details the coefficients and statistics, typical of the spatial lag regressions for child mortality, morbidity and wealth, estimated for North Western Nigeria. Nearest neighbour relationships were used determine the spatial weights matrix to estimate spatial lag regression model according to Anselin (2005).

In North West Nigeria, water quality is the primary water-related factor that correlated with poverty. A 1% decrease in the number of people who access their primary drinking water from unprotected well or surface water is associated with a 1.1% decrease in child mortality. Weaker evidence was found linking water access to child mortality: An average reduction of ten minutes taken to access the primary water source is correlated with a 1.7% decrease in child mortality rates. Similarly, a 1% increase in a district's irrigated area corresponds with a 0.04 standard deviation improvement in height-for-age ratios. Education is the strongest non-water correlate: A one year improvement in average schooling attainment is associated with a 0.6% decrease in child mortality rates, all other factors held constant

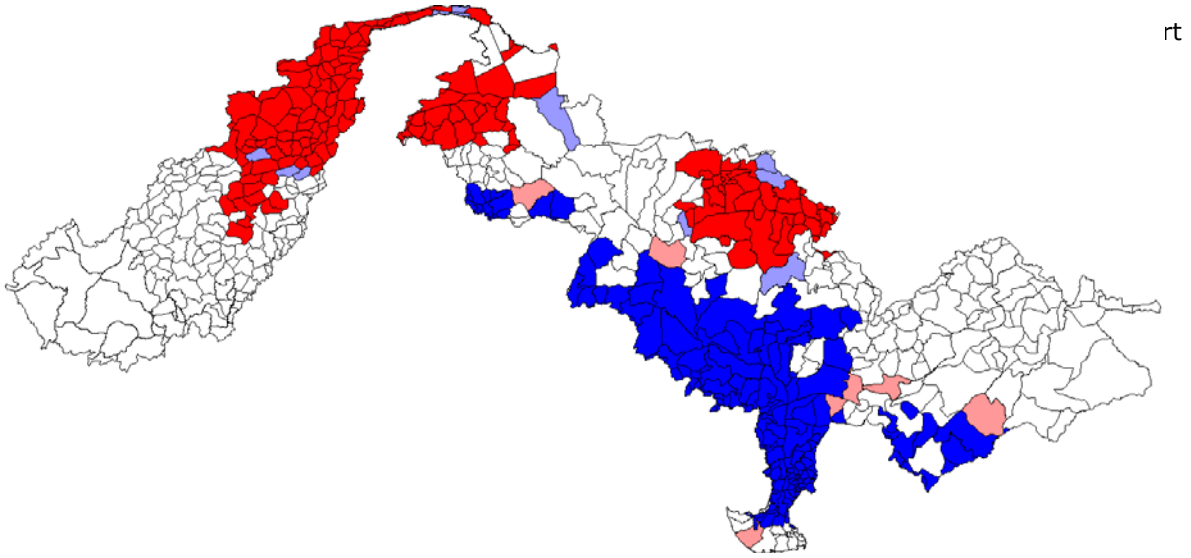

Figure 50 (A): LISA clusters of child mortality (proportion of children who die before age 5 yrs) across active Niger Basin. Moran's I value of 0.679 indicates moderate spatial autocorrelation in this variable

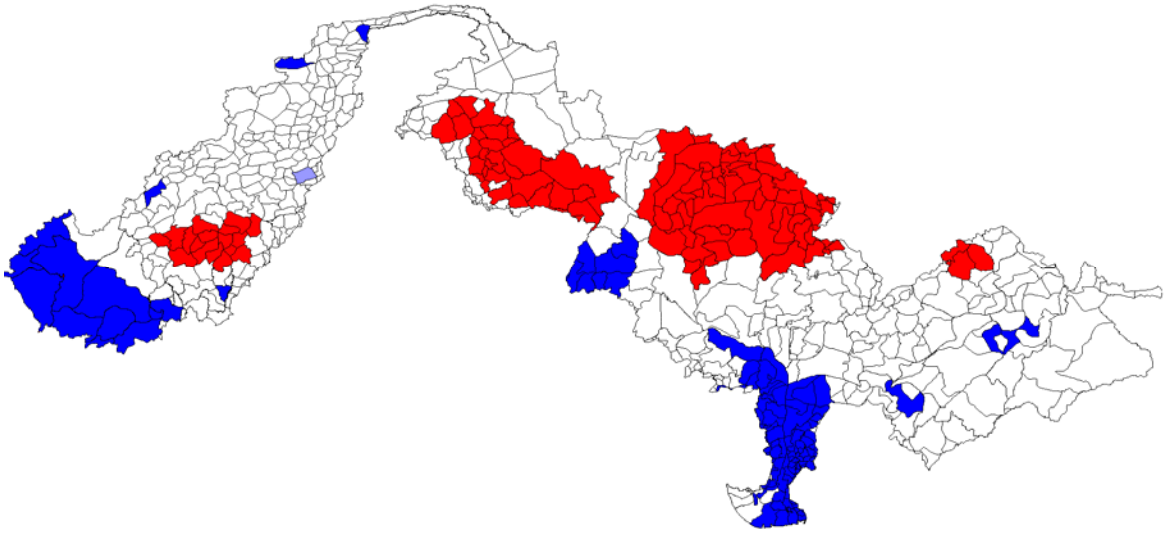

Figure 50 (B): LISA clusters of child morbidity (height for age ratios) across active Niger Basin. Moran's I value of 0.833 indicates high spatial autocorrelation in this variable.

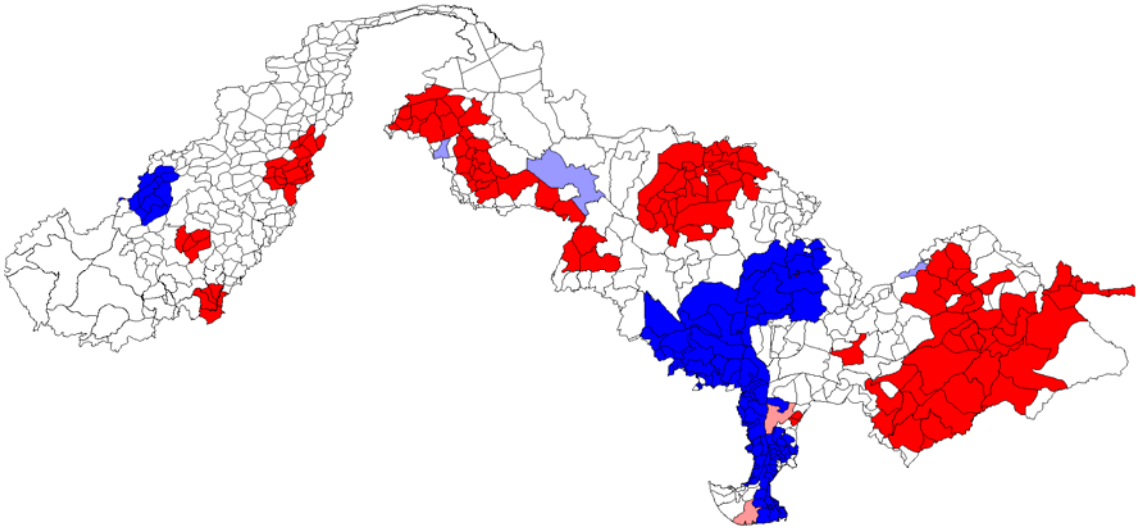

Figure 50 (C): LISA clusters of relative wealth across active Niger Basin. Moran's I value of 0.767 indicates moderate spatial autocorrelation in this variable.

The Central Mali region is an important area of the Niger Basin containing the Ramsar listed Inner Delta – a highly productive flood plain covering an area of over 80 000 km^2. This region features average child mortality rates of 240 per 1000 live births. The relationship between water and poverty is ambiguous in this region. Non-water variables were more clearly correlated with poverty. For instance, a one year increase in average schooling levels is associated with a 3.1% decrease in child mortality rates.

In East Burkina Faso, the use of unprotected water is correlated to poverty suggesting that quality is more important than quantity or access in this region. Environmental degradation, as measured by the World Wildlife Fund's 'Human Footprint' score significantly explained wealth and child mortality. An increase in environmental damage was associated with an increase in child mortality and a decrease in wealth.

In East Nigeria and North Cameroon, the use of unprotected water sources is significantly correlated both with reduced wealth and increased child mortality. A 1% decrease in the use of unprotected well and surface waters is associated with a 0.16% decrease in child mortality. Evidence was also found for a positive correlation of dams and irrigation on poverty levels. Education is associated with reduced poverty in the wealth and mortality models, and a 1 year increase in average education levels is associated with a 0.7% decrease in child mortality. Table 3 summarises the water and non-water determinants of poverty, estimated using spatial lag regression at the scale of administrative district.

Table 9: summary of spatial lag regressions at the scale of poverty hotspots.

Poverty Hotspot	**Measure of poverty**	**Strongest water poverty variables**	**Strongest non-water poverty variables**	**Utility of the TARWR variable**
North West Nigeria	Identified using all three metrics. Wealth index model strongest (R^2 = 0.956)	Water access Unprotected water Irrigation TARWR	Education Telephones	Moderate – child mortality only
Central Mali and the Inner Delta	Identified only in child mortality. Wealth index model strongest (R^2 = 0.816)	Unprotected water	Education Telephones Malaria	Limited – contradictory signs
East Burkina Faso	Identified using all three metrics. Child morbidity model strongest (R^2 = 0.791). Consistency of results weak.	Unprotected water	Education Environ. damage	Limited – child morbidity only, contrary signs
East Nigeria and North Cameroon	Identified only in wealth index. Child mortality model strongest (R^2 = 0.647)	Unprotected water	Education Population density Malaria	Limited – not significant
South and Central Nigeria *('wealth hotspot')*	Identified using all three metrics. Wealth index model strongest (R^2 = 0.632)	Unprotected water	Access to towns Education Electricity Telephones	Limited – contrary sign, small effect

Table 10: Variables explaining wealth, morbidity and mortality in North Western Nigeria region.

	Wealth Index		Child Height for Age Ratio (s.d)		Child Mortality Rate (prport^n)	
(Constant)	-0.32330	**	-2.90450	***	-0.07228	*
Population density (people/km^2)	0.00017	***	-0.00018	**	0.00001	
Population (people)	-		-		-	
Telephones (proportion)	-		1.32720	**	0.05563	
Electricity (proportion)	-		-		0.01361	
NPP (produced) (tonnes/0.25° cell)	-		-		-	
Access ('00 km)	-		0.52565		0.03358	
Education (years)	0.07467	**	0.08867	***	-0.00655	***
Forest Cover (proportion)	-0.16014		0.22228		0.01170	
Cattle density (units/km2)	-0.00217		-0.01003	**	-0.00076	**
Chicken density (units/km2)	0.00130	***	-		0.00024	
Sheep density (units/km2)	0.00003		-0.00381	**	0.00021	
Goat density (units/km2)	-		0.00257		0.00006	
pig density (units/km2)	-		-0.01177		-0.02104	***
Unprotected water (proportion)	-0.73068	***	-0.34122		0.10797	***
Water Access (minutes)	-0.00046		-0.00408		0.00171	***
Dams ('00 km)	-0.23005	***	0.03517		0.00041	
Irrigation (percent)	0.00645		0.04289	*	0.00126	
Precipitation (mm/yr)	0.00083	***	0.00064		0.00008	*
TARWR (m3/yr/km2/person)	-0.00014		-0.00034		-0.00015	**
Drought Economic Risk (decile)	0.00346		-0.01672		-0.00159	
Human footprint (1-100 index)	-		-		0.00109	
Malaria prevalence (parasite ratio)	-0.43230	*	0.44091	*	0.03178	
Moran's I for residuals	**-0.014**		**-0.059**		**0.017**	
Akaike information criterion	**-92.14**		**6.77**		**-327.14**	
Aprox. pseudo adj. R^2	**0.95**		**0.92**		**0.89**	
Spatial weights matrix	**3 nearest neighbors**		**2 nearest neighbors**		**1 nearest neighbor**	
Sample size	**34**		**65**		**71**	

* = statistically significant at 90%, ** = 95%, ***=99%. Note that a positive child morbidity coefficient means increasing height for age ratios and thus an improvement in health.

At a national level TARWR is only weakly correlated with widely used development and poverty indicators. Even at district scales, the absolute quantity of water available per capita is only occasionally successful in predicting child mortality, morbidity or the asset index. Water quality, however, was more clearly associated with these measures of poverty. At most poverty hotspots there were significant correlations between the proportion of people drinking from unprotected water sources and the incidence of poverty. The area of irrigated land was associated with decreases in poverty in only two cases, North West Nigeria (by one poverty metric) and in Eastern Nigeria and Northern Cameroon (by two metrics). There was a variety of other variables which we tested for correlations with poverty, such as livestock (sheep, cattle, goats, pigs and chickens), the percentage of human appropriation of net primary productivity and forest cover. Whilst there is evidence that some of these variables play a role in

explaining poverty levels in some locations they were not systematically reliable or significant determinants.

6.4. Links between poverty and water, poverty and agricultural productivity

A statistical relationship between water quality and child health poverty measures seems consistent with the vital role given to water and sanitation in alleviating poverty (UNDP/SEI 2006). Insufficient access to clean water is known to impact on human health, through the development of water-borne diseases (e.g. diarrhoea, cholera) and water washed diseases (e.g. scabies, trachoma) (Bradley 1974). Diarrhoea is the third cause of child mortality in West Africa after malaria and respiratory infections (ECOWAS-SWAC/OECD 2008) and new water borne diseases such as Whipple disease are still emerging (Fenollar et al. 2009).

Literature suggests that agricultural water management provides a pathway out of rural poverty (Namara et al in press). In this study, weak correlations were found between agricultural water determinants and poverty variables. TARWR does not account for difficulties in accessing water and therefore only provides a theoretical value of water potentially available for agriculture. The metric also does not translate into annual inflow and recharge variations, crucial in countries that regularly experience drought and flooding in the same year (Rijsberman 2006). Although TARWR is a commonly used indicator, in the Niger basin it does not accurately reflect the water availability situation of a community nor its poverty status.

Hussain and Hanjra (2004) argue that increased irrigation and proximity to dams provides a pathway out of poverty, indicating community opportunities and capacity to access and transform water into food. this analysis found such a relationship in only some instances. The spatial regression analyses suggest either that irrigation's contribution to rural welfare is low in the Niger Basin, or that the spatial extent of irrigation is too limited at present to cause any detectable reduction in poverty at this scale of analysis. The literature suggests that irrigation will be crucial for the future economic development of the basin, along with improvements in the productivity of rain-fed agriculture. However, it may be that the benefits of irrigation do not yet accrue to the people engaged in its practice, or that they do so at levels too small to register in these analyses.

The relative wealth advantage of the Office du Niger, illustrated in Figure 50(C) and the analysis of Zwarts et al. (2006) suggest that so far the benefits of irrigation are confined to local irrigators and external investors and do not sufficiently accrue to the local poor.

The Office du Niger region is one of the oldest and largest irrigation schemes in Sub-Saharan Africa and expansion of irrigated agriculture is cited as a factor in regional poverty reduction. In general terms expansion can be accomplished by either improved water efficiencies reliant on existing impoundments or the construction of new dams (e.g. the proposed Fomi dam in Guinea) associated with maintaining existing water efficiencies.

A successful rehabilitation of the area was undertaken between 1983 and 1994 which saw average rice paddy yields tripling to 5t/ha. Previously abandoned lands were cultivated and the settler population grew by 222% (Aw and Dejou, 1996). By 2004, the average paddy yields had increased to 6.5t/ha; water use dropped from 1,500m^3/t to 250m^3/t and cultivation intensity has risen from 60% to 115% (Diemer, 2004).

As an alternative to engineered solutions, successful rehabilitation was achieved by micro management and institutional reforms, implemented by the Malian government in return for capital investment by donor countries (Zwarts et al. 2005, 2006; Molden 2007). Institutional reforms included the privatization of non-irrigation activities enabling farmers to sell produce and buy their imports at will. Decision making has gradually shifted from government officials to farmer representatives and formalized by 3 year performance contracts between the government and farmers. The arrangements have improved the effectiveness of incentives, evidenced by increased agricultural outputs and subsequent productivity.

In this study, agriculture related indicators including primary productivity, soil quality or livestock numbers, provide little explanatory power over poverty. A similar study in Malawi by Benson et al. (2005) found that a rise in maize yields actually resulted in increased poverty, presumably due to equity issues, with higher yields not benefiting local populations. Despite agricultural productivity growth being expected to reduce poverty in the rural agriculture-dominant economies of West Africa (Thirtle et al. 2003), poverty prevails in areas of good soil quality, high productivity and sufficient water availability.

These results point to the complexity involved in transforming available water into adequate food production and a pathway out of poverty. Beyond reliable water access, food production relies on several additional conditions being met such as access to land, labour, seeds, fertiliser, pesticides, tools and machinery, fuel, storage, transformation processes, roads, markets and political security. Hanjra et al. (2009) point to significant correlations between these variables and agricultural productivity, however variable interactions are critical in determining resultant poverty. Some of these factors may be stationary at the regional scale (such as roads and access to markets); others such as access to land may vary widely from one family or ethnic tribe compared to another within the same village and thus require detailed analysis. The latter structural causes of poverty are notably caused by the positioning of individuals in the socioeconomic structure (Mulwafu and Msosa 2005).

Overall, it is difficult to isolate one contributing factor to poverty. Instead, one must look at the capabilities (e.g. level of training, diverse income sources, capital and support networks) of a household or community (Chambers 1992), as these determine whether they will fall or subsist in a state of poverty. The absence, presence or quality of water do not in themselves act as determinants of poverty as it's what people can or don't do with it, according to their capabilities that influence poverty. For instance, access to clean water may be seen as an implicit guarantee of improved health, but if wells are not maintained

or communities prefer the taste of the water from the nearby pond (Becerra et al, submitted), then no impact on poverty levels may be seen.

6.5. Conclusion

Policy decisions are often made at state or national level, and regional perspectives or understanding of poverty cannot be presumed to be aligned or concordant with the differentiation of poverty, livelihood vulnerability or institutional diversity across the entire Niger basin (Hyman *et al*. 2005). More effective policy that influences water access or productivity is likely to be reliant on mixes of sequenced instruments tailored to address temporally and spatially diverse poverty patterns. An important focus of the poverty research was the development and application of methods capable of aligning water management and poverty data at scales that are administratively and politically feasible across the Niger basin countries.

The first research objective was to identify methodologies capable of integrating impact analysis and policy formulation that reliably differentiates poverty at these multiple scales. A second research objective was to map poverty at a unit of analysis that aligns water productivity and water access with poverty data, revealing opportunities for water policy formulation. A final objective was to provide evidence based analysis that guides effective policy development in the direction of the causes of poverty at scales that reflect the most exposed communities.

The lack of a comprehensive metric that reliably captures the multi factorial characteristics of water poverty has led to a raft of measurement techniques, each with advantages and disadvantages. Attempting to develop another poverty index or measurement criteria was not the aim of this research. Our primary aim was to assess and develop methods to detect and analyse a hypothetical relationship between water and poverty through statistical methods and poverty mapping.

To account for a high proportion of subsistence livelihoods and a large non-market, hybrid economy we used child mortality, child stunting and a composite wealth index as poverty metrics. The analysis of spatially referenced child mortality, child morbidity and the wealth index identified three major poverty hotspots in the Niger basin. These are situated in Southern Mali and the inner Delta, North East Burkina Faso and North West Nigeria (Figure 51). There is broad convergence in the spatial correlation between poverty measures illustrated in Figure 51. Communities situated in regions of intersecting hotspots for the three poverty metrics are those expected to face the greatest poverty and vulnerability challenges.

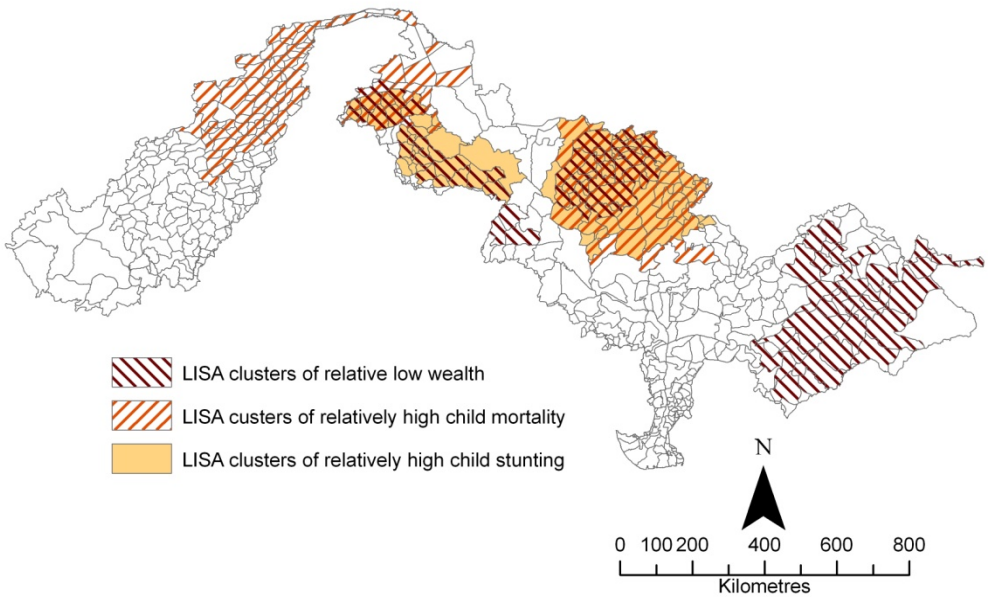

Figure 51: Overlapping map of significant poverty hotspots

We found that education and access to improved water quality are the only variables that are consistently significant and relatively stationary across the study area. At all scales, education is the most consistent non-water predictor of poverty while access to protected water sources is the best water related predictor of poverty. They can therefore be addressed with whole of catchment scale policies with less attention to regional differences.

The variables demonstrated to be statistically non-stationary (i.e. their influence varies across the landscape) may be more appropriately addressed using a geographically targeted policy approach. The differences in coefficient estimates are likely to be symptomatic of the ways in which a variable influences communities subject to local conditions.

Similar studies evaluating the significance of explanatory variables in poverty mapping have found limited correlations between poverty and agro-ecological or socioeconomic determinants (Hyman et al 2005). While established relations between water variables and poverty exist, notably water quality impacts on health and therefore poverty, these vary substantially through space and time. Access to water for agriculture and productive purposes plays a crucial role in poverty alleviation but is not a sufficient condition and much will depend on the capabilities and endowments of a given household or community. The research completed for Work package 1 indicates that landscape and scale matters in water poverty. Interactions between environmental, social and institutional factors are complex and an evaluation of poverty and its causes requires analysis at multiple spatial resolutions.

The poverty maps, estimated at a high resolution scale, can be viewed as evidence based, easy to interpret participatory tools, rather than a final product. The cadastral representation of the vectors of poverty enable the community, policy makers and administrators to visually evaluate the relative effectiveness of

alternative policy incentives and actions, the relative distribution of resources and investment priorities.

Combining the research from the other Challenge Work Packages with the poverty coefficients, is intended to provide a reliable basis for agencies to explore the social dimension that enables adaptive water system management. Agencies are thus able to concentrate on regions and cases that describe incremental but large change and investigate social sources of renewal and re-organization.

Estimating the covariance of significant, spatially referenced factors that comprise water related poverty in the Niger basin, combined with GIS mapping would enhance the usefulness of deliberative tools. This would be especially salient to evaluating portfolio approaches to poverty reduction, targeted sequencing of instruments and prioritization of investments across several factors. This is the subject of ongoing research.

7. Intervention analysis

7.1. Background

7.1.1. Introduction

This report is the result of web based literature reviews and secondary information gathering. It summarizes the Niger basin countries major development missions, goals, objectives, challenges, and constraints, and suggests potential interventions that may ameliorate the identified development constraints.

The basin countries can be categorized into water resources producers, consumers, both producers and consumers, and minimum contributors and consumers. As in many (transboundary) rivers, upstream and downstream conflicts emanating from the development of the Niger river are inevitable and are expected to be intense, particularly given the rapidly increasing demands for water for the additional users (population growth) and uses (industry, hydropower, ecosystem).

Recommended interventions are highly contextual and require rigorous analysis for each watershed in the basin. They will vary according to climatic and socio-economic conditions and notably according to the livelihood strategies and agricultural systems. The main livelihood/agricultural systems observed in the different sections of the basin include: dry and wet season cropping systems, pastoral systems, crop-livestock systems, and fishing. The major crops grown in the basin are yams, cassava, rice, groundnuts, millet, plantains, cocoa beans, maize, sugarcane, and cotton. The dry season livelihood systems include Fadama, recession flood farming, agro-forestry and irrigated rice farming. Wet season livelihood systems include cereal cropping, transhumant herding, etc.

7.1.2. Key development challenges and constraints of the Niger basin

The Niger basin is characterised by extreme rural poverty. The United Nations Human Development Index, a composite ranking based on national income, life expectancy and adult literacy rate, ranks all of the Niger Basin countries in the lowest quintile of countries (UNDP 2007). Several structural factors are responsible for maintaining large numbers of people in extreme poverty. Development constraints and challenges vary across the basin. Some of the prominent challenges to generate sustainable growth are: (1) degradation of land and water resources, (2) climate change and climate variability, (3) vulnerability to disasters, (4) poor performance of irrigation and other water infrastructure, (5) competing demands between sectors, uses, and users for water, (6) inadequate investment in water infrastructure, (7) inadequate public services, (8) poor performance of agricultural sector, (9) institutional and governance failure, (10) prevalence of poverty and inequality, (11) high population growth and rural urban migration, (12) poor macro-economic performance, and (13) limited livelihood strategies or unemployment.

7.1.3. Key development goals and objectives

Faced with these challenges, the Basin countries have developed key goals and objectives. These are formulated in various policy documents such as the Niger basin "shared vision" process, poverty reduction strategy papers, United Nations Millennium Development Goals, and the New Economic Partnership for Africa's Development, specifically the Comprehensive Africa Agricultural Development Program, pillars 1, 2, 3 and 4.

Many of the basin countries have adopted all of United Nations Millennium Development Goals and this is reflected in their respective Poverty Reduction Strategy Papers. These include: Eradicate extreme poverty and hunger, Achieve universal primary education, Promote gender equality and empower women, Reduce child mortality, Improve maternal health, Combat HIV/AIDS, malaria and other diseases, Ensure environmental sustainability, and develop a Global Partnership for Development.

Specifically, basin countries have defined the following broad development objectives:

1. Increase income, improve living standards and alleviate poverty, especially among the poorest section of the population
2. Improve access to health, and education services, and increase life expectancy
3. To increase per capita GDP, generate decent jobs and increase wealth and share it equitably while at the same time safeguarding the environment.
4. Sustainable management of the Niger basin's natural resources
5. Political stability, good governance and an appropriate institutional framework to accelerate the decentralization process to improve the functioning of the government and its institutions, to improve the economy's fundamentals and competitiveness, in particular the investment climate for private sector development
6. Economic and sub-regional integration in which water resource development infrastructure plays a decisive part
7. To maintain good macro-economic policies in order to achieve more evenly distributed high and sustainable economic growth
8. Development of infrastructures and the productive sector to ensure better productivity of factors of production and economic growth
9. To contribute to job creation and income generation for the poor, in order to reduce the incidence of rural poverty
10. Agricultural development program that will drastically reduce food imports, boost agricultural exports through stabilization and expansion of rain-fed production, intensification through irrigation and accelerated commercialization through private sector participation

7.2. Potential interventions

Improvements in agricultural water management and in the management of the Niger basin water resources can have significant effects on poverty (Namara et al in press). In order to address some of the development challenges and meet the basin development objectives, the following interventions are recommended:

7.2.1. Ensuring right to secure access to water for the poor

The rising demand over limited water resources in the Niger basin will lead to prioritised allocation of resources, putting vulnerable populations at greater risk. Legal framework to guarantee acceptable minimal quantities of water and land per person may be required. Enabling collective rights to water and land may also guarantee the access to water by the rural poor

7.2.2. Developing and improving agriculture and water infrastructure

Investment in water infrastructure is largely underdeveloped in the basin, due to insufficient levels of investment. This includes wells, small reservoirs, but also non water infrastructure (roads, communication, electricity), which are required to fully develop agriculture. Existing agricultural infrastructure must also be improved. They are currently poorly operated and maintained, due to economic, institutional, managerial failures. Their governance and management must be strengthened. To enhance the productivity of existing infrastructure it is notably important to develop multiple use of water (integrate livestock and small-scale fisheries and aquaculture.

7.2.3. Upgrading rain-fed systems

The vast majority (95%) of the Niger basin population depends on rain-fed agriculture. Thus, a modest productivity improvement in the rain-fed system can have significant impact on poverty reduction and food security.

One of the limiting factors in rain-fed systems is soil moisture stress. Interventions to reduce the effect of drought and increase productivity in rain-fed farming systems of the Niger basin include rainwater harvesting; improving on-farm water management through adopting/adapting soils and water conservation practices such as mulching, ridging, and minimum or zero tillage, etc.; developing moisture stress tolerant crop varieties through both conventional and unconventional crop breeding approaches; and encouraging the adoption of agro-forestry practices. The impact on yields of such techniques may be marginal without the addition of fertiliser; however by reducing water stress these techniques may also reduce the risk factor which currently prevents rainfed farmers from investing in fertiliser and other inputs.

Otherwise four main strategies exist: increase the rainfed production area (by rehabilitating ecosystems where it has disappeared, increase land productivity of the rainfed agriculture (independently of water), develop water efficiency where it is scarce (essentially north of 700 mm for millet and sorghum), increase plant tolerance to water excess. Research should continue as much on the resistance to drought in all key development phases, than on reducing drainage sensitivity.

7.2.4. Improving access to Agricultural Water Management innovations

Innovations and technologies allowing farmers to abstract, channel, distribute water effectively (pumps, sprinklers, drip) but also to store, transform, condition products are not within the financial reach of the vast majority of small holder farmers. Economically, agricultural performance can be improved through a better credit system. The organisation of the market chain (stocks) as well as access to input markets can also be improved.

7.2.5. Strengthening Niger basin's water governance

To develop and support development efforts over the long term, effective cooperation between stakeholders and implementation is required. Good clear governance is required to ensure water resources are developed in an equitable, participatory and sustainable way.

The NBA provides an ideal platform to develop integrated water resource management at the basin level, but efforts must be made before it can fully and successfully develop and manage water resources at the basin scale.

7.2.6. Reducing the vulnerability of poor people to climate shocks and other hazards

Floods, drought, climate change, and climate variability contribute to increased vulnerability. Mitigation strategies such as early warning systems and storage options are required to help reduce the impact of extreme events.

7.2.7. Ending terrestrial and aquatic ecosystem degradation:

The prevalence of low productivity extensive rain-fed agriculture such as those based on the slash and burn systems are threatening terrestrial ecosystems resulting in significant biodiversity and soil loss. The latter has also an impact on the overall availability of water. To reverse the trend, efforts have to be made in the area of reforestation, land reclamation, development of natural forests and protected areas, as well as development of community forestry and agro-forestry. This shall be complemented by improving rural people's access to alternative energy sources such as hydroelectric power.

Further recommendations are provided in the concluding section.

Conclusions and Recommendations

As part of the CPWF research for development programme, the Basin Focal project aimed to identify a number of outstanding research questions but also recommendations on ways to reduce rural poverty through improvements in agricultural water management. Major insights are provided below.

Water availability

- Reduced rainfall in the 1970s and 1980s affected runoff in the basin differently. In the upper basin, runoff deficit was high and more consequent than rainfall deficit, due to the cumulative effect of reduced rainfall on groundwater levels. In Sahelian parts runoff coefficients increased, partly due to reduced rainfall but mainly to increased agriculture and reduced natural vegetation. These variations in climate and river regime are essential to take into account when designing future dams
- Climatic scenarios for the Niger basin predict decrease rainfall in western West Africa and an increase in central parts. Temperatures, variability, dry spells and extreme events are also set to increase.
- Available hydrological data allows tools such as WEAP, MIDIN and rainfall/runoff modelling to be implemented by stakeholder. These should be used in participatory manner to predict changes in flow from rainfall, dam building, land use changes etc
- A better understanding of the Inner Delta (Ramsar wetland), notably through hydrodynamic modelling of the flood and studying the associated water uses (agriculture, livestock, fisheries, ecosystems) is required.

Agriculture and water productivity

Irrigation

- Agricultural withdrawals already impact on ecosystems such as the Inner Delta and Niger Delta. Extending dry season irrigation will require additional dams and will impact heavily on wetlands and their biodiversity, notably the environmental services and the livelihoods of a million herders, fisherman and traditional rice growers in the Inner Delta.
- Small scale irrigation is currently more water efficient and recommendations for its sustainable and equitable expansion should be examined

Fisheries

- Fisheries are rarely included in national or pro-poor policies because their importance has not properly been evaluated
- Vulnerable to changes in river flow, fisheries in the Inner Delta are estimated to suffer a reduction of fish catch by 28 tonnes for a reduction in 1m3/s during the flood period of the preceding year. The construction of the Fomi dam will result in the loss of 3700-4900t/yr.
- Fish culture in ponds, irrigated perimeters or reservoirs may provide opportunities to perturbed fisheries, however the communities presently involved in fishing are poorly prepared to manage this new activity.

Livestock

- To improve the performance of livestock systems, it is recommended to

- Research plant and animals requiring low levels of water
- Develop services (traction, by products, dairy products) and their commercialisation
- Increase available fodder, through better rangeland management, tree and shrub planting, access to crop residues and reduced bushfires
- Improve the health and vaccination coverage
- Improve protection of agropastoral activities notably by securing transhumance routes and access to pastures and water

Rainfed

- Current farmer strategies to reduce risks (due to rainfall deficit) prevent intensification and solutions to reduce crop failure risk are necessary for farmers to invest in fertiliser and other inputs which are essential to boost yields
- North of the 13th parallel, soil and water conservation techniques must be promoted and in the south, maintaining soil fertility is the priority
- Research dry cereals and tubercular to improve their yields and drought tolerance. These are crucial to rural families but often neglected by research which favours cash crops
- Research and improve integrated systems such as agropastoral, agroforestry as well as post harvest systems, conditioning and commercialisation.

Water productivity

- WP calculations must be refined due to uncertainties in yield and water use. Return flows and the current other uses of "wasted" water must be closely examined to ensure improvements in water efficiency do not negatively affect downstream and other uses
- WP provides an indication of water use but interpretation and formulation of recommendations appears complex (especially where water is not scarce or under competition)
- In livestock, research grazing patterns in the field to improve estimations of water consumption and water productivity
- Standard definitions and methodologies are required to allow better comparison
- Integrated water productivity calculations of the whole system (agriculture, fisheries, livestock, hydropower, ecosystems) may improve the value and interpretation of water productivity

Institutions

- The progressive introduction of new legislation and structures (decentralisation, IWRM, NGO projects) and the continued dominance of customary laws creates a legal pluralism, leading to confusion and conflicts. The change dynamic can however result in positive institutional innovations, notably the increased recognition of women, youth or minority groups often discriminated against under traditional law.
- Water rights are greatly embedded in land rights meaning land tenure security conditions the secure access to water resources and investments in agriculture.

- Land tenure is affected by the legal pluralism and reforms favouring individualized tenure and land titles. New participative and communal land titling systems may help protect the tenure rights of the poor
- Innovation is needed to design local systems to secure water and land access and property rights, rather than attempting to replace it with systems "imported".

Water poverty

- The analysis of spatially referenced child mortality, child morbidity and the wealth index identified three major poverty hotspots in the Niger basin, situated in Southern Mali and the Inner Delta, North East Burkina Faso and North West Nigeria
- Education and access to improved water quality are consistently statistically correlated with the poverty indices in these hotspots. These variables are relatively stationary across the study area and can therefore be addressed with whole of catchment scale policies with less attention to regional differences.
- TARWR and irrigation development were only occasionally associated with poverty, but were not systematically reliable or significant determinants.
- Though no causal links can be inferred, a relationship between water quality and child health poverty measures seems consistent with the vital role given to water and sanitation in improving health and alleviating poverty. Improving agricultural water management has the potential to reduce poverty, but the pathway is more complex and the impact less immediate. It will notably depend on the whole production to commercialisation chain as well as community capabilities.
- Interactions between environmental, social and institutional factors are complex and an evaluation of poverty and its causes requires analysis at multiple spatial resolutions. Estimating the covariance of significant, spatially referenced factors that comprise water related poverty in the Niger basin, combined with GIS mapping would enhance the usefulness of deliberative tools.

Interventions and future threats

- Agriculture in the basin which faces problems of soil fertility, pests, crop diseases etc, will be subject to several additional threats and challenges.
- Climatic scenarios for the Niger basin predicting increased temperatures, variability, dry spells and extreme events as well as reduced rainfall in western parts of West Africa will increasing the strain on already vulnerable agriculture.
- Projected dam building will inherently produce negative impacts downstream. Tradeoff analysis must be undertaken in consultation with local stakeholders to ascertain which element must be favoured (hydropower, irrigation, fisheries, ecosystems…) and how to minimize negative impacts.
- The increase in basin population from 95 million in 2005 to between 186 and 384 million according to the scenarios will lead to greatly increased demands on natural resources and increase vulnerability of rural poor communities. Future population trends depend essentially on the speed of fertility decrease, which currently exceeds 6-7 children per woman and in countries like Mali is not decreasing, leading to an increase in the population growth rate.

- Successful interventions have been introduced over the years, however solutions to achieve sustained and widespread impacts on rural poverty are still lacking.
- Improvements in rainfed agriculture can significantly reduce poverty thanks to the large population dependant on it. Current farmer strategies to reduce risks (due to rainfall deficit) prevent intensification and solutions to reduce crop failure risk are necessary for farmers to invest in fertiliser and other inputs which are essential to boost yields.
- Recommended interventions include: water harvesting, drought resistant crops, early maturing crops, micro doses of fertiliser, multiple use systems, seasonal forecasts. Improvements are required in all sectors (markets, financial services, training) and notably governance to secure access to land and water.

References

ABN, BRLi, DHV (2007). Etude sur l'élaboration du Plan d'Action de Développement Durable (PADD) du Bassin du Niger. Phase I : Bilan-Diagnostic.

ABN and BRL (2007). Evaluation des prélèvements et des besoins en eau pour le modèle de simulation du bassin du Niger: Rapport définitif. Niamey, Autorité du bassin du Niger, secrétariat exécutif: 143p.

ABN (2007). Elaboration du plan d'action de développement durable du Bassin du Niger. Phase 2: Schéma directeur d'aménagement et de gestion. Rapport définitif. BRLi-DHV-Isaldes, 332 p.

ABN (2008). carte de localisation des principales nappes et réserves du bassin avec des indications de leur capacité normale. ABN/ Niger-HYCOS, Niamey, Niger. <http://www.abn.ne >

Aboubakar, A (2003) 'L'initiative du bassin du Niger (IBN) : développement durable et gestion intégrée d'un grand fleuve', Afrique Contemporaine no. 206, 179-203

Achard, F. (1992). Les ressources fourragères de la station sahélienne expérimentale de Toukounous. Analyse floristique (herbacées et ligneux), structure démographique du peuplement ligneux, relations herbes-arbres. Dakar : UNESCO-MAB, projet RCS Sahel, volet Niger.

AMNESTY INTERNATIONAL, 2008
http://report2009.amnesty.org/fr/regions/africa

Anselin, L. (2005) 'Exploring spatial data with GeoDa: A Workbook', Spatial Analysis Laboratory, Department of Geography, University of Illinois, Urbana, Illinois.

Ardoin-Bardin, S., A. Dezetter, E. Servat, J.E. Paturel, G. Mahé, H. Niel†, C. Dieulin (2009). Using general circulation model outputs to assess impacts of climate change on runoff for large hydrological catchments in West Africa. Hydrological Sciences Journal, 54(1), 77-89.

Aw, D., & Dejou, C. (1996). Office du Niger: Ensuring food security for Mali. *World Bank Findings: Africa region no. 61*.

Balk, D, Pullum, T, Storeygard, A, Greenwell, F and Neuman, M (2003) 'Spatial Analysis of Childhood Mortality in West Africa, Calverton, Maryland,USA: ORC Macro and Center for International Earth Science Information Network (CIESIN), Columbia University.

Bakiono A.M., (2001), Rapport sur le recensement des provinces de la Ngounié et des Hauts Bassins, CERED, Burkina Faso, 118 p.

Bana, I., Conde, N., (2008) 'Perspectives de développement du Bassin du Niger', Niger Basin Authority, http://www.unwater.unu.edu/file/2.+ABN+Niger.pdf

Barriere, O. et C., 2002 ; Un droit à inventer. Foncier et environnement dans le delta intérieur du Niger. Ed. IRD, coll. À travers champs, 476 p.

Bazie, J. B. (2006). Reconnaissance, identification et caractérisation des usagers de l'eau du bassin du fleuve Niger en vue de leur implication et participation effective au processus de la Vision Partagée, Synthèse Régionale, ABN.

Belsley, D. A., E. Kuh, and R. E. Welsch. (1980). Regression diagnostics: Identifying influential data and sources of collinearity. New York: John Wiley and Sons.

Benson, T, Chamberlin, J, and Rhinehart, I (2005) An investigation of the spatial determinants of the local prevalence of poverty in rural Malawi, *Food Policy* 30 (2005), pp. 532–550

Béné C. et al., (2009) Vulnerability in African small-scale fishing communities. Journal of International Development (in press)

Bessembinder, J.J.E., Leffelaar. P.A., Dhindwal, A.S. and Ponsionen, T.C. (2005). Which crop and which drop, and the scope for improvement of water productivity. Agric. Water Manage., 73(2) : 113- 130.

Bradley, D.J. (1974) Chapter in Human Rights in Health, Ciba Foundation Symposium 23, 81–98.

Brummett, R.E., Lazard, J. & Moehl, J. (2008). African aquaculture: realizing the potential. Food Policy 33: 371-385.

CEA, (2007). Situations des transports en Afrique. Rapport de la CEA, Addis Abeba, Ethiopie, 16 p. <http://www.uneca.org/crci/5th/The-transport-situation-AfricaFR.pdf>

CEDEAO/ ECOWAS, (2006 – 2009). Atlas Web de l'intégration régionale de l'Afrique de l'Ouest/ The Web Atlas on Regional Integration of West Africa. <http://www.atlas-ouestafrique.org >

Chambers R. and G. Conway (1992). Sustainable rural livelihoods: practical concepts for the 21st century, Brighton, Institute of Development Studies

CIA (2008) 'The World Factbook', Central Intelligence Agency, Washington D.C. Available online [15 March 08] at < www.cia.gov/library/publications/the-worldfactbook/
index.html >

Clanet, J.-C., (1994), Le pastoralisme au Sahel central, s/d Dir. J. Gallais, LEDRA/ PIV- Paris – Sorbonne, 701 p.

Clanet, J.-C. and Ogilvie, A., (2009).- Farmer-herder conflicts and water governance in a semi-arid region of Africa. Water International 34:30-46.

Cochemé, J., Franquin, P. (1967). Une étude d'agroclimatologie de l'Afrique sèche au sud du Sahara en Afrique Occidentale. Rome, FAO/UNESCO/WMO.

Cook, S. and Gichucki, F. (2007). Analyzing water poverty: Water, agriculture and poverty in the basins: CGIAR Challenge Program on Water and Food.

Cotula, L. (2002). Gender law, Women's rights in agriculture, FAO Legislative Study, N°76, 159p.

Cotula, L. (2006). Land and water rights in the Sahel; Tenure challenges of improving access to water for agriculture. IIED, Issue Paper, n°139, March, 98 p.

Coulibaly I., (2007), « Les acquis du mouvement paysan en Afrique de l'Ouest », Fondation Gabriel Péri, http//www.gabrielperi.fr/IMG/article/articlePDF/Communication-de-Ibrahima.pdf.

de Wit, C.T., (1958). Transpiration and crop yields. Versl. landbonderz. 64 (6), 1–87.

De Noray, M.-L. (2003). Waza Logone : Histoires d'eaux et d'Hommes, World Conservation Union-IUCN, On line : http://vertigo.revues.org/index5130.html

Dieulin 2007 Dieulin C., 2007.- Afrique de l'Ouest et Centrale. Bassins hydrographiques. Paris, IRD Editions, 1 map.

Diemer, G. (2004). Reform of Governance of the Office du Niger in Mali *International Network on Participatory Irrigation Management Newsletter 12*.
ECOWAS-SWAC/OECD (2008). Communicable diseases, Population series. Available online [4 Nov 09] at < http://www.oecd.org/dataoecd/56/39/40997324.pdf >

Duteurtre, G. (2004). Normes exogènes et tradition locale : la problématique de la qualité dans les filières laitières africaines. In Cahiers Agriculture, Numéro spécial " L'Alimentation des villes ", 13 (1), pp. 91-98. http://www.john-libbey-eurotext.fr/fr/revues/agro_biotech/agr/e-docs/00/03/FE/E8/article.md

Fage, J. D. and Tordoff, W., (2002). An history of Africa, Routledge, London, 653p.

FAO (2000) 'Water Resources and irrigation in Africa', Aquastat, Food and Agriculture Organization, Rome. Available online [29 Sep 08] at < http://www.fao.org/nr/water/aquastat/watresafrica/index.stm >

FAO (2007) 'Global map of irrigation areas – version 4.0.1', aquastat, Food and Agriculture Organization, Rome. Available online [29 Sep 08] at <

http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm >

FAO, (2008a). Raising Water Productivity. FAO Agriculture 21 Magazine. http://www.fao.org/ag/magazine/0303sp2.htm

FAO, (2008b). Water Productivity. *In* Unlocking the Water Potential of Agriculture. Food and Agriculture Organization, Rome, Italy. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/006/Y4525E/y4525e06.htm

FAO, (2009).- - Fisheries and Aquaculture Information and Statistics Service – http://www.fao.org/figis/servlet/SQServlet?ds=Aquaculture&k1=COUNTRY&k1v=1&k1s=159&outtype=html Accessed 27/07/2009

Fenollar F, Trape J-J, Bassene H, Sokhna C, Raoult D. (2009) *Tropheryma whipplei* in fecal samples from children, Senegal. Emerging Infectious Diseases, 15(6).

Füssel, H. (2007). Vulnerability: A generally applicable conceptual framework for climate change research, Global Environmental Change, 17, 155-167.

Gleick, P. (1999). The human right to water. Water Policy, 5(1), 487-503.

Grafton, R.Q., W. Abramowicz, D. Dupont, H. Nelson, R.J. Hill and S. Renzetti (2004). The Economics of the Environment and Natural Resources. Blackwell Publishing

Guengant, J.-P., (2009). Migrations internationales et développement, colloque Ripiecsa, Bobo-Dioulasso, IRD – AIRD, http://www.aird.fr/ripiecsa/index.htm

Hamilton K. and Clemens, M (1999). Genuine savings rates in developing countries. World Bank Economic Review, 13(2) pp333-356.

Hanjra, M, Ferede, T and Gutta, D.G. (2009) Reducing poverty in sub-Saharan Africa through investments in water and other priorities, *Agricultural Water Management* 96 (2009), pp. 1062–1070.

Hanjra, M. and Gichuki, F. (2008) 'Investments in agricultural water management for poverty reduction in Africa: Case studies of Limpopo, Nile, and Volta river basins', *Natural Resources Forum, vol. 32, pp. 185-202*

Hilborn R. and Walters, J. (1976) in Grafton et al. (2004) Op Cite. *pp 459*

Hodgson S. (2004). Land and Water – The Rights Interface, Rome, FAO, Legislative Study, N° 84, 130p.

Hussain, I. and Hanjra, M.A (2004) Irrigation and poverty alleviation: review of the empirical evidence, *Irrigation and Drainage* 53 (2004), pp. 1–15.

Hussain, I., H. Turral, D. Molden, and M.D. Ahmad (2007). Measuring and enhancing the value of agricultural water in irrigated basins. *Irrig. Sci*., 25: 263-82.

Hyman, G., Larrea, C. and Farrow, A. (2005) 'Methods, results and policy implications of poverty and food security mapping assessments', Food Policy, 30, pp. 453–460

IPCC (Intergovernmental Panel on Climate Change) (2007). IPCC Working Group 1. AR4 report <http://ipcc-wg1.ucar.edu/wg1/wg1-report.html> Accessed June 2009.

IRIN (2008-2009), humanitarian news and analysis, a project of the UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org

IWMI. (2000). Water Issues for 2025: A research perspective. The contribution of the International Water Management Institute to the World Water Vision for food and rural development. IWMI, Colombo, Sri Lanka .

Jacob, J.-P., (2005) ; Sécurité foncière, bien commun, citoyenneté. Quelques réflexions à partir du cas burkinabé; Ouagadougou, Etude RECIT n°6, IUED, 26 p.

Kasperson, J. and Kasperson, R. (2001) 'Global environmental risk', United Nations University Press and Earthscan, Tokyo.

Kristjanson, P., Radeny, M., Baltenweck, I., Ogutu, J., & Notenbaert, A. (2005). Livelihood mapping and poverty correlates at a meso-level in Kenya. Food Policy, 30, 568-583.

Koné, A. (2008). Gestion du Bassin du Fleuve Niger : La mise en place de la coordination régionale divise la société civile). Le Républicain, http://www.maliweb. net/category.php?NID=34595.

Krantz, L. (2001). The Sustainable Livelihood Approach to Poverty Reduction: An Introduction: Swedish International Development Agency, Stockholm.

Laë, R. (1992). Influence de l'hydrologie sur l'évolution des pêcheries du delta central du Niger de 1966 à 1989. Aquatic Living Resources 5:115-126.

Laë R., S. Williams S., Malam Massou A., Morand P. and Mikolasek O. (2004). Review of the present state of the environment, fish stocks and fisheries of the River Niger (West Africa) XXX

Lavigne Delville Ph. et Hochet P. (2005). Construire une gestion négociée et durable des ressources naturelles renouvelables en Afrique de l'ouest, rapport final de la recherche, GRET/CLAIMS/AFD, 183 p.

Lawrence, P, Meigh, J and Sullivan, C (2002) 'The Water Poverty Index: an International Comparison', Keele Economics Research Papers no. 19, Keele

University, Keele, UK.

Le Houérou H. N. (1984). Rain use efficiency: an unifiying concept in arid land ecology. Jal of Arid Environment, 7, 213-247.

Lund, C. (2000). African land tenure:Questioning basic assumptions, Dryland Issue Paper, n°E100 IIED, London, 27p., http://www.iied.org/pubs/pdfs/9023IIED.pdf.

Measure DHS (2008) 'Country Datasets: Benin (2001), Burkina Faso(2003), Cameroon (2004), Cote d'Ivoire (1998-9), Guinea (2005), Mali (2006), Niger (2006), Nigeria (2003)', Macro International, Calverton, Maryland, USA. Available online [29 Sep 08] at < http://www.measuredhs.com >

Mainuddin, M., Eastham, J., and Kirby, M. (2009). Water-use accounts in CPWF basins: 7. Simple water-use accounting of the Niger Basin. CPWF Working Paper. Colombo, Sri Lanka: CGAIR Program for Water and Food.

Mainuddin, M., Kirby, M., and Chen, Y., 2008. Spatial and temporal pattern of land and water productivity in the Lower Mekong river basin. Basin Focal Project Working Paper No. 5. Colombo, Sri Lanka: Challenge Program on Water and Food (CPWF).

McAuslan, P. (2006). Improving Tenure Security for the Poor in Africa – Framework Paper for the legal Empowerment Workshop – Sub-Saharian Africa, FAO, LEP Working Paper.

Meisel, N. and Ould Aoudia, J. (2007). A New Institutional Database : « Institutional Profiles 2006 », Agence Française de Développement, Working Paper, n°46, September, 35p.

Milleville, P., 2007 ; Une agronomie à l'oeuvre: pratiques paysannes dans les campagnes du Sud ; Ed. Arguments, Paris, Coll. Parcours et paroles, IV- 241 p.

Mitchell, T, Carter, T, Jones, P, Hulme, M, New, M, (2004) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100)', Working Paper 55, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.

Molden, D. (1997), Accounting for water use and productivity. *SWIM Paper 1*, International Irrigation Management Institute, Colombo, Sri Lanka

Molden, D (ed.) (2007) 'Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture', International Water Management Institute and Earthscan, Washington D.C.

Molden, D., Murray-Rust H., Sakthivadivel R., Makin I. (2003). A water-productivity framework for understanding and action. In: J.W. Kijne, R. Barker

and D. Molden (eds). Water Productivity in Agriculture: Limits and Opportunities for Improvement. CAB International, Wallingford, UK: 1-18

Molden D., Oweis T., Steduto P., Bindraban P., Hanjra M.A., Kijne J., (2009). Improving agricultural water productivity : Between optimism and caution. Agricultural Water management, doi : 10.1016/j.agwat.2009.03.23

Molle, F. and Mollinga, P (2003) Water policy indicators: conceptual problems and policy issues. Water Policy, 5: 529-544

Monteny, B.A. & Casenave, A. (1989). The forest contribution to the hydrological budget in Tropical West Africa. Ann. Geophys. 7: 427-436.

Mulwafu, W. and Msosa, H.K. (2005) IWRM and poverty reduction in Malawi: a socio-economic analysis, *Physics and Chemistry of the Earth* 30 (2005), pp. 961–967.

Namara, R., Hanjra, M., Castillo, G., Ravnborg, H.M., Smith, L., Van Koppen, B. (in press). Agricultural water management and poverty linkages, Agricultural Water Management, In Press, Corrected Proof, Available online 5 July 2009

Neiland A. and Béné C. (2003). Review of River Fisheries Valuation in West and Central Africa A contribution to the Water, Ecosystems and Fisheries Review Workshop, organised by the World Fish Center, Phnom Penh, 15-17 February 2003

NEPAD (Nouveau Partenariat pour le Développement en Afrique) (2006). Plan d'Action pour le Développement des Pêcheries et de l'Aquaculture en Afrique/ Action Plan for the development of African fisheries and aquaculture. Johannesbourg, Afrique du Sud, 29 p.

Niasse, M. (2006). Les Bassins transfrontaliers Fluviaux, Atlas de l'Intégration Régionale d'Afrique de l'Ouest, Série Espaces, CEDEAO-CSAO/OCDE, 20p.
Niasse, M. (2008). Analyse Institutionnelle. Volta Basin Focal Project Report No 15. IRD, Montpellier, France, and CPWF, Colombo, Sri Lanka, 51 p.

Niger Basin Authority, (2005). Regional Synthesis on National Multi-sectoral Studies', Niger Basin Authority, Niamey, Niger.

Niger Delta Environmental Survey (NDES), (1999). Phase I Report, Vol. 1. Environmental and Socio-economic characteristic (revised edition).

Noemdoe, S., Jonker, L. and Swatuk L.A (2006). Perceptions of water scarcity: The case of Genadendal and outstations. Elsevier Ltd. 31: 15-16; 771- 778 p.

North D. (2005).Understanding the Process of Economic Change, Princeton, Princeton University Press. 45 p.

OMS (2006); Le Rapport sur la santé dans le monde 2006 – Travailler ensemble pour la santé; 203 p.

Ostrom E., (1990), Governing the Commons. The Evolution of Institutions for Collective action, Cambridge, CUP.

Ostrom, E. (2000). Private and common property rights. Indiana University. 176 p.

Ostrom E., Dietz T., Dolsak N., Stern P., Stonich S., Weber E. (eds) (2002). The Drama of the Commons, Washington DC, The National Academy Press, 489p. http://www.nap.edu. http://www.nap.edu.

Paturel, J.E., Servat, E., Kouame, B., Lubes, H., Ouedraogo, M., Masson, J.M. (1997) Climatic variability in humid Africa along the Gulf of Guinea - Part two: an integrated regional approach. Journal of Hydrology, 1997, 191: 16-36.

Pergola P. (2009) : Contribution a l'analyse de la productivité de l'eau en élevage dans le bassin du fleuve Niger. Rapport de stage de second année, Master Biologie Géosciences Agroressources Environnement, Spécialité Ecologie Fonctionnelle et Développement Durable, Parcours Elevage des Pays du Sud : Environnement, Développement, Université de Montpellier II, CIRAD. 47 p

Preston, B. L., & Stafford Smith, M. (2008). Framing vulnerability and adaptive capacity assessment. Paper presented at the Pre-Workshop Draft, Climate Adaptation Flagship Workshop.

Ramazzotti, M., (1996). Readings in African Customary Water Law, Legislative Study, n°58, FAO, Rome.

Rijsberman, F.R. (2006) Water scarcity: fact or fiction?, Agricultural Water Management 80 (1–3) (2006), pp. 5–22.

Rockstrom J., Barron J., Fox P. (2002). Water productivity in rain-fed agriculture challenges and opportunities for smallholder farmes in drought-prone tropical agroecosystems. In Water productivity in Agriculture : limits and opportunities for improvement (eds) JW Kijne, Barker R., Molden D., CAB international.

Runge, C.F. (1992). Common Property and Collective Action in Economic Development. In Bromley, D.W. (eds.), Making the Commons Work: Theory, Practice, and Policy, San Francisco: Institute for Contemporary Studies, pp. 17-39.

Rutstein, S and Johnson, K (2004) 'The DHS Wealth Index', DHS Comparative Reports no. 6, Measure DHS, Calverton, Maryland, USA.

Schönegg, G. and Martel, P., (2006); Les conflits liés à la transhumance transfrontalière entre le Niger, le Burkina Faso et le Bénin, DED, Fachreferat für Ländliche Entwicklung, Wasserwirtschaft und Ressourcennutzung.

Seckler, D. (1996). The new era of water resources management: From "dry" to "wet" water savings. IWMI research report 1.

Seckler, D.;Amerasinghe, U.; Molden, D.; De Silva, R.; Barker, R. (1998). World water demand and supply, 1990 to 2025: Scenarios and issues. IWMI research report 19. International Water Management Institute, Colombo , Sri Lanka .

Seckler, D., D. Molden and R. Sakthivadivel. (2003). The concept of efficiency in water-resources management and policy. In: Kijne et al. eds. 2003. Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford , UK . Pp. 37-51.

Serpantié, G., Lamachère, J.-M. (1989). Pour une connaissance des conditions de mise en oeuvre des aménagements du ruissellement. ORSTOM, France. 32 p. <http://www.documentation.ird.fr/fdi/notice.php?ninv=fdi:30484>

Setboonsarng, S (2005) 'Child malnutrition as a poverty indicator: an evaluation in the context of different development interventions in Indonesia', ADB Institute Discussion Paper no. 21, Asian Development Bank, Manila.

Showers, V., (1973). The world in figures. Toronto, John Wiley and Sons

Sullivan, C.A. and Meigh, J.R. (2003) The Water Poverty Index: Its role in the context of poverty alleviation. Water Policy, 5(5).

Tabutin, D. and Schoumaker, B., (2004), The Demography of Sub-Saharan Africa from the 1950s to the 2000s. A Survey of Changes and a Statistical Assessment, *Population-E*, vol. 59, n°3/4, pp. 455-555.

Thirtle, C., Lin L. and Piesse, J. (2003) The impact of research-led agricultural productivity growth on poverty reduction in Africa, *Asia and Latin America. World Development* (2003), pp. 1959–1975.

Toulmin, C. (2008).Securing land and property rights in sub-Saharan Africa : The role of local institutions », *Land Use Policy*, n°26, pp. 10-19.

UNDP/SEI (2006) Linking Poverty Reduction and Water Management, prepared on behalf of the Poverty-Environment Partnership, 82 pages. Available online [3 Nov 09] at < http://www.energyandenvironment.undp.org/undp/index.cfm?DocumentID=5689 &module=Library&page=Document >

UNDP (2007) 'Human Development Report 2007/2008: Fighting Climate Change', United Nations Development Program, New York.

UNESCO (2006) 'The State of the Resource in Water: A Shared Responsibility', United Nations Educational Scientific and Cultural Organisation, & World Meteorological Organisation, New York.

UNESCO (2008) 'Education for all: global monitoring report, regional overview: sub-Saharan Africa', United Nations Educational Scientific and Cultural Organisation, New York.

UN Population Division (2006) 'World Population Prospects: the 2006 Revision Population Database', accessed online [12 Dec 08] at <http://esa.un.org/unpp/index.asp?panel=1 >

UNICEF (2008) 'State of the World's Children', United Nations Children's Fund, New York

Uyigue, E. and Agho, M. (2007). Coping with climate change and Environmental degradation in Niger Delta of Southern Nigeria. CRDC, Nigeria. 3 p

VATICAN, (2009), Synode africain au Vatican : l'Eglise se mobilise pour l'Afrique, La Croix, déc. 2009 et http://www.vatican.va

Vincent, K (2004) 'Creating an index of social vulnerability to climate change for Africa', Working Paper 56, Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK.

White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. UNESCO, Natural Resour. Res. 20: 1-356

Wisner, B, Blaikie, P and Cannon, T (2004) 'At Risk: natural hazards, people's vulnerability and disasters' (2nd Edn.) Routledge, London.

World Bank (2009) 'PovcalNet online Poverty Analysis Tool', available online [4th Feb 09] at < http://go.worldbank.org/NT2A1XUWP0 >

WRCU, (2007). Strategic Plan 2007-2015, ECOWAS, Ouagadougou, 321 p.

Zoebl, D. (2006). Is water productivity a useful concept in agricultural water management? Agricultural Water Management, Volume 84, Issue 3, pp. 265-273

Zwarts, L. Bvan Beukering, P., Kone, B., & Wymenga, E. (2005). *The Niger, A Lifeline: Effective water management in the Upper Niger Basin*. Mali / The Netherlands: RIZA, Lelystad / Wetlands International, Sévaré / Institute for Environmental Studies, Amsterdam.

Zwarts, L; Beukering, P; Koné, B., Wymenga, E; Taylor, D. (2006) The Economic and Ecological Effects of Water Management Choices in the Upper Niger River: Development of Decision Support Methods. International Journal of Water Resources Development, 22 (1) pp. 135-156

Project reports

Baati S., Boucher F., Marquis H., 2009, *Analyse institutionnelle de la gestion des usages agricoles de l'eau dans le bassin du fleuve Niger*, TGE, AgroParisTech-ENGREF, février, 33p. + Annexes.

Bader, J.-C. (2008). Note sur l'état des prévision climatiques en Afrique de l'Ouest : cas du bassin du Niger. IRD, Montpellier and CPWF, Colombo, Sri Lanka. 5 p.

Barbier, B. et al. (2009). Productivité de l'eau d'irrigation dans le basin du fleuve Niger (Draft). CIRAD/ 2iE, Ouagadougou, Burkina Faso and CPWF, Colombo, Sri Lanka. 151 p.

Boyer, J.-F. (2009). BFP Niger, rapport final. HSM, IRD Montpellier and CPWF, Colombo, Sri Lanka. 11 p.

Boyer, J.-F. (2007). Site : < www.BfpNiger.eu >

Boyer, J.-F. (2008-09). Base de données sur la productivité de l'eau dans le bassin du Niger, format IDIS, www.BfpNiger.

Caron, A., (2009). BFP Niger – Institutional analysis. IRD, Montpellier and CPWF, Colombo, Sri Lanka. 4 p.

Cecchi, P. (2009). Les petits barrages en Afrique de l'Ouest et note sur les aménagements du Bani. IRD, Montpellier and CPWF, Colombo, Sri Lanka. 4 p.

Dieulin C., 2007. Afrique de l'Ouest et Centrale. Bassins hydrographiques. Paris, IRD Editions, 1 map.

Dieulin, C. (2008). Bassin hydrographique du fleuve Niger.IRD Montpellier and CPWF, Colombo, Sri Lanka, 1 map.

Da Dapola, E. C. (2008). Les techniques de conservation des terres et de l'eau dans le bassin du Niger. Université de Ouagadougou, Burkina Faso and CPWF, Colombo, Sri Lanka, 61 p.

Diop, A. T., Ickowicz, A., Touré, I., Diop N. A. (2009a). Les productions animales dans le bassin du Niger : tendance évolutive – productivité de l'eau – optimisation. ISRA/ ENEA/ CiRAD/ PPZS, Dakar, Sénégal and CPWF, Colombo, Sri Lanka. PPT.

Diop, A. T., Diop, A. Touré, I. and al. (2009b). L'élevage et le pastoralisme dans le bassin du Niger. LENRV/ PPZS/ CIRAD, Dakar and CPWF, Colombo, Sri Lanka, 164 p.

Diop, A. T., Diop, A., Touré, I. and al. (2009c). Productivité de l'eau en Elevage et optimisation des ressources fourragères du bassin du fleuve Niger. LENRV/ PPZS/ CIRAD, Dakar and CPWF, Colombo, Sri Lanka, 16 p.

Droy, I. (2009a). La pauvreté liée à l'eau sur le bassin du fleuve Niger. IRD, UMR C3 ED and CPWF, Colombo, Sri Lanka, 12 p.

Droy, I., (2009b). Pauvreté et inégalités sur la zone Office du Niger. , IRD, UMR C3 ED and CPWF, Colombo, Sri Lanka, 21 p.

Droy, I. (2009c). La nouvelle pauvreté des producteurs de coton ou le « paradoxe de Sikasso ». IRD, UMR C3 ED and CPWF, Colombo, Sri Lanka, 6 p.

Elbaz-Poulichet, F., Casiot, C., Seidel, J.-L., Mahé G., Olusegun, A. (2008). Quality of water resources in the Niger basin and in the region of Lagos (Nigeria)- Preliminary study of inorganic contaminants. IRD, HSM and CPWF, Colombo, Sri Lanka. 6 p.

Kaboré- Sawadogo, S. (2008). La privatisation des zones pastorales dans le bassin du Niger. INERA, Ouagadougou, Burkina Faso and CPWF, Colombo, Sri Lanka, 42 p.

Labbé, O. (2007). Analyse institutionnelle de la gestion des usages de l'eau en Afrique de l'Ouest, Bassin du Niger et de la Volta, Mémoire de fin d'études d'ingénieur agronome, ENSAT, IRD, AgroParisTech-ENGREF, 127p.

Labbouz,B. (2008). Analyse du cadre institutionnel de la gestion de l'eau et de ses usages dans le Bassin du Fleuve Niger – Synthèse de la littérature sur la résilience des systèmes socio-écologiques, AgroParisTech-Engref, avril, 31 p.

Langevin, C., Labbouz, B. (2008). Analyse institutionnelle de la gestion et des usages de l'eau autour d'un ouvrage hydraulique dans le Bassin du Niger, Etude de cas : le seuil de Talo, IRD – AgroParisTech-ENGREF, septembre, 83 p.

Marquette, C. (2008). Cartographie sur la productivité de l'eau dans le bassin du Niger. Master Université de La Rochelle/ IRD, Montpellier and CPWF, Colombo, Sri Lanka, 12 p.

Mahé, G., Lienou, G., Paturel, M. (2009). BFP Niger – Water availability and access. IRD, Montpellier and CPWF, Colombo, Sri Lanka 78 p.

Morand, P., Lemoalle, J., Tiotsop, F., Sekou, C. (2009). BFP Niger – Fisheries. IRD, Montpellier and CPWF, Colombo, Sri Lanka, 71 p.
Ovize, M. (2009). Mém. de Master, Univ. Montpellier III et IRD, Montpellier and CPWF, Colombo, Sri Lanka, 128 p.

Namara, R.E., Barry, B., Owusu, E. (2009). Niger Basin Focal Project Intervention Analysis - An overview of the development challenges and constraints of the Niger basin and possible intervention strategies.

Nematollahi-Gillet Azyadé, 2009, Identification d'indicateurs institutionnels pertinents relatifs au neuf pays riveraines du bassin du fleuve Niger et analyse des données, AgroParisTech-ENGREF et UMR GREThа-CNRS 5113, septembre, 43p. + Annexes.

Pergola, P. (2009). Contribution a l'analyse de la productivité de l'eau en élevage dans le bassin du fleuve Niger. Master Université de Montpellier II, CIRAD, and CPWF, Colombo, Sri Lanka. 47 p.

Serpantié, G. (2009a). Dans quelles situations le concept de productivité de l'eau pluviale est-il pertinent : écosystèmes naturels : le cas des savanes? IRD, Montpellier CPWF, Colombo, Sri Lanka, 11 p.

Serpantié, G. (2009b). Le concept d'efficience de l'eau pluviale est-il pertinent ? Agricultures pluviales à base d'annuelles. IRD, Montpellier and CPWF, Colombo, Sri Lanka, 32 p.

Serpantié, G. (2009c). L'utilité de l'eau pluviale sur le bassin du Niger. IRD, Montpellier and CPWF, Colombo, Sri Lanka, 71 p.

Ward, J., Kaczan, D. and Lukasiewicz, A. 2009. A water poverty analysis of the Niger River Basin, West Africa. Report for Niger Basin Focal Project as part of The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka.

List of Acronyms

ABN/ NBA : Autorité du Bassin du Niger/ Niger Basin Authority
ACMAD: African Centre of Meteorological Applications for Development
AGRHYMET: Regional centre for training in agriculture, hydrology, and meteorology
AIRD : Agence Inter-établissements de Recherche pour le Développement
AWP : Available water productivity
BRL : bureau d'études/ Cie nat. d'aménagement de la région Bas- Rhône et du Languedoc (CNARBRL)
BFP : Basin Focal Project
CC : Capacité de Charge (en UBT/ ha)
CEA : Commission Economique pour l'Afrique (ONU)
CEP : Coefficient d'Efficacité Pluviométrique (id. RUE)
CGIAR: Consultative Group on International Agricultural Research
CILSS: Permanent interstate committee for drought control in the Sahel
CIPEA : Centre International Pour l'Elevage en Afrique
CIRAD : Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CPWF : Challenge Program on Water and Food
CSE : Centre de Suivi Ecologique
ECOWAS : Economic Community of West Africa States
EIER: Inter states school of rural development engineering
ENEA : Ecole Nationale d'Economie Appliquée
ENGREF : Ecole Nationale de Génie Rural et des Eaux et Forêts
ETM : Evapotranspiration maximale
ET0 : Evapotranspiration de référence
ETP : Evapotranspiration potentielle
ETR : Evapotranspiration réelle
FAO : Organisation des nations unies pour l'alimentation et l'agriculture
FAOSTAT : statistiques de la FAO
FCFA : Franc de la Communauté Financière d'Afrique
FEWS NET: Famine Early Warning System Network
GDP: Gross Domestic Product
GEF: Global Environment Facility
GRET: Groupe de Recherches et d'Echanges Technologiques
GTZ : Deutsche Gesellschaft fur Technische Zusammenarbeit
GWP/ WATA: Global Water Partnership/ West Africa water partnership
HYCOS/AOC: Hydrological Cycle Observing System/ West and Central Africa
ICRISAT: International Crops Research Institute for the Semi-Arid tropics
IFAN: Institut Fondamental d'Afrique Noire
IIED: International Institute for Environment and Development
INRA: institut National de Recherche Agronomique, France
IPCC: Intergovernmental Panel on Climate Change
IRCT: Institute de Recherche sur le Coton et le Textile
IRD: Institut de Recherche pour le Développement
ISRA : Institut Sénégalais de Recherches Agricoles
IUCN: World Conservation Union
IWRM: Integrated Water Resources Management
LWP: Livestock Water Productivity

NEPAD: New Partnership for Africa's Development
NGO: Non Governmental Organisation
OMD: Objectifs du Millénium pour le Développement
ON : Office du Niger
PPZS: Pôle Pastoral Zones Sèches
PR : Petit Ruminants
PRESAO: Seasonal forecast for West Africa
RIPIECSA : Recherches Interdisciplinaires et Participatives sur les Interactions entre les Ecosystèmes, le Climat et les Sociétés en Afrique de l'Ouest
RFE: Rainfall Estimation
RUE: Rain Use Efficiency
RWP : Rain Water Productivity
UBT/ LU: Unité de Bétail Tropical/ Livestock Unit
UCAD: Université Cheik Anta Diop, Sénégal
UGB : Université Gaston Berger
UMR: Unité Mixte de Recherche
UNDP: United Nations Development Programme
UNEP: United Nations Environment Programme
UNESCO: United Nations Educational, Scientific and Cultural Organisation
UNO: United Nations Organisation
USAID: United States Agency for International Development
USD: US dollar
WAEMU: West African Economic and Monetary Union
WCD: World Commission on Dams
WHO: World Health Organization
WI: Wetlands International
WMO: World Meteorological Organisation
WP: Water Productivity
WWF: World Wild Fund