The interaction between freshwater ecosystem services, climate change and poverty in the Sahel

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1. Introduction

This input is to provide a 'short summary of the interaction between freshwater ecosystem services, climate change and their impact on poverty. . .[and] outline the research priorities for the region in these fields.. . .[and] suggest how the research should be organised.

Water is situated in a wider framework of ecosystem services (including 'provisioning' and 'regulating' services) and is prioritised in Goal 6 of the MDGs:

Reduce by half the proportion of people without access to safe drinking water

The Sahel like other drylands is in continuous transition as its ecosystems and human systems adapt to many drivers of change, including climate change, demographic and economic change, and changes in natural resource management (de Oliveira, Duraiappah, & Shepherd 2003; Dobie & Goumandakoye 2005). While resilience has been observed in both natural ecosystems and human systems (Mortimore 1998), sustainable development (or poverty reduction) will only be achieved through an adaptive co-evolution (Reynolds et al. 2007). Water provision and the regulating functions of water in the ecosystem are embedded in this broader problematic.

2. Why water ecosystem services are likely to become increasingly constrained in the Sahel

Rainfall is seasonal, variable and increasingly scarce northwards, and aridity impacts affect all primary production, though to a varying extent and in different ways. Average annual rainfall declined from the 1960s to the 1990s by up to a third and has not fully recovered (Hulme et al. 2001). While the trend was general, its severity varied locally (Badiane, Khouma, & Sène 2000; Mortimore 2000). The direction and strength of future trends may differ from west to east. Climate change scenarios for the region do not all agree (Hulme et al. 2005) - indeed, predict opposite trends (Haarsma et al. 2005; Held et al. 2005). According to the IPCC, 'it is uncertain how rainfall in the sahel. . .will evolve this century' (IPCC 2007, p. 866).[1]

Hydrology. The Sahel has relatively few perennial rivers and surface water bodies. Flow regimes reflect rainfall in the semi-arid region (with the exception of the Chari system in Chad, which has its headwaters in the sub-humid zone). The shallow Lake Chad had diminished by 2001 to less than a tenth of its size in 1963.[2] Declining surface water flow has curtailed the expansion of irrigation, most conspicuously in the Chad Basin. Seasonal streams with associated flooding in topographical depressions (such as inter-dunes in old dunefields, flood plains along rivers, and closed drainage basins or oases) are important for supporting grazing and temporary settlements. For drinking, watering animals and domestic use in permanent settlements, Sahelians depend on groundwater. Access to the sub-surface aquifers was vastly extended when concrete-lined, free access wells were provided by governments throughout the twentieth century to replace the hand-dug and dangerous wells on which people formerly depended, and over which exclusive access rights were sometimes enforced. Major droughts still have an impact on depth to water tables, however, especially in rural areas, and so do dam constructions in catchment headwaters. A second technical revolution is following the drilling of boreholes, which can open deeper aquifers where they exist; however both shallow and deep aquifers are under pressure from urban water extraction, especially where fossil water is used or slow, long-distance recharge of water tables reduces the sustainable levels of offtake.

Water markets: food production. Population grew at 2.4% 1960-1990 (a doubling period of 30 years) and is projected to continue to increase rapidly to 2020 (Snrech 1995). In terms of food security, a large proportion of the population will continue to be self-provisioning though not

[1] The IPCC is currently reviewing a draft *Technical Paper on climate change and water* (Letter to governments, www.ipcc.ch/letter_government_ipcc_tp_climate_change_water.pdf)

[2] See (Gore A L 2006), p 116 for satellite photos.

necessarily self-sufficient. Market demand for food commodities will continue to rise very rapidly with urbanization (the regional average predicted to increase from 40% in 1990 to 63% in 2020). This includes major cities within the Sahel (e.g., Niamey, Dakar, Kano), and those in sub-humid and humid West Africa, which are markets for exported commodities (e.g., livestock, cowpeas). In Nigeria (the most urbanised country in the region), the food producing (farming) population will soon be exceeded by the non-producing population.[3] There is rising demand for meat (e.g., in Senegal, Faye et al. 2001), which requires more water per kg to produce than cereals.

Water markets: urban demand. The predicted scale and spatial patterning of urbanization has major implications for delivery of water ecosystem services. The growth of primate cities (which in absolute terms, far exceeds that of smaller towns) concentrates demand for industrial, domestic and drinking water (including major institutions such as schools, universities, army barracks) at points that have to be supplied by costly infrastructure. Though often inadequate for the health and welfare of poor people, improved access to piped water is raising per capita consumption and demand well above rural levels. There is a mismatch between urbanization and the availability of blue water in the Sahel which is likely to worsen. On the other hand, high levels of unemployment among urban migrants depress purchasing power and expectations.

In view of the changes outlined above, constraints can be expected to intensify in Sahelian water ecosystem services, *regardless of the direction of climate change*. Their management is therefore a challenge facing both policy and user communities. This synopsis suggests that a transition must occur from a perception of water as a free and unlimited good to one of scarcity in which management is driven by considerations of value.

3. A review of ecosystem water services

Scarcity – possibly increasing under climate change - does not impact in the same way on all users, so there is a need to disaggregate ecosystem water services in a way that is relevant to poverty reduction policies. This is presented here within an ecosystem services framework, in which the main benefits of water to livelihoods can also be perceived. It is suggested that this typology provides a suitable framework also for disaggregating water-poverty interactions, and for approaching policy responses and the necessary supporting research. Ecosystem services, then, include water provision for:

1. Drinking and domestic use (rural and urban)
2. Rainfed agriculture
3. Irrigated agriculture
4. Livestock production
5. Harvesting aquatic organisms (mainly fishing; also medicinal plants)
6. Industrial use
7. Non-consumptive use (power generation, transportation)
8. Ecosystem functioning (aquifer recharge, maintenance of wetlands, micro-climates, and pedo-climates for nutrient cycling)
9. The 'cultural' and aesthetic functions of ecosystems (including tourist attractions) in so far as these depend on water

1. Drinking and domestic use

This has both quantitative and qualitative aspects, and the challenge differs between rural and urban areas. With regard to quantity, water deprivation is a key indicator of **poverty** in its own right. However deprivation is relative, and the expectations of village people (dependent on wells or boreholes) and of urban people with access to taps or the means to buy water are widely different. With regard to quality, confinement of access to water that is polluted and carries vectors of waterborne diseases is a measure of poverty.

[3] FAOSTAT, data on agricultural work force

Rural populations in the Sahel are predominantly dependent on **wells and boreholes** because perennial surface water is scarce, except close to the few major rivers (Niger, Senegal, Yobe, etc.). The adequacy of shallow aquifers (commonly 30-40 m) to meet demand is a complex function of depth to water table (itself dependent on geology, soil and surface infiltration, and seasonal rainfall), water yield (dependent on recharge and on quality of maintenance), the labour costs of lifting, distance to place of consumption, and numbers of consumers. In many parts of the Sahel, the sandy substrate facilitates recharge, and the dispersed distribution of the population in small villages minimises concentration of offtake. Large numbers of new boreholes have recently been added to the infrastructure of concrete wells originating in the colonial era, and a question hangs over the sustainability of a continuously intensifying network of extraction points (see Section 8 below). The provision of wells and boreholes is a public sector responsibility, though there are exceptions among livestock producers (see Section 4 below). In terms of water consumption per capita, and by comparison with international standards, rural populations in the Sahel are water-poor, but there must be considerable doubt whether significantly higher levels of consumption could be supplied universally and sustainably. Water use is also an indicator of economic differentiation, as wealthier people can use their larger financial or labour resources to acquire water in larger quantities.

The urban poor, however, are more likely to depend on **piped water systems**, also provided by the public sector, via infrequent street taps. Urban water systems are prone to under-investment, maintenance problems and supply interruptions. These can be put down to the rapid growth of cities through uncontrolled in-migration, accentuated by short-term peaks during droughts, but are as often caused by power failures, construction faults, or corruption leading to a shortage of capital funds. Storage losses affect water infrastructure especially dam siltation and distribution leakages in cities. Inhabitants of better-off districts whose voice is heard more easily in the administration receive more water more often. Water charging systems are difficult to operate efficiently and work against the poorest. Delivery to poor households often depends on carriers who may even control access to water outlets. Thus delivery costs also emphasise water deprivation. These factors may created a market failure in water whereby the poor pay and the rich get it free, which is a major factor of social differentiation. Some projects have attempted to address this market (e.g., through water charges) with the risk that acceptance of water as a bought asset will make matters worse not better.

Water quality is in principle more easily assured through integrated urban water systems than in a multiplicity of independent rural sources. However, shortages of recurrent funding are quickly expressed in breakdowns in treatment plants which render the entire urban population vulnerable to health risks. A growing market for safe water is suggested by the sales of bottled water, which have spread from a few francophone cities in the 1960s to most West African markets today, and from imported sources to a range of local spring water suppliers, assisted by plastic bottle technology. This trend among a growing salaried class, however, should not deceive: poor people in urban areas are still at risk. As for the villages, the shift to boreholes from open wells (into which polluted water containers must be dipped) is a significant technical change which should reduce the high incidence of waterborne illness.

Piped water systems in urban areas are prone to local failures in the treatment of sewage, which finds its way into streamflow and exposes water users downstream to health risks. In the dry season, it is common for urban waste water to be used for irrigating vegetables and fruit trees in the peri-urban zone. Well water may also be polluted where sewage drainage and treatment is inefficient or non-existent.

Water quality extends the concept of a basic human right to water from a quantitative measure to that of a guarantor of minimal health and welfare, and much needs to be done before such a principle is incorporated into water law, equity in access, water governance institutions, and economic policies, especially in poor countries.

2. Rainfed agriculture

Rainfall, on which rainfed agriculture depends, is intrinsically variable in the Sahel and became increasingly so from the 1960s to the 1990s. In agricultural terms, this means periodic precipitation deficits (agricultural droughts) or excesses (leading to flooding or waterlogging) in relation to **plant water requirements.** In recent decades, droughts have been geographically extensive while floods are usually restricted to low lying land, though there have been occasions when heavy rainfall has even damaged late-maturing crops on the highly absorptive sandy soils. Such temporal variability in the distribution and intensity of rainfall demands efficient water use. It is widely believed that indigenous practice can be improved through scientific inputs, such as: better forecasting or prediction of the rainfall; new cultivars bred for drought resistance or early maturation; seed priming to facilitate rapid germination and early growth; engineering and agronomic adaptations to control run-off, maximise infiltration and optimise planting and weeding cycles; and decision support tools to optimise resource allocations under conditions of uncertainty. However, while impressive adoption rates are reported for some improved technologies, the benefits tend to be localised where promotion has been undertaken, and some (in particular, decision support tools) are still experimental. A significant gap still exists between scientific and local capabilities, notwithstanding the fact that some science-based programmes have run for a decade or more.

Rainfall interacts with soil nutrients and biological activity to determine **plant biomass productivity** (including crop yields). Early research found that in the arid Sahel, annual rainfall is a strong correlate of productivity, because nutrients are not limiting, whereas in the semi-arid Sahel (where rainfed farming is undertaken), nutrient deficiencies may set a ceiling to productivity (Breman & de Wit 1983; Penning de Vries & Djiteye 1991). Though originally based on rangeland vegetation, these findings have significance for agricultural potentials. However, water-nutrient interactions are more complex than this, and recent research emphasises the importance of soil biology, even in drylands where aridity limits the activities of organisms, and especially where organic manure is used rather than agro-chemicals alone(Harris 2002; Mortimore & Harris 2005; Uphoff et al. 2006). It is noted that water (rather than soil moisture) is necessary for making compost, which can double yields on poor soils.

It may be hypothesised that whereas some water-use efficient practices may be accessible to poor people, others, along with productivity-enhancing techniques requiring additional inputs, may not. This distinction has equity implications. The poorest farmers are often to be found on the dry margins of the farming zone, sometimes illegally (e.g., north of the 250 mm isohyet which delimits the *zone pastorale* of Niger). Other than prohibition in certain areas, dry farming is not a subject of water policy, and many project interventions have emphasised productivity rather than water management goals.

3. Irrigated agriculture

Irrigation, seen as a major technical opportunity for meeting food sufficiency targets from the 1920s until the 1980s, has run into major difficulties arising from a number of sources:

- soil salinity (e.g., on the Yobe River irrigation scheme in north-eastern Nigeria, built in the early 1960s), not successfully corrected by water management;
- leakages, inefficient water management and high maintenance costs (e.g., the Kano River scheme in Nigeria);
- high operating costs and poor economic planning, which threatens the viability of schemes or forces a change in the intended crop regime;
- declining water resources unforeseen by the initiators (e.g., the South Chad scheme in Nigeria, where consultants and planners underestimated evidence of rainfall variability in the Chad Basin);
- negative social side-effects such as resistance to displacement at dam sites, sometimes dealt with violently, inequitable land distributions; and

- negative off-site effects of dams on ecosystems and natural resource users downstream.

The rehabilitation of old irrigation schemes (e.g., the **Office du Niger**, Mali) nevertheless attracts public sector investment. They cannot be neglected because they make a significant contribution to employment and national economic growth.

Small-scale irrigation (by medium sized farmers commanding significant capital and often having privileged access to riverside land) was successfully promoted in northern Nigeria during the 1990s with the support of the World Bank. By and large, irrigation is not a direct solution to poverty in the Sahel as it rarely benefits poor proprietors; however, it provides employment for those who may find it a stepping stone to better livelihoods. Irrigation can no longer be seen as a solution to drought, as naively promoted by Nigerian governments during the 1980s. But as a strategy for advancing livelihoods through small-scale investments and growing food commodity markets – vegetables, fruit, niche crops (e.g., northern Nigeria, greater Dakar) – it may justify more policy research, along with other ways of mobilising small-scale market production, e.g., through community action.

4. Livestock production

Scarcity and variability of 'green' water are among the determinants of livelihoods based wholly or partly on livestock production. Nomadic or transhumant pastoralists have the option of moving their herds according to geographical variations in rangeland productivity. As advocates of pastoralism try to emphasise to policy makers, such mobility is rational, efficient and non-destructive of the natural resource. Research, including modelling approaches, tends to confirm this. State-imposed impediments like closed borders and zones of exclusion however suggest a need for evidence-based policy review.

Mobile grazing systems in the Sahel also depend on access to scarce surface water and wetland grazing during the dry season. Wetlands however are increasingly appropriated by farmers, including irrigators (Section 2 above), assisted by tenure regimes that allow chiefs to allocate these valuable resources without taking account of uncodified grazing or watering rights. Not only the resource but also the access routes ('cattle tracks') may be alienated from the pastoralists. There has been a significant increase in conflict, including violent incidents (e.g. along the Hadejia River in northern Nigeria). There is a variety of institutional arrangements for sharing pastoral and farming rights to land and water in the Sahel. Access to ponds and government wells is generally negotiated successfully. Bambara farmers in Mali constructed wells in order to attract nomadic herds to their fields for manuring benefits (Toulmin 1992). In some countries (e.g., Nigeria) there is need for a coherent policy on pastoral rights, taking account of changing conditions, and supported by research on good practice, negotiating frameworks, and equitable tenure. Water is at the centre of these issues, and added urgency arises from increasing human and livestock populations. It may be noted that the rationale of mobile grazing systems, which its advocates have fought hard to defend against unsympathetic policy makers, derives fresh relevance under conditions of increasing rainfall variability predicted in climate change scenarios.

5. Harvesting aquatic organisms

Rainfall decline, increased seasonality in flow regimes, increased offtake for irrigation or urban water supply, and barriers to fish movements in the form of dams, have had negative impacts on the freshwater **fisheries** of the Sahel, other than in the largest rivers (Niger, Senegal). However, the creation of large new water bodies (e.g., the Tiga Dam in Nigeria) can enhance fisheries significantly. Fishing is largely unregulated by states though at the local level, strong institutions well founded in tradition usually control access. All Sahelian fisheries are probably exploited to their limits, and the introduction of large-scale technologies would result in over-fishing with possibly irreversible effects. Protection should be the cardinal principle of policy, compatible with markets. The focus of policy should be the catchment (a principle accepted in

dryland India, for example), on the ground that the hydrological network should provide the strongest basis for an integrated management system to reconcile the interests of fishers and other stakeholders. Fishers often feel marginalised b y centralised policy and regulation (Allison). A 'final solution' to contested claims is unlikely, where intensifying agricultural water use runs against less intensive lower value uses such as capture fishing. Effective negotiating processes involving and empowering artisanal fishing groups and marketing co-operatives are essential in order to cope with the dynamics (and politics) of fish ecosystems.

Market incentives for small-scale investments in fishery are strong. Fish farming, however, has not enjoyed widespread success, and in any case transforms the ecosystem, reduces biodiversity, and promotes monoculture especially where the carnivorous *Tilapia* species is bred.

6. Industrial use

Industrial centres are rare in the Sahel, but unfortunately (from a water management perspective), plant is highly concentrated at a few major centres where industrial demand is highly constrained by supply capacity – or soon will be – and in competition with domestic and institutional demand. Industrial demand for water is either provided through urban water systems via infrastructural investments, or industrial plants may have their own boreholes. Either way, a *laissez-faire* approach seems to have characterised government policy which has placed a higher priority on employment and wealth creation and tended to regard water as infinitely available, though often expensive to deliver. Few if any incentives are provided to encourage efficiency in water use. Nor do taxation regimes often reflect the social, environmental or opportunity costs of industrial water use. It is increasingly clear, however, that offtake – whether from public or private supplies - should be disciplined by catchment capacities (Section 8 below). Arguing that priority should be given to income generating (high value) water use could produce perverse impacts on poverty, if rights to domestic water are blocked. An additional problem concerns drainage and pollution. Chemical pollution risk is high where inadequate controls are applied to effluents, which may be spread from small tributaries far into catchments (e.g., Kano River, Nigeria).

7. Non-consumptive use

Energy generation from dams is rare in the Sahel because relative relief is low, good dam sites are rare and there are few perennial streams with sufficient discharge. A majority of dams are used for irrigation rather than power generation; the major exception (the Niger Dam in Nigeria) runs well below its capacity partly because of reduced flow during the four decades since its construction. For similar reasons, the value even of major rivers for transportation is very small, because few rivers provide economic links between major population centres or between seaports and their hinterlands; seasonal flow variations restrict shipping to a few months each year. Even at local level, water transport has given way to expanding road networks. Tourism is low key except for the Niger between Bamako and **Timbuktu**; the potential of Lake Chad disappeared with its water in the 1970s. Given the urgency of other water management issues, non-consumptive use is unlikely to gain much attention from policy makers.

8. Catchment functioning (a regulatory service)

The flow regime, and the contribution made to ecosystem 'health', by a catchment is the result of a balance between runoff, infiltration and offtake. All three are materially affected by land use decisions:

- **Runoff** and **infiltration** are linked with land use as well as with slope, surface and soil characteristics. Trees increase evaporation losses, reduce aquifer recharge but may moderate flow variability; clearance for farming increases infiltration and recharge (where soil conditions are favourable), but may increase runoff and flow variability (DFID 2005). Crops and agricultural intensification increase evaporation

during the growing season, but increasing dry season flow through soil storage and better catchment management is a useful objective of policy. Land use decisions can be influenced, not only by regulation, but by incentives such as payments for environmental services (PES)(Tipper 2002). However, measures need to be highly specific to catchments.

- **Catchment 'closure**' (a point where recharge is threatened and other users are deprived) is provoked by increased water offtake, especially for irrigation, usually because market incentives and legal provisions favour the exclusive appropriation of the resource at the expense of its own sustainability and of downstream users. Because large irrigation schemes in the Sahel are controlled by the states, and smallholders dominate (with very little capacity for withdrawing or transporting water), the Sahel has not yet seen a crisis on the scale of the Murray-Darling River in Australia. Localised conflicts of interest are however, common enough, for example where local farmers appropriate wetland grazing areas needed by transhumant livestock in the dry season, and where dam construction for irrigation or urban water supply displaces farmers or produces adverse downstream effects.
- **Aquifer exhaustion** (referred to above), can occur independently of surface flow where they include elements of fossil water or long distance underground flow, and is a risk near some Sahelian cities (e.g., Maiduguri). Geological basins in sedimentary rocks are quite common in the Sahel and southern Sahara. The sustainability of deep aquifers can be threatened by quite a small offtake.
- **Ecosystem functioning**. Maintenance of wetlands, micro-climates, and pedo-climates for nutrient cycling are examples of how water enables ecosystem functioning either in its natural state or under exploitation. Excessive offtake threatens ecosystem health and the 'supporting' services, 'cultural services' and potential tourist attractions it offers. If water shortage diminishes plant biomass productivity, or increases fire risk, carbon sequestration or emissions are affected.

Catchment planning is an urgent priority in the Sahel, given the reduction in overland and underground flows already evident as a result of declining rainfall during the past four decades. Underground aquifers are especially at risk, as few data are collected or hydrological models built. Instead, governments tend to drill boreholes to capture votes from rural areas. For example, during the 1980s, the Rimi administration of Kano State, Nigeria, embarked on a much publicised programme of '1,000 boreholes', enough for at least one in every village area. In the eastern half of the state, where sedimentary sand formations predominate, the water table is continuous, maintains a constant depth, and recharges from higher altitudes under more rainfall, so the boreholes (and others put down later) had no difficulty in finding water. But in the western part of the state, which lies on granites irregularly weathered and fractured beneath the surface, sites were chosen without geophysical survey and large numbers failed.

4. Summary of research needs

The foregoing review of ecosystem water services has suggested the following lines of policy research:

1. *Drinking and domestic use:* first, faced with increasing scarcity in relation to demand in the region as a whole, and increasing concentration of demand in major cities, the Sahel needs long-term planning for evidence-based investments in public water provision that match supply and demand on a catchment or urban area basis. Second, more hydrological modelling will be necessary for negotiating the transition from water perceived as an unlimited free good to water as a scarce and valuable commodity. Third, and given the inability of the state to provide water services alone, cost-sharing approaches need to be developed within frameworks of water law, regulation, and equitable distribution suited to the needs of individual countries. Fourth, the water needs of *industrial use (7)* and large institutions – usually sited on or near urban areas – must be included in long-term planning

because even if independent of public water provision, they may draw down rivers or aquifers with detrimental effects on future supply for drinking or domestic use. Finally, policy research needs to confront the issues raised by a rights-based approach to minimal standards of water quality, especially for poor people, in the context of growing quality water markets, in which they have little economic power.

2. *Rainfed agriculture:* the productivity of Sahelian production systems, until now, has been based to a large extent on indigenous knowledge and skills in managing the effects of rainfall variability. Science, however, has tended in the past to ignore this resource and instead pursued new technologies and management systems more concerned with productivity than with managing variability. Uptake and impact have therefore been very uneven, while in some situations the new approaches are still at an experimental stage. A goal for research, therefore (and one that is central to our present concern of water services provided by ecosystems), is to achieve a stronger convergence between indigenous and scientific knowledge systems. An appropriate focus is the decision maker (at farm, community, or policy levels) whose capacity to critique and implement promising new technologies is central. This observation should not, of course, obscure the fact that in some areas, encouraging progress has already been made.

3. *Irrigated agriculture:* notwithstanding large areas judged to be feasible for irrigation schemes, the policy emphasis has undoubtedly shifted from public sector interventions with all their problems (population displacements, cost overruns, mismanagement of water, non-viability, etc.) to enabling privately financed small-scale irrigation in response to new urban markets (e.g., the World Bank supported projects in Nigeria). However, this approach also entails difficulties (such as equity in access to land and water, contested rights between farmers and livestock producers and/or fishers). Research on land use change, legal and customary rights, stakeholder consensus building, negotiations, and natural resources governance institutions is at least as important as on technologies, which are well known.

4. *Livestock production:* there are two major researchable issues facing livestock producers. The first is access to drinking water for animals, which concerns both the right to walk to and use surface water, and also the labour costs of raising water from wells when this is unavoidable. The second is the capacity of the (rainfed) ecosystem to provide edible biomass in adequate quantities and at acceptable cost in a context of rapid (and in some areas, virtually completed) transfers of natural rangeland to farmland. In areas wet enough for farming, the controversial question of pastoralists' rights to common rangeland *vis a vis* farmers' rights to appropriate it is likely to become less important in the long run than the animal owner's need to gain access to adequate quantities of crop residues. The seasonal and spatial dynamics of livestock production complicate the problematic. There are many knowledge gaps in this theme.

5. *Harvesting aquatic organisms:* catchment planning would provide a better supporting framework for protecting this ecosystem service than a *laissez-faire* approach but local management must remain in the hands of local associations as has always been so (e.g, in the office of 'fishing captain' found in northern Nigeria). Harvesters, alas, have always had to work with water that is left to them by more privileged users, and subject to the vagaries of rainfall. Social science research could usefully investigate ways of strengthening the negotiating powers of fishers and capacity to develop locally based conservation strategies informed by catchment level data and policies. One thing that is certain in the uncertain world of fishers is that markets will go on growing. Their product is popular and imported ocean fish are not necessarily a substitute.

6. *Industrial use:* see under (1) above.

7. *Non-consumptive use:* a low research priority in the Sahel

8. *Catchment functioning:* see under (1) above. This theme works to a different agenda from that of water supply; however, a need to balance demand and supply is considerably more complex a goal when the need for a healthy functioning ecosystem able to provide supporting services (9) is included, as it must be, in an integrated approach to water planning. Experimental models are needed of institutional and knowledge management frameworks that can achieve this goal through research and action.

5. Water-poverty interactions – some general issues for policy research

In addition to the foregoing suggestions, we can identify some general issues that would justify concerted policy research:

- With the emergence of **water as the most scarce factor** in developing livelihoods and welfare in the Sahel, attention must be paid to the **institutions** needed to govern access, regulate distribution and markets, negotiate for investments and give voice to the most marginalised users, their rights and their rationales of water use (e.g., mobile pastoralists – a small minority – and urban poor – a rapidly increasing minority). The transition from water understood as a free good to water seen as increasingly scarce (and therefore valuable, contested, and marketed) need not alter an underlying right to its use. However, an institutional framework will become increasingly important to resolve water issues. There is also a pressing need for inter-sectoral negotiation even within governments. The key levels for such a framework will be (a) state legislation and goal-setting, (b) city or catchment planning and regulation, and (c) community control and stakeholder negotiation.
- In water ecosystem services**, scarcity** works to emphasise **poverty** and has the potential to lock poor people into water deprivation, income or welfare loss and health risk. This tendency is worsened by recent and ongoing changes in the wider environment – including rainfall decline, urban migration and unemployment. It is most acute in urban areas, where the poorest people have the least access to **safe** water, and where livelihoods may even depend on reprocessing sewage water (see Section 3 above). It exists at micro-scale in villages where the weakest are least able to command adequate water, even where it is free at source (however, there may be compensating benefits of kinship or patronage). Market forces are increasingly important (water sellers; municipal water charges; bottled water). But to leave markets to solve scarcities runs counter to regarding access to safe water as a human right. Votes can be caught (or repaid) by improving the public water supply (e.g., in Kano – mentioned above - and Gombe States, Nigeria).[4] Such examples suggest that popular morality recognises and values a right to water with a corresponding obligation on governments, some of whom however are remarkably slow to act on it. There is need to construct transparent, accountable and pro-poor water governance that is fully responsive to demand, using social science knowledge, experience in other places, and an open action-research programme implemented through local government and communities.
- The provisioning functions of water are affected by **variability** and will continue to be so. However, productivity rather than variability issues have tended to dominate development research and interventions. Variability of rainfall impacts directly on subsistence production with attendant risks of divestment, indebtedness, loss of resource access, increased health risks on a 'ratchet' of marginalisation or poverty, which weakens the strategy of carrying forward the income from a 'good year' to compensate the losses of the 'bad' – a principle that applies across the range of livelihood activities. Asset-stripping in bad years feeds the process of social differentiation. Better insurance mechanisms would therefore have both short- and long-term benefits. Adaptive strategies based on past experience in subsistence farming may not always be suited to today's conditions. An increasing need for capital (fertilizer inputs, labour-saving tools, rental of natural resources, transport, storage, etc) correspondingly increases the risk that the poorest may not be able to recover. Agricultural economic research has not generally taken adequate account of water, either as a

[4] The Governor of Gombe State in Nigeria achieved huge popularity by investing heavily in urban water supply in his capital city. He was re-elected in the recent national elections for state governors

consumptive good or as a variable factor of production (an exception is (Toulmin1992)). Its function in production and livelihood systems needs to be re-evaluated and policy implications identified.

- A **diversity** of solutions to water deprivation will be needed to match the diversity of situations found in the Sahel. While each major city and its peri-urban zone offers a coherent (and unique) planning and policy arena, outside such cities the catchment offers the most appropriate framework. However, decentralisation alone cannot deliver solutions to conflicting stakeholder interests in water, especially in an overall context of increasing scarcity, as is already experienced in some areas. The role of the state and of policy at the national level needs redefinition, as the colonial model of patrimonial provision has assumed undemocratic, unaccountable and under-capitalised dimensions and has too often been subverted by special interests. Much research may be needed to delineate the problematic of water ecosystem service provision, water law and regulation, followed by identifying appropriate policy directions – infrastructure, pricing strategies, rights, payments for environmental services, local and national institutions.
- Water **markets** will increase rather than go away especially as the Sahel moves (if it does) from being a 'basket case' in African development towards greater prosperity based on higher-valued commodities. Use of water for crop, fruit or fodder production is subject to capital being available for small-scale flood management on wetlands and low-cost water lifting technologies upwards through pump sets to major infrastructure. This disqualifies the poor, who lack privileged access to wetland resources, and who may be excluded entirely from dam sites or major irrigation schemes. The policy objective must be to translate the slogan 'make markets work for the poor' (rather than punishing them) into a programmatic framework across the range of water services reviewed above. Research to support such policy needs new thinking between inter-disciplinary and cross-cutting actors (government, communities, individuals).

6. Research structure and mechanisms

This is a complex theme requiring a separate and longer discussion. Some priorities may be briefly suggested:

- **Actors** should include not only policy makers and researchers but water users across the range of services and existing stakeholder organisations, recognising that the action-research appropriate for policy research in a field that directly affects every individual in society must be inclusive and negotiated from the design stage onwards.
- Supporting **research and consultation** could aim to bring together national capacity in water management and the related disciplines implied in this review, to set out a finite work programme to be carried out alongside a policy consultation and with overlapping participation. A structure for involving water users in public fora at critical points in the programme could be linked directly to collaborating communities at study sites. The governing body directing the programme and the policy debate would qualify for donor assistance. Further details of the research and consultation would be worked out in the light of national circumstances.
- The role of research should be not only to feed the process with scientifically based knowledge but also (through appropriate social science initiatives) to empower indigenous knowledge and experience for a **knowledge sharing** process. It is essential that national researchers are given a role in policy strategising and not confined to the traditional 'recommendations' format. For this role they will need strong support from an international partner in accessing knowledge resources from elsewhere in the world.
- Action research will need to move rapidly on to policy making at a **programmatic level** as a preliminary to national policies, but policy need not be kept waiting for programme completion before taking effect; a fluid interaction between knowledge-gathering, action research and policy making through a democratic process is ideal but calls for skilful management.

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