11 The fish-based farming system

Maintaining ecosystem health and flexible livelihood portfolios

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Key messages

- The fish-based farming system occupies the edges of Africa's water bodies along coastlines, lakeshores and the floodplains of river systems and provides a diversified, flexible and resilient livelihood portfolio for some 22 million sub-Saharan fisher-farmers with half of those living in extreme poverty. The fisheries operations provide 30 to 50 per cent of household income.
- System performance is under threat from land use changes that affect the quality, quantity and timing of the water supply, notably deforestation and the construction of dams upstream but also conversion to large-scale irrigation. On coasts overfishing is an issue.
- Maintaining the drivers of ecosystem productivity and especially the natural flooding regime is crucial. Governance inspired by traditional systems with strong involvement of the users in all stages of planning and management will facilitate development trajectories that are adapted to local context, favouring incremental rather than wholesale change.

Summary

The fish-based farming system encompasses mixed fishing/farming households that derive from 30 to 50 per cent of their income from fisheries and engage in a wider livelihood portfolio including forestry, livestock production, hunting and gathering. It covers a range of ecosystems, climatic zones and sociopolitical contexts. The majority of rural households in the system engage in small-scale fishing, especially young men using canoes and gill nets, but women and children also operate on foot. Fisheries can still be regulated by traditional institutions, but the trends are towards ineffective, state-based regulation or free-for-all situations. Externally financed, larger-scale operations at greater distances from the farm are on the rise.

Fishery productivity is largely dependent on the flood pulse linked to seasonal rainfall patterns. Deforestation, land degradation and weather extremes are creating unfavourable, sharper and shorter flood peaks. River regulation by dams decreases system extent and productivity. Trends are towards declining recession agriculture, pasture production and fish reproduction. Large-scale irrigation systems tend to replace the system and exclude its original beneficiaries.

Understanding of the system's functional requirements and its wide-ranging benefits is scanty in both government and development agencies, and thus some pessimism about its future is justified. Emphasis has been on extracting more from the system through industrialisation and upscaling, including for export, but failures are rife. Less attention has been directed to maintaining and enhancing system productivity through ecosystem management interventions, and facilitating the small-scale fisher-farmer's operations through co-management. The absence of an enabling environment and heavy local taxation favours self-sufficiency rather than marketing.

Maintenance of the structural and functional integrity of the wetland ecosystems should be a key focus, especially maintaining the flood pulse, including through managed flood releases from dams. Co-management, based on traditional governance systems, has a better chance of effectively banning destructive techniques and safeguarding nursery areas and reproductive seasons. There is a need for jointly analysed and agreed interventions, more flexible mesh-size regulations suited to local conditions, irrigation systems designed to add to the natural system, and maintenance of input-effective recession agriculture and other flood-based biodiversity, ecosystems and livelihoods. Given climate change uncertainties, planning must include wide error margins for floodplain infrastructure.

Aquaculture production is rapidly expanding. The introduction of inappropriate species should be avoided. Emphasis should be on fish that are low in the food chain (e.g. tilapia) and also on the preservation of the natural systems and existing water bodies. Small-scale testing, incremental technological improvements and household level roll-out may be the more sustainable and equitable approach. Culture of the ubiquitous, oil-rich and nutritious catfish *Clarias gariepinus*, which survives in almost any habitat and is the perfect fish to be smoked, offers opportunities using simple village ponds seeded from the wild.

Much can be learned from projects initiated by non-governmental organisations, but interventions should preferably be embedded in local government and operate over medium-scale timeframes. Support through holistic (non-sectoral) and non-dogmatic rural extension workers with a thorough understanding of the local context should be prioritised. Options for governance reform determined via multi-stakeholder dialogue and considering evidence, livelihood security, human rights and cross-sectoral and cross-scale interactions need to be explored.

Introduction

Fishing is an ancient human activity, much older than agriculture, and has probably been a key part of what made us a successful species. Dug-out canoes are known from the Lake Chad basin in 9000 BP, and bone harpoons and hooks of similar age are found in many areas in the formerly wet Sahara and Sahel.

The fish-based farming system encompasses mixed fishing/farming households – the fisher-farmers tend to have a flexible and opportunistic livelihood portfolio that, besides farming and fishing, includes livestock, forestry, hunting, gathering and often occasional wage-earning (Box 11.1). The question as to whether the people on Lake Victoria's shores should be designated as 'farming fishermen' or 'fishing farmers' (Geheb and Binns 1997) illustrates that livelihoods in Africa can combine the best of both worlds, terrestrial and aquatic. For this system, full household livelihood spectra have rarely been assessed, and accurate estimates are hard to come by as the system is mostly linear in nature, stretching along coastlines, lake shores and rivers in a 50 km wide strip that is not generally considered as an administrative or statistical unit. In the floodplains of the Zambezi

Figure 11.1 The basic production unit of hundreds of thousands of sub-Saharan fishers: a dugout canoe, a paddle and a gill net in the Tana delta floodplain, Kenya.

Source: Olivier Hamerlynck.

(Turpie et al. 1999) and the Rufiji (Turpie 2000) the majority of the farming households derive from 30 to more than 50 per cent of their income from fisheries.

Fishing is generally practised in close proximity to the household farm. As the farming part of the system is treated in other chapters, this chapter emphasises the fisheries aspects. The chapter focuses on smallholders and does not address the full-time fishers that are disconnected from farming for most of their lives or fish away from home for extended periods. These are not part of the system but may easily move in (and back out) for varying time periods.

A large proportion of farming households in proximity to large and small water bodies engage in small-scale fishing often temporarily (occasionally, seasonally or in a specific age class – most commonly young men). The basic fishing unit consists of a dug-out canoe, a nylon net and a paddle (Figure 11.1). The low capital cost of the tools partly explains the flexibility with which farmers can engage in fishing, to procure high protein content food (plus essential vitamins, fatty acids and oligo-elements) for consumption or to obtain immediate cash for social needs such as school fees (Paul et al. 2011) and medical care. In shallow water bodies, fish are also obtained on foot by women and children using mosquito nets or woven baskets. There is a trend towards externally financed fishing operations on a larger scale (larger vessels with engines and bigger nets) where fisher-farmers become employees and quit farming, at least seasonally. These individuals move out of the system but the rest of the household remains in the system.

Overall description of the system and subsystems

The fish-based farming system, stretching along the African coastline and across its centre (Figure 11.2), occurs in a wide range of climatic zones and ecosystems. Average length of growing period (LGP) ranges from basically zero on the desert fringes to the entire year near tropical water bodies. The subsystems have many similarities with the neighbouring farming systems described in other chapters, but they also have some characteristics that set them apart. The proximity of large bodies of water, the oceans lapping sub-Saharan Africa's rim, the Great Lakes in the Rift Valley and the large floodplains along some of Africa's main rivers, create conditions such as increased rainfall, reduced evaporation from cloud cover and comparatively abundant surface- and groundwater that lift LGP constraints.

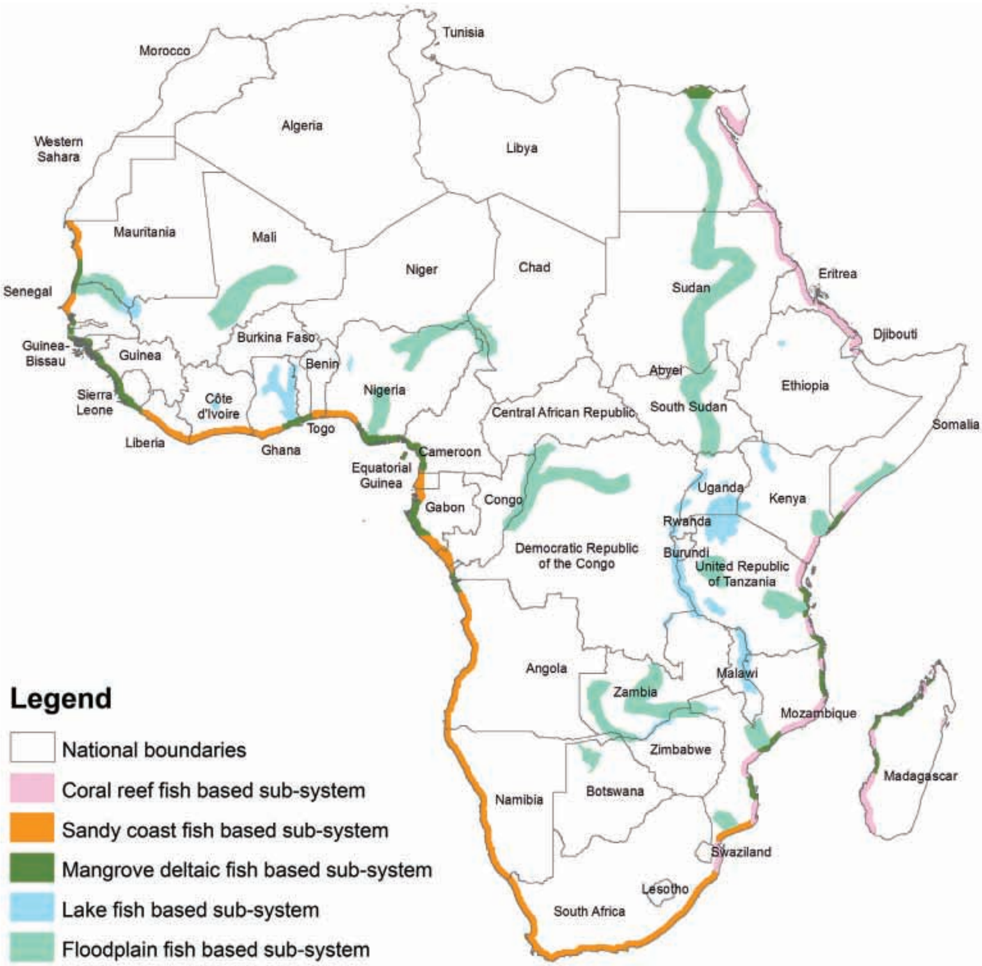

Figure 11.2 Map of the fish-based farming subsystems; note the linear shoreline nature of the system, bordering a wide range of farming systems especially mixed maize, agropastoral, pastoral, tree crop, forest-based and irrigated.

Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

Box 11.1 Typical smallholder farm household profile in the fish-based farming system

Juma and Fatima are in their twenties and have three children. Juma's mother is also part of the household and neighbours in need (e.g. a widow and her children) often share the meals. The family owns a cow, a dozen chickens and three goats, and cultivates two small plots totalling 1.25 ha, one close to the house (0.25 ha) with some tree crops (coconut, cashew, mango, banana), beans and oilseeds, the other (1 ha) in a flood-prone area where they intercrop rice, their preferred staple, with maize. An alternative would be sorghum in drier valleys such as the Senegal and the Niger. Yields are in general below 1 t/ha but can reach 1.5 to 3 t/ha for rice. There is no need for inputs nor much weeding and, in good years, they are self-sufficient.

During the planting and harvesting season Juma puts out a gill net at night in the adjacent lake and, after the flood, he also fishes with a friend during the day using a rented canoe.

In unfavourable years, he joins a team in the forest to cut trees and saw them into planks. Alternatively he can join an expedition for illegal fisheries or ivory poaching in an adjacent protected area to mobilise cash for school fees. He also does odd jobs such as road maintenance, school building or census work whenever the opportunity arises.

Basic data in Table 11.1 describes the sub-Saharan part of the farming system as displayed in Figure 11.3 and excludes the North African fish-based subsystem areas found in Egypt (Figure 11.2) for which data was not readily available. Table 11.1 and Figure 11.3 also do not include the floodplain fish-based subsystem, which is only indicated for illustration purposes in Figure 11.2.

The fish-based system covers an estimated 3 per cent of sub-Saharan Africa and is home to about 4.2 per cent of its agricultural population, that is some 22 million people, of whom about 50 per cent subsist in extreme monetary poverty (less than US$1.25 a day). In addition, of that surface area, about one-third is uninhabited water body, so rural population density is quite high at 50 inhabitants per km^2. The system also typically contains large and rapidly growing urban centres, with a population three times that of the rural areas.

Most fish-based farming subsystems have fast population growth rates (e.g. 3.3 per cent over the past 50 years around Lake Victoria) in comparison with the less well-watered surrounding areas. These high growth rates are partly explained by immigration, especially in areas where the fish-based farming system has established itself around newly created artificial lakes (dam reservoirs).

An obvious difference between fishing (or hunting) and livelihoods dominated by farming or livestock keeping is that there is a cash return on a daily basis as well as a dependable supply of animal protein. With water serving as a transport medium, markets are on average five hours away. This is almost half of the time needed by the dominant, adjacent farming systems.

The situation is complex and variable across the fish-based farming subsystems. In general, rural livelihoods in proximity to large water bodies (temporary or permanent)

Table 11.1 Basic system data (2015): fish-based farming system

Item	*Data*
Total human population (million)	102.2
Agricultural population (million)	21.6
Total area (million ha)	74.7
Cultivated area (million ha; % of total area)	4.8; 6
Irrigated area (million ha; % of cultivated area)	0.65; 13
Total livestock population (million TLU)	41.7
Major agroecological zone	Tropical warm subhumid
Length of growing period (average, days ; core range, days)	194; 150–330
Access to services (low/medium/high)	Medium-high
Distance to 50k market (average, hr; core range, hr)	5.0; 2–10
Agricultural population density (persons/total area; persons/cultivated area)	0.3; 4.5
Livestock density (TLU/total area; TLU/cultivated area)	0.6; 8.6
Standard farm and herd size (cultivated area/household; TLU/household)	1.2; 10.6
Extreme poverty (% of rural population)	48

Source : Refer to Table 2.4.

Note: Basic data refer to the sub-Saharan African portion of the farming system.

show a high degree of occupational flexibility in response to changing circumstances and climatic events and, because of the low capital outlay of the basic fishing operation (canoe, paddle, nylon net or even a mosquito net or a reed basket), which can be owned, rented or borrowed, and the low level of skill required, entry or exit from the fishery is easy. Many fishers will only practise this comparatively risky activity (hippos, crocodiles, sudden storms) during a particular time of their lives (e.g. before they have access to land), or seasonally (during or after extensive flooding). As a passive, low intensity activity (setting the nets in the evening, hauling them in in the morning), fishing is easy to combine with a multitude of resource-harvesting or income-generating occupations. The basic economic unit is the household (or even the extended family), and though some individuals may focus more on fisheries, the other members of the unit will predominantly farm.

Small-scale fisheries are known to be high employment multipliers generating land-based jobs. The multiple contributions of fishing to human well-being[1] are rarely captured in sectoral statistics – which tend to concentrate on formal, industrial fisheries operations and are notoriously unreliable for small-scale fisheries (De Graaf et al. 2011) – and macroeconomic accounting (Béné et al. 2010a).

Some ethnic groups still derive their identity from fisheries (e.g. the Bozo on the Niger River). In other societies fishing is restricted to certain castes, but the trend is towards livelihood diversification (Ellis 1998) with both fishing and livestock keeping becoming an integral part of the portfolio in traditional 'farming' families and vice-versa.

The basic unit in the system remains the dugout canoe or two canoes operating a larger net together. Increasingly, groups of fishers using longer nets will work from bigger vessels with or without outboard or inboard engines, especially on the coast and in lakes. Thus, there can be a gradual (often seasonal) or total disconnect between farming and fishing with fishing becoming a full-time, lifelong, salaried activity in the employ of

Figure 11.3 Map of the fish-based farming system in sub-Saharan Africa.

a town-based owner/operator or as a member of a collective organisation (e.g. in west Africa). The borders between the fishing-farming system and other livelihood spectra are therefore highly porous. The presence of high added-value species (e.g. groupers, snappers, Nile perch, shrimp, crabs, rock lobsters, octopus or sea cucumbers) for export or for local tourist resorts facilitates the move to full-time fishing. Such areas (coast, lakeshores) typically have high population densities and a scarcity of productive land, which reduces farming opportunities, and thus large numbers of fishers competing for few fish. So, in spite of a potentially high value catch, most of these fishers still live a 'hand to mouth' existence and can resort to desperate and unsustainable strategies such as dynamite fishing on coral reefs, the use of poisons or large seine nets, often owned by investors for whom the fishers are just low-paid manual workers. With high catches and good money generated in outlying camps where the normal household structure is absent, much of the proceeds may be spent on alcohol, drugs and female company, making these areas prone to high HIV-AIDS incidence (Seeley and Allison 2005).

Often, when fisheries' productivity in proximity to the household farm is in decline, migration to richer grounds will occur lasting several weeks or months (Nunan 2010) with high demand from urban centres a major driver. These migrating fishers compete with the local fisher-farmers and, because the migrants often use less selective or more destructive fishing or fish processing techniques, this can lead to conflict.

There are five main subsystems defined by the characteristics of the water bodies fished, whether salty or fresh water, as well as the dominant substrate type (hard, coral, sandy, muddy, mangrove) (Figure 11.2). Aquaculture can be combined with each of the subsystems.

The coastal fish-based systems can be subdivided into two main subsystems: (1) the coral reef coast fish-based subsystem and (2) the sandy coast fish-based subsystem. The freshwater fish-based systems can be subdivided into: (1) the lake fish-based subsystem and (2) the floodplain fish-based subsystem. The brackish water, mangrove and estuarine deltaic fisheries is named the deltaic fish-based subsystem.

Coral reef coast fish-based farming subsystem

This subsystem stretches from southern Somalia to southern Mozambique and along the shores and islands of the western Indian Ocean (including the western and northern coasts of Madagascar), as well as in the Red Sea.

On the Swahili coast all manner of traditional vessels, from tiny dugout canoes (Figure 11.4) to larger vessels, can be seen leaving the beaches or coves at sunrise, setting out to fish on inshore or off-shore reefs. They use a plethora of active and passive gear, including hand lines, baited baskets, gill nets, seine nets and spears. On calm, moonless nights lights are used to attract small pelagics and post-larval reef fishes but also the larger predatory fish

Figure 11.4 Coral reef fishing operation using traditional baskets that are set close inshore (Tanga, Tanzania).

Source: Olivier Hamerlynck.

hunting the small ones. Fishing is mainly practised during the northeast monsoon season ('Kaskazi' – November to March) with moderate winds and a calm ocean. During the main rains (March to May), fishers shift to agricultural activities. During the southeast monsoon ('Kusi' – June to September), strong winds and waves restrict fishing.

In addition to boat-operated fisheries, a very important livelihood activity is the gleaning on foot of exposed reef flats at low tide, in particular during spring tides. This fishery targets a range of aquatic species, e.g. sea cucumbers that are dried and exported to Asia (Eriksson 2012), molluscs (cephalopods such as octopus, and gastropods both for consumption and for trade in sea shells) and crustaceans that are dislodged from under rocks as well as a range of creatures used as bait for the canoe-based fisheries. While finfish fisheries are an almost exclusively male activity, women and children are involved in reef-flat fisheries. On easily accessible reefs this can lead to a rapid depletion of the various resources (Andrefouet et al. 2013). The capture of live coral fish for the aquarium trade has not really taken hold in the western Indian Ocean. Similarly, aquaculture of crustaceans and fish is low technology and small-scale, and the existing operations remain entirely dependent on wild-caught seeding animals or fattening of wild-caught crabs.

Much of this farming subsystem has replaced lowland coastal forest, one of the planet's richest and most threatened biodiversity hotspots (Myers et al. 2000), leaving only small 'sacred' groves (Robertson and Luke 1993) and a few protected areas. Initially the soils are productive but gradually, with nutrients taken up by crops and leached out by rain, they become poor. Maintaining productivity requires adding and retaining nutrients, preferably by mulching and adding animal dung in principle available from the comparatively trypano-tolerant Zebu cattle and small ruminants typical of this subsystem.

Figure 11.5 High density of reef fishes in Mafia Island Marine Park, Tanzania.
Source: Olivier Hamerlynck.

Coral reefs are highly diverse (Figure 11.5) and among the most valuable ecosystems on earth, providing a range of ecosystem services (De Groot et al. 2012) but vulnerable to a range of direct and indirect drivers of change, few of which are currently being adequately addressed.

Sandy coast fish-based farming subsystem

Sandy coasts occur all along Africa's Atlantic shores from Morocco down to southern Senegal (the Siné-Saloum) where the mangrove systems take over. Just east of Sherbro Island in Sierra Leone they dominate again down to the Cape of Good Hope (where rocky shores predominate). Then there are sandy coasts again along the southern shores of the western Indian Ocean north to Mozambique where coral reefs and coastal mangrove systems take over until the upwelling areas along the Somali coasts (at about 7°N).

These coasts are highly dynamic with strong wave action and violent rip currents, which pose a challenge to fisheries using small craft. They are also characterised by upwelling of nutrient-laden, cold water leading to high productivity. Upwelling is strongest on the coasts of Mauritania, Namibia and Somalia. Upwelling is more variable in the Gulf of Guinea but still an important driver of fisheries productivity. Strong upwelling attracts some of the most sophisticated and powerful trawlers on the planet. Hundreds of thousands of tonnes of mainly pelagic fish are caught, either through licensing agreements with the coastal nations or illegally. Such vessels also "stray" into inshore waters, in theory reserved for small-scale fisheries.

The motorised canoe-based fisheries initially developed in Ghana (Akyeampong 2007) and spread to Sierra Leone and all the way to northern Angola. The technology was adopted and adapted further north in Senegal and Mauritania.

With its spread along the African coasts, the subsystem covers many different climate zones, rainfall regimes and livelihood practices. In the areas fringing on the Sahara fisheries are combined with mobile livestock keeping. In northern Senegal fisher-farmers practise market gardening (vegetables), further south they farm millet and groundnuts ('le bassin arachidier'). Other variations occur in the cereal-root crop, the root and tuber crop, tree crop and the forest-based systems.

In west Africa, starting from the 1980s after the failure to establish local industrial fisheries, there was a strong expansion of motorised fisheries using 'pirogues' (Figure 11.6); these are modified from river canoes to resist the strong wave action and pass the sandbars on the windswept sandy beaches. When local stocks declined the fisheries migrated to richer waters, first seasonally but increasingly through permanent settlements (Chauveau and Jul-Larsen 2000). From Senegal, the migrant fisheries expanded north to the western Sahara and southward into the deltaic fisheries areas. From Ghana they expanded westward to Ivory Coast and eastward to Nigeria and Cameroon, and from Benin to the Congo (Marquette et al. 2002) and Angola.

West Africa is characterised by migrations and dynamic livelihood strategy shifts (Njock and Westlund 2010). Coastal people as well as sedentary farmers from the Sahel have moved to the cacao growing areas and other plantations or to the oil-producing nations. Former desert nomads and traders from the Sahara opened shops and businesses in the fast-growing urban centres along the coast. Floodplain dwellers from the Inner Delta of the Niger have become the predominant fishers of the lagoon systems of Ivory Coast. Statistics on life-history trajectories are notoriously hard to come by, but it is thought that only about 10 per cent of the west African artisanal[2] fishers engage in fishing as a full-time, life-long activity

Figure 11.6 The settlement of Guet N'dar in the Senegal River Delta dates back to the eighteenth century. It is home to thousands of fishers who migrate all along the west African seaboard and catch some 30,000 tonnes annually. Trucks from many countries come there to load cheap pelagic fish while the expensive bottom-living fish and prawns are flown to Europe.

Source: Olivier Hamerlynck.

and produce 90 per cent of the catch (Chauveau and Jul-Larsen 2000). These are not considered part of the fishing-farming system. The vast majority of fishers will practise farming or, especially those who have fisheries associated skills (e.g. engine maintenance), move into other economic activities (e.g. transport) seasonally, temporarily or permanently.

Typically women, though excluded from boarding the pirogues, dominate the processing and marketing part of the fisheries (Bennett 2005). Especially in Ghana (the famed 'Mama Benz' after their preferred vehicles, the Mercedes[3]), this has evolved into the pre-financing of fishing operations (equipment, fuel, gear) to secure privileged access to the catch.

Artisanal fisheries provide crucial cheap protein to the populations of the west African sub-region. The migrant fleets often compete with sedentary locals and with the mostly foreign-based industrial fisheries targeting the same stocks (Atta-Mills et al. 2004). West African artisanal fisheries have now developed to a level where overfishing occurs, especially of more long-lived bottom-dwelling fish for export. However, our understanding of the dynamics of the food chain in these systems and of the drivers of ecosystem change (upwelling, the different fisheries) is limited. It is advisable to regulate access and gear use as well as secure nursery and reproduction areas through Community Conserved Areas or Marine Protected Areas, preferably based on collective action and traditional management systems.

Lake fish-based farming subsystem

The shores of the African lakes along the branches of the Great Rift Valley present highly varied landscapes – from the small high altitude Ethiopian lakes to the giant, desert Lake Turkana, the lush green papyrus swamps of Lake Victoria, the oil palm plantations on the sandy rims of northern Lake Tanganyika and the rocky shores of its more southerly parts, and the lower rainfall, Baobab savannahs by Lake Malawi. The lakes often have a highly diverse fish fauna whose complex biogeography is linked to ancient connections with the Nile, low water level periods with isolation as well as species introductions. The fisheries in these lakes have a wide range of socioecological contexts and generalising across them is a challenge. It should be noted that, as was the case for the sandy shore fisheries, attempts at industrialisation in Lakes Victoria, Tanganyika and Malawi by the introduction of trawlers have been largely unsuccessful. Since the 1960s fisheries have been rapidly expanding in all these areas and are now practised by hundreds of thousands of people in the lakes and dam reservoirs, especially night-time fishing for small pelagics using lights. There is a trend towards full-time fishing as employees of companies, but many are still fisher-farmers.

The Lake Victoria fisheries are the subject of highly controversial and often ideological debates with contradictory interpretations of ecosystem changes, overexploitation and impacts on human well-being. The dominant discourse is that overfishing is the major threat to the Lake Victoria fisheries, but detailed analysis does not seem to confirm this (Kolding et al. 2008). In 1960, an estimated 10 million people lived within 100 km of the shores of Lake Victoria. Currently this is probably over 50 million and still highly dynamic, doubling every 22 years and with at least 1.5 million depending directly on the lake fisheries (some 200,000 fishers operating from about 50,000 boats plus the associated land-based jobs). Population density is among the highest in rural Africa with over 200 inhabitants per km^2 in the Kenyan and Ugandan sectors (Odada et al. 2004). At the same time the fishery has developed exponentially in spite of spectacular changes in species composition.

The fishery targeting the introduced Nile perch is largely (about 75 per cent) destined for export and is an important source of income for local fishers, even though most of the added value profits the fish traders, export companies and supermarket chains that sell the fish abroad (Béné et al. 2010b). Three other species, whose consumption is predominantly African, are important: the introduced Nile tilapia (*Oreochromis niloticus*) which is a 'middle-class' food for city dwellers, the small freshwater shrimp *Caridina nilotica*, which is converted to fishmeal and, most significantly, the 500,000 tonnes of the tiny (maximum 10 cm) pelagic silver cyprinid *Rastrineobola argentea*. This species is sundried and exported throughout eastern and southern Africa for human consumption but also converted to fishmeal for animal feed, including aquaculture. With similar small pelagics caught in Lakes Tanganyika (Mölsä et al. 1999) and Malawi (Weyl et al. 2010), the cyprinid is a major source of cheap protein for vulnerable people over a vast area. It is hard to overstate the impact even small quantities of fish protein and fatty acids can have on human well-being, especially for children.

Productivity of lakes and reservoirs used to be thought of as determined only by the static variables depth and dissolved solids. Increasingly, fluctuations in water level are thought to play a significant role (Kolding and Van Zwieten 2012). As is the case in floodplains, freshwater pulses linked to rainfall bring additional nutrients from run-off, and the higher water level will flood vegetated shorelines to provide suitable habitat for fish to spawn as well as provide the juveniles with abundant food and reduced predation.

The farming system with which the fishery combines is determined by rainfall and LGP along the north-south gradient. Pastoral systems dominate around Lake Turkana and crops are restricted to the deltas of inflowing rivers. In the highland perennial system around the shallow and productive Lake Victoria plantains feature prominently in the landscape and in the diet. Further south, in the drier maize mixed system around the deeper and stratified large lakes such as Lakes Tanganyika and Malawi, farming opportunities are rainfall constrained. Fishing-farming systems also exist around innumerable smaller lakes and the reservoirs of hydropower dams, although, for the latter, productivity is comparatively low, except during the initial boom linked to the nutrient inputs from the dying terrestrial vegetation as the dam is filled. The smaller Rift Valley lakes are in general alkaline, which limits their productivity.

A relatively new type of this subsystem is developing around the reservoirs of hydropower dams, which form new lakes such as Lake Volta (Zwieten et al. 2011) and Lake Kariba (Tweddle 2010). These have attracted migrant fishers in west Africa from the Niger River Inner Delta, for whom it is a profitable, seasonal switch from the floodplains. Poverty in the fishing communities of Lake Volta relates to a wide range of non-fisheries-related socioinstitutional factors, including land ownership, debt, access to health, education and financial capital as well as marginalisation from political decision making (Béné and Friend 2011).

Floodplain fish-based farming subsystem

Because of the strong seasonality of rainfall, most large river systems in Africa have extensive floodplains (Table 11.2), covering over 300,000 km^2. In west Africa some of these floodplains, such as the Niger River Inner Delta in Mali and the Senegal Valley, have been intensively fished, grazed by livestock and farmed, probably for millennia, and have developed 'tribes' (e.g. Bozo and Somono) or castes (Subalbe – in fact a Fulani 'non-caste') specialised in fisheries. They have relatively high population densities in comparison with the neighbouring arid and semi-arid lands and are true fish-based farming systems with strong interactions with both agropastoral and irrigation farming systems. Other floodplains, such as the Congo River system, are more or less inaccessible and have low population densities (Béné et al. 2009) and considerable potential for expansion.

Table 11.2 Main African river basins and their floodplain systems with an estimate of their extent in km^2

Major river basins	*Extent (km^2)*	*Floodplain basins*
Nile basin	93,000	Sudd, Kagera
Congo basin	70,000	Middle Congo depression, Kamulondo, Malagarasi
Lake Chad basin	63,000	Chari and Logone River system
Niger/Benue basin	38,900	Niger central delta, Benue River
Zambezi basin	19,000	Kafue flats, Barotse plain, Liuwa plain
Western basins	19,000	Floodplains along the Senegal, Volta and Ouémé
Eastern basins	9,270	Kilombero, Rufiji, Tana
Southern basins	7,500	Okavango, Pongolo, Limpopo

Source: Modified from Tockner and Stanford (2002).

Figure 11.7 Migrating Bozo fishers in the Faguibine system in Mali with one donkey cart to move the canoe, the other for the gear, camping equipment, food, firewood and the family.

Source: Olivier Hamerlynck.

In the vast Sudd marsh on the Nile in South Sudan data is scant because of decades of insecurity. Still others are inside protected areas and therefore uninhabited or, as the Okavango Delta, advertise themselves as 'untouched' by humans and are primarily high-end, wildlife-viewing destinations, even if traditional fishing (Mmopelwa and Ngwenya 2010), recession farming and mobile livestock keeping also occur. So, in many large and small floodplains mixed livelihoods are practised but on a scale and by groups of people who tend to be invisible in the national statistics.

African floodplain fish-based farming subsystems are strongly seasonal environments with little scope for full-time, lifelong fisheries-only livelihoods unless migration to areas with inverse seasonal dynamics is an option. Thus Bozo fishers from the Niger River Inner Delta (flood peak in November) move to the neighbouring Faguibine (flood peak in March) system (Figure 11.7, Box 11.2); others will fish seasonally in dam reservoirs such as Manantali.

The key characteristic of these systems is their regular seasonal flooding. Floods, in spite of their negative reputation, are actually the engine in system productivity. Local user communities perceive them positively (Duvail and Hamerlynck 2007) and understand the many ecosystem services that they provide, such as groundwater recharge (allowing recession agriculture), deposition of fertile silt, productive fisheries with on average 40 to 60 kg of fish caught per ha flooded per year (Welcomme 2008) and the development of pasture that will take wild and domesticated herbivores through the long dry season.

Recession agriculture (Box 11.2) is often the dominant activity complemented by a wide range of alternative livelihood strategies (Béné et al. 2003; Turpie 2000). Fishing is alternated with other activities, including agricultural work such as clearing, hoeing, sowing and harvesting, often in intricate calendars that can also show strong inter-annual variation depending on rainfall and floods.

With population expansion into marginal areas, an increasing number of temporary water bodies that used to be reserved for seasonal grazing and watering of animals are now permanently settled, often by marginal groups such as liberated serf castes in the Sahel. Livelihoods there combine recession farming, small-scale irrigation, market gardening and fishing or even low-intensity forms of aquaculture (seeding the water body with catfish and/or 'tilapia' fry).

Figure 11.8 Floodplain farming in Rufiji, Tanzania (photo taken from a cashew tree). The maize is intercropped with rice in the deeper parts of the naturally flooded depression. Both the chicken coop and the house are on stilts.

Source: Jean-Luc Paul.

In the wetter areas with access to denser woody vegetation (wooded grasslands, woodlands and forests) these livelihoods can be further expanded with timber and non-timber forest products, such as wild food gathering including bush meat (Brashares et al. 2004), honey gathering or production, traditional medicine, pole cutting, charcoal production and logging. Permanent tree crops such as banana, cashew and mango can also play an important role in these systems.

Because of the generally low predictability and high variability in these systems (timing and abundance of seasonal rainfall, timing and extent of flooding) resource use strategies, crop choices and timing of planting are often highly opportunistic and oriented towards risk avoidance.

Thus, in floodplain systems, each household will clear and plant several plots (often less than a hectare), situated at a different elevation and on varying soil types. These plots are intercropped for example, rice interspersed with maize (Figure 11.8), often using both fast- and slow-maturing varieties. By sowing over a range of dates linked to rainfall events they hedge their bets under different flood (height and duration) and rainfall scenarios in the hope that at least one crop in one plot will provide sufficient starch for subsistence. Should everything sowed or planted be washed away, the fisheries – which are highly productive after an intense flood pulse – will be the immediate alternative followed by the planting of recession crops such as pumpkins that thrive under conditions of high soil moisture, groundwater recharge and the deposition of fertile loam and clay by the flood. By their very nature these floodplains usually have comparatively low population densities, and certain populations may only be present seasonally, especially mobile livestock keepers. Recession farmers can supplement their food resource base, income or increase the fertility of their fields by bartering cereals and fish for milk and meat products, charging levies for grazing on the stubble fields or 'cultivating' specific grasses appreciated by the livestock of nomadic herders, as is done in the 'bourgoutières' (plains where *Echinochloa stagnina* grows) of the Niger River Inner Delta in Mali.

There are many possible variations on this theme using different crops. For example, in drier areas sorghum or millet will replace maize, or cash crops such as cotton or sesame may be favoured. Different types of beans and vegetables such as okra (*Abelmoschus esculentus*) and other Malvaceae such as *Hibiscus sabdariffa* (roselle, 'bissap') and various Cucurbitaceae (squashes, melons, gourds, cucumber, pumpkins, luffas and watermelons), onions, tomatoes and spices (various types of chilli but also aniseed, cumin, garlic, etc.). Sweet potato can be a high added-value crop on sandy dunes in proximity to water bodies.

Box 11.2 Just add water: recession agriculture of Lake Faguibine in Mali

About 100 km west of Timbuktu lies 'Lake Faguibine', a triangular depression of about 50,000 ha (Hamerlynck et al. 2016). The rainy season consists of a few showers totalling about 100 mm between August and October, when the dunes neighbouring the 'lake' briefly turn green and are grazed mainly by camels. In December water appears in the lake's south-eastern corner, some 175 km from the banks of the Niger River. By March the lake is flooded and Bozo fishers, who have brought their canoes on donkey cart, set up their gill nets. Up to 3 km away from the edge of the water, Eklan and Bella groups start hoeing and plant three seeds in each pocket: a seed of maize (to be harvested in June), a seed of sorghum (to be harvested in September) and a bean or some other crop (cotton, groundnuts, vegetables). As water infiltrates into diatomite soils and evaporates in the hot desert winds, farmers move down with the water's edge and put the emerged land under cultivation. The only inputs are seeds and labour, keeping livestock out of the fields, harvesting, loading the produce on donkeys and taking it to the market or storage.

This is recession agriculture at its best. No hydraulic infrastructure, no machinery, no pumping (the lake is about 10 m below the flood level of the Niger River), no fertiliser and no pesticides. Organic farming in the Sahara and all done by the 'poorest-of-the-poor', the recently affranchised subservient castes! Admittedly, production per ha is low (only 1 or 2 tonnes) in comparison with the theoretical maximum expected in irrigation systems. Recession agriculture works and has done so for centuries, which is more than can be said for the nearby large-scale irrigation system of Lake Horo. That system has cost several thousand $US per ha to build, and many millions to run until both the donors and the government gave up. Its traditional users have now gone back to recession agriculture, which functions very well at a fraction of that cost (Adamczewski et al. 2011). In the Sahel many intermediate forms of water control exist, from purely passive inundation to 'modern' irrigation (Barbier et al. 2011). The traditional and modern systems are complementary and successful small-scale irrigation (wheat, rice, vegetables, spices) using a pump, and a simple layout of small embankments is found in the higher floodplains along the canals supplying the Faguibine system.

In spite of its socioeconomic effectiveness, recession agriculture has hardly been researched (in Google Scholar it will yield a few hundred hits while irrigation yields millions) or promoted. It works as long as flooding regimes of rivers are maintained, restored or enhanced by managed flood releases from hydropower dams, even when subsidies are withdrawn (Comas et al. 2012).

Deltaic fish-based farming subsystem

Most of Africa's major river systems with a coastal outlet form deltas where sediments brought down from the continent are deposited. These are colonised by extensive and highly productive mangrove systems, especially where there are strong tides that create dynamic interchanges between fresh and marine waters. Key areas in west Africa include the 'Rivières du Sud' between the Sine Saloum estuary in Senegal and Sherbro Island in Sierra Leone (Cormier-Salem 1999), and the Niger and Cross River deltas in Nigeria. To the north of and in between these systems are more dynamic coasts that support the sandy coast fish-based farming subsystem. From central Africa to Angola, most of the coasts are highly dynamic and mangroves are confined to the main estuaries. The same is true for the (small) estuaries along the coasts of southern Mozambique. Substantial deltas with characteristic mangrove systems reappear at the mouths of the Save and Pungue Rivers, but the major ones along the east African seaboard are the Zambezi and the Rufiji (Richmond et al. 2002). The Ruvuma and Tana Rivers also have much smaller but important deltas. The mangroves in the estuaries of western Madagascar share the same characteristics (Duvail et al. 2017).

The fisheries in the deltaic subsystem target many species, but major, often export-oriented, income earners are the crustaceans, especially shrimp and crabs but also sharks for their fins. Traditionally, penaeid shrimp are caught using passive fish barriers using the tides, but inshore areas of deltas can also be intensively fished by trawlers (Munga et al. 2012), which can lead to conflict when they interfere with small-scale operations. The high bycatch-(especially of juvenile fish)-to-shrimp ratio of trawlers draws complaints, especially when discards wash up on shore. Finfish are important for the local food supply, especially the fattier clupeids, shads, mullets and tarpons that can be smoked and dried. Smaller fish and shrimps caught with mosquito nets, often by women, are also dried and used as seasoning. Depending on the surroundings of the specific river mouth, households can combine this type of fishery with coral reef or soft substrate fishery (or even lake or floodplain fishery), often on a seasonal basis or in a shorter lunar-based cycle in accordance with the migrations and activity patterns of the target species.

Figure 11.9 Harvesting of tidal rice in the Tana Delta, Kenya; tree crops include coconut, banana, mango and Nipa palm.

Source: Olivier Hamerlynck.

Again, the farming system with which the fisheries is associated will depend on the climatic zone and LGP, but tree crops such as coconut, banana, mango and other fruits and various palms (oil palm, nipa), cereals such as maize, and root crops such as cassava, feature prominently where conditions are favourable. In both west African and east African deltas, one very specific form of cultivation in this subsystem is tidal or mangrove rice cultivation, combining river floods and the tidal bore to passively irrigate fields cleared in the mangrove system (Figure 11.9). These lands are often targeted for industrial shrimp aquaculture.

Trends and drivers of change across the system

Fifty years after independence from colonial rule, the fish-based farming system in Africa is still struggling with the colonial and early post-colonial attitude of "local systems are inappropriate and either underperform or overexploit and they need to be replaced by 'modern' i.e. western European/American models". Projects and programmes funded by multilateral and bilateral partners, national discourse and training programmes tend to push for radical change in resource use systems, emphasising private property, increases in scale and industrialisation of harvesting and processing. This approach tends to emphasise economic rent rather than social welfare (Béné et al. 2010a). In addition, choosing 'modernity' often means ignoring or externalising environmental and social costs, which harms biodiversity and thus undermines ecosystem service delivery and the well-being of vulnerable people. Indirect drivers of change (Nelson et al. 2006) such as demography, economic processes (e.g. globalisation), scientific-technological innovation, distribution pattern processes (as captured by the income inequality or GINI index) and cultural, social, political and institutional processes (belief systems, governance, policies, legal framework) have major impacts on the functioning of the fish-based farming system. It is important to recognise that different cultures may evolve along different development pathways (Harrison and Huntington 2000). Influencing these indirect drivers requires intervention at the political level, often on a regional or even global scale. The direct drivers of change include land use change (deforestation, expansion of cultivation into increasingly marginal areas, large-scale biofuel plantations); resource extraction patterns (mining, protected areas) and the increased use of external inputs (fertilisers, pesticides, irrigation water); development of energy sources such as hydropower and fossil fuels and their associated emissions of greenhouses gases; and the modification (genetic engineering) and movement of organisms (in particular invasive species associated with aquaculture). These are particularly strong impactors on the system. This chapter will focus on drivers specific or local to the fish-based farming system, which are summarised later in Table 11.3. Many of the drivers have strong interlinkages and can all push in the same direction. The subdivisions below are therefore somewhat artificial.

Demography

Sub-Saharan Africa's population has been growing very rapidly but is in transition with fertility rates decreasing in general and, as a consequence, annual growth rates trending downwards towards 2 per cent, expected to be reached in sub-Saharan Africa between 2040 and 2050 (United Nations 2013). North Africa has already achieved this transition. Population tends to be high in comparison to the availability of social services and ecosystem productivity. With often about half of the population below 15 years of age, the strains on education and development of gainful employment opportunities will continue.

Figure 11.10 Migrating (often transnational) groups of fishers funded by city-based investors are increasingly competing with local, farm-adjacent, part-time fishing operations. The migrants often use destructive gear that damages the resource base, in this case a very large seine net that will rake the coral reef. These nets have been provided by well-meaning development projects and were originally intended for offshore pelagic fishing (Tanga, Tanzania).

Source: Olivier Hamerlynck.

Massive un- and underemployment have associated risks of political instability and declining well-being. Longer lifespans mean increasing dependence ratios and additional stresses on the poorly funded health systems. New chronic diseases such as diabetes, hypertension and cancer require adaptation of the service delivery systems, so far primarily geared towards infectious and parasite-related ailments.

Associated with these demographic trends is rapid urbanisation, including in the coastal parts (Parnell and Walawege 2011) of the fish-based farming system, around the Great Lakes, and around floodplains with an associated high and ever-increasing demand for affordable fish protein. Poverty levels can be expected to remain high, and hunger can occur, especially when the water-related ecosystem services are hampered by inadequate floods.

Natural resources and climate

The fish-based farming system is highly dependent on water quantity, quality and dynamics, and draws on both the characterising water sources and local rainfall. The variability in weather, climate and water resources resulted in the development of broad and flexible livelihood portfolios, especially in the dynamic floodplain and deltaic systems where target species (both fish and invertebrates) are more opportunistic.[4] While the flexibility makes these farming systems more resilient, they are still susceptible – very few human societies can forego a few successive dry years or even a single production season. This was evident during the prolonged droughts in the Sahel (1970s to 1980s) and currently in the Horn of Africa.

For major parts of the system, productivity is dependent on the flood pulse linked to the pronounced seasonal rainfall patterns. In the flood-dependent systems, almost all resources react in concert as they are all dependent on the same drivers, i.e. there are bundles of water-related ecosystem services. Even the seemingly more static lake systems are dependent on flood pulses, mainly through their effect on the nursery areas. In an increasing number of basins, the beneficial effects of the flood pulse are in jeopardy as deforestation and land degradation create sharper and shorter floods. Trends are towards declining recession agriculture, pasture production and fish reproduction. Also, river regulation by storage dams decreases the flooded surface area and system productivity (Box 11.3). Large-scale irrigation systems tend to 'replace' the system and exclude or marginalise its traditional beneficiaries.

The easy entrance into fishery and its attractiveness to young males means that the number of fishers can be expected to continue to grow and contribute to overfishing, especially through externally financed migratory operations. Fisheries conducted near the homestead have incentives to use sustainable techniques and levels of exploitation, often formalised through traditional governance systems. When harvesting away from home such considerations become irrelevant from the fisher's perspective. Migratory (and destructive) fisheries (Figure 11.10) are typical for west Africa (Chauveau and Jul-Larsen 2000), and are increasing along the east African coast (Crona and Rosendo 2011), the lakes (Geheb and Crean 2003) and even in floodplains of the Zambezi and the Rufiji.

Overfishing is apparent when increased effort no longer results in increased total catches or when the average size of the fish landed is decreasing (Welcomme et al. 2010). In Lake Victoria (Kolding et al. 2008) eutrophication from urbanisation, deforestation and expansion of agriculture has resulted in higher lake productivity but has also favoured alien, invasive water hyacinth (*Eichhornia crassipes*) and an increased risk of anoxia.

Global climate change models are performing well, but the models at the scale relevant for the fish-based farming system have high uncertainty levels (Müller et al. 2011). Climate models for the Sahel predict anything between a 30 per cent increase to a 30 per cent decrease in rainfall (Shanahan et al. 2009). Prolonged droughts and reductions in flooded surface areas would be detrimental for floodplain and deltaic subsystems and negatively affect lake and coastal systems. It would therefore seem wise to prepare for a (few) worst case scenario(s). More extreme (rainfall) events and associated short and sharp flood peaks hamper fish reproduction and may wash away crops.

For coral reef systems additional declines in the resource base are expected through climate change-related ocean acidification (Hoegh-Guldberg et al. 2007), rapid sea level rise and increased storm damage. These vulnerabilities, based on an index that combines sensitivity and adaptive capacity, most strongly affect sheltered, high water temperature coasts such as Kenya, Tanzania and north-west Madagascar where communities are already stuck in a poverty trap (Cinner et al. 2012).

Box 11.3 The restoration of the Senegal River Delta in Mauritania: a success story

After the Sahel drought of the 1970s and 1980s two dams were built on the Senegal River, a storage and hydropower dam upstream at Manantali in Mali and a salt-wedge dam close to the river mouth at Diama. The multifunctional floodplains in between, traditionally consecutively used for fisheries (flood season), recession agriculture and livestock grazing (dry season), were to be converted to several hundred thousand hectares of irrigated agriculture. When the dams were completed (in 1990) the productive delta, which had already lost biodiversity values and ecosystem services during the drought, was excluded from flooding and turned into a saline desert. Hundreds of hectares of mangrove died, the rich *Echinochloa* pastures shrivelled up, thousands of hectares of *Sporobolus* used for traditional mat weaving disappeared and the rich shrimp and finfish fisheries collapsed.

Between 1993 and 1997, sluice gates were built in the Diama Reservoir embankment allowing re-flooding of the major deltaic floodplains and subsequently flush the estuarine part. Designed through a participatory process emphasising local knowledge, the co-management arrangement mimicked the original optimal flooding (Hamerlynck and Duvail 2003).

Under the managed flood releases the grassland ecosystems bounced back quickly, and currently, after 20 years of re-flooding, the mangrove and floodplain *Acacia* forests have reached maturity. The communities of fishers, livestock keepers and farmers revived. About 60 fishery households produce 150 tonnes of fish and 1 tonne of shrimp annually, earning over US$100,000 (about US$10 a day during the five-month season). After flood recession, thousands of cows come to graze. The dunes and floodplain edges where groundwater recharge has taken place produce vegetables, mainly onions and beets. The biodiversity has also bounced back with several hundred thousand migratory and breeding waterbirds present during the flooding season. The area has now been designated as a biosphere reserve.

In contrast, after 25 years of repeat funding of the irrigation schemes in the Senegal Valley, even the development bankers admit that, out of the hundreds of thousands of hectares of irrigation envisaged, the few tens of thousands of hectares that have actually worked (for a while) are highly unlikely to ever be economically viable (Dickmann et al. 2009).

Energy

The fishing operations in the system have a low level of mechanisation and consumption of fossil fuels, except for the largely motorised canoe-based west African fisheries, but much of the fish processing is still wood energy intensive and impacts on vegetation can be substantial (Abbot and Homewood 1999; Feka and Manzano 2008) in spite of improvements through the use of wood-saving kilns ('chorkor'). These are still not used everywhere and are also not easy to install in areas that flood. Appropriate technology breakthroughs could lead to major productivity gains by reducing the high post-harvest losses and save energy at the same time (e.g. mobile processing kits and solar drying).

Human capital/knowledge sharing/gender

The mobility linked to the strongly seasonal characteristics in large parts of the system impacts negatively on school attendance. Even in more sedentary settings, the emphasis of national and donor-driven programmes seems to have been on larger coverage of the school-going population rather than quality. As a result teachers often come from areas outside of the system and rarely address understanding of the local environment.

Vessel-based fisheries are almost exclusively male, but women (and children) do fish, in particular on foot using mosquito nets and traditional baskets or gathering by hand on reef flats, targeting species (fish, crustaceans, molluscs) or life stages that will not affect the commercial fishery. The small amounts taken are important in the food spectrum especially for the most vulnerable women-led households. The health benefits of eating even tiny amounts of fish for developing children cannot be over-emphasised. Still, the use of mosquito netting (Figure 11.11) typically triggers repressive regulation associated with government-imposed mesh-size restrictions (Abbott and Campbell 2009) not based on an analysis of its impacts. A few hundred women, who twice a month (during spring tides) pull a 3 m wide mosquito net over 50 m in a 50,000 ha mangrove system to catch a few kilograms each of Sergestid shrimp to sun dry and use as a food seasoning, are unlikely to endanger the resource. The regulatory bodies tend to ignore traditional and local knowledge and often operate on assumptions rather than observation. Co-construction of knowledge based on participatory monitoring and research could be highly beneficial (Duvail et al. 2014). In many areas women play a key role in fish processing.

Figure 11.11 Fishing a seasonal pond in proximity to the floodplain farm in Rufiji, Tanzania using traditional baskets for catfish and a mosquito net for small freshwater shrimp. In theory this is illegal, but as the pond will dry out within a month the fish will die anyway.

Source: Jean-Luc Paul.

In east Africa especially there is scope for the empowerment and capacity building of women. Culturally, the odds are stacked against women, for example household workloads, getting hold of cash, land inheritance or even simply holding on to the hut and the basic household tools in case their husband dies (these can be taken back by his family). Gender issues also feature prominently in the alternative livelihoods that are proposed by the conservation-minded non-governmental organisations (NGOs) such as seaweed farming. Promoted as a success story (the cosmetics industry buys these products very cheaply), the activity entails unacceptable workloads, very low pay and a high disease burden in the women (Fröcklin et al. 2012). A large proportion of the women in the fish-based farming system are stuck in a poverty trap, and it will require some seriously innovative thinking to help them to get out through sustainable livelihood development and breaking down the social, economic, cultural and political barriers that are keeping them trapped.

Science and technology

The availability, effectiveness and simplicity of nylon nets have been a major driver in the expansion of fisheries in Africa, not only for full-time fishers but also in former exclusively farming households. Increasingly, cheap but illegal monofilament nets are entering the market, replacing traditional gear made from natural biodegradable fibre. Monofilament gear 'continue to fish' even when they are lost or discarded – so-called ghost fishing (Matsuoka et al. 2005).

African coastal income-generating activities catering for global markets can, in general, not compete with the Southeast Asian operators. New techniques with good potential such as fish-aggregating devices, which can bring pelagic species such as tuna within reach of artisanal fishers operating from small vessels, have been insufficiently tested, supported over too short periods or introduced in inappropriate locations. The use of artificial reefs and enrichment techniques using juveniles of target species are still in their infancy. Development projects tend to concentrate on changing a single aspect of the activity and focus on productivity gains by introducing 'better' things, i.e. bigger boats, stronger engines, larger nets or adding 'more of everything', often in the places where the fishery is already saturated. Sustainable development of commercial fisheries in this system requires appropriate, integrated management of the ecology, market and trade issues to facilitate adoption and success.

Other enhancement technologies such as fingerponds (Kipkemboi et al. 2007) have not been tested appropriately, neither have the associated market and trade issues been looked into (see 'Markets and trade').

The programme to eradicate the tsetse fly across sub-Saharan Africa (Van den Bossche and Delespaux 2011) opens up parts of the system to livestock with major implications for the household livelihood spectrum. Tsetse-ridden African savannahs were naturally protected and often turned into national parks or reserves (Beale et al. 2013). The eradication of river blindness similarly led to biodiversity loss (Thiollay 2006). Massive changes in land use, such as proposed by the World Bank (2009), to turn savannahs into cereal-growing areas will not only affect biodiversity but also water availability in the adjacent fish-based farming subsystems.

Science and technology that builds on what already exists locally, looking for incremental improvements rather than wholesale change, should be promoted.

Markets and trade

Land has become a major market commodity (Margulis et al. 2013). In its euphemistically titled report (Hall 2011) *Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits?* the World Bank points out that of the 45 million ha under negotiation in 2009 by, essentially, foreign investors, 70 per cent were in Africa (Deininger and Byerlee 2011). Much of this land grab intended for biofuel rather than for food production, is in fact also, or even mainly, a water grab (Mehta et al. 2012; Woodhouse 2012). It will have major impacts on the fish-based farming subsystems, even when the land use conversions are on system-adjacent lands (Duvail et al. 2012). Sovereign wealth and hedge funds are speculating on commodities and can create food scarcities against which the vulnerable, who face challenging survival decisions almost every day of their lives, have no defence.

Large water bodies in the tropics and subtropics, especially coral reef coasts but also lakes, are attractive to the affluent in temperate areas. In Kenya, tourism accounts for about US$100 million annually, more than the export of coffee. In Zanzibar tourism represents about 20 per cent of GDP, about half the income from cloves *Syzygium aromaticum*. Tourism can, in principle, be an effective development lever as it can create non-extractive livelihoods. But it can also lead to exclusion of already marginalised fishers from badly designed marine protected areas (Wamukota et al. 2012). Locals rarely benefit from tourism development because conversion from fishing/farming requires a too large capacity jump. Tourism is sensitive to even 'small' and localised incidents such as a single bomb in a bar, a disease outbreak (a few cases of cholera) and electoral violence, which can have multi-year impacts. The low-level jobs that the locals have access to are usually the first to suffer when a freak incident occurs. This is especially true for tourism based on coral reefs in Africa as there is ample competition from Caribbean, Southeast Asian and Pacific coastal and island states.

The spread of mobile phones and cheap sturdy motorbikes is improving marketing in many areas. A major constraint remains with fish processing and conservation techniques.

Policies and institutions

The dominant narrative about fisheries in the fish-based farming system is that they are overexploited and that the massive use of illegal and destructive gear is responsible for this. Marine fisheries on continental shelves are indeed almost all overfished but mainly by industrial operations (Pauly et al. 2002). The same does not necessarily hold for the small-scale fisheries that concern us here. Lack of understanding of the diverse and flexible resource use strategies of the fisher-farmer as well as of the functioning of the complex ecosystems they rely upon has hampered the development of useful and effective management advice.

Understanding of the system's functional requirements and its wide-ranging benefits is scant in both government and development agencies, and thus some pessimism about its future is justified. Emphasis has been on taking more out of the system through industrialisation and upscaling, including for export, but many of these schemes have failed. Another trend is towards externally financed larger-scale operations at greater distances from the farm. Less attention has been directed to maintaining and enhancing system productivity through ecosystem management interventions and facilitating the small-scale fisher-farmer's operations through co-management. The absence of an enabling environment and heavy local taxation result in farmer emphasis on self-sufficiency rather than marketing.

In certain areas, fishing operations are still regulated by traditional local institutions, but the trends are towards largely ineffective state-based regulation (often not flexible enough to adapt to local conditions), or free-for-all situations leading to overexploitation. Traditional governance systems have either been ignored or dismantled by colonial and post-colonial governments seeking to replace them with 'modern' institutions. Small-scale fisheries operations, in spite of its unselective nature and its violation of policy and legislation on minimal size, seem to be appropriate to maintaining the structure and functioning of exploited ecosystems (Kolding and van Zwieten 2014).

Comprehensive government control is technically impossible at reasonable cost and also hard to implement because it is not adapted to context. Thus nationwide mesh-size regulations may make sense for the comparatively simple three-species Lake Victoria fisheries, but they are meaningless and even counterproductive for other ecosystems where fishers adapt their gear to seasonal and inter-annual variability (e.g. flood extent), to the behaviour of individual species, and to opportunities and labour demands of other livelihood activities such as farming (Hamerlynck et al. 2011). Many fisheries are thought to be open access or common property resources whose traditional access regulations have been eroded and that therefore could easily lend themselves to 'tragedy of the commons' (Hardin 1968) situations. Some parts of some subsystems are definitely overfished, but there are also many examples of traditional and modern mechanisms for collective action (Ostrom 1990) that regulate effectively. Some of the most spectacular of these are the collective fisheries in seasonal wetlands in west Africa (De la Croix et al. 2014), where rituals are required before the 'Master of the Waters' officially opens the season and thousands of people can enter the water simultaneously (Figure 11.12). These collective fisheries also involve complex catch redistribution mechanisms (Jacob 2003).

Figure 11.12 Collective fisheries in the floodplain of the Niger River in Guinea.
Source: Kevin de la Croix.

The sectoral thinking and planning by development institutions forces an artificial distinction between the fisheries and the farming parts of the system, although both are strongly interlinked. A similar concern occurs where integration is required across other sectors such as water, natural resources, wildlife, tourism and health. With the trend towards decentralisation, integration should in principle become easier, facilitated through local level, inter-sectoral dialogue and participatory planning with the resource users. When conducted by people who are in touch with the household realities, some of the large-scale quagmires we have been led into by the centralised government outlay and the export-oriented donor support may be avoidable. Still, at the local government level, there remain issues with capacity and the means to mainstream bottom-up processes.

Fisheries management models were essentially developed for single species fisheries in the North Atlantic and are inappropriate for the overwhelming complexity and diversity, both biologically and socioeconomically, of the multi-species, multi-gear, multi-user fisheries of Africa's coastal and inland waters. Instead of trying to force these imported models onto the system, it would seem more appropriate to study the system's rapid adoption of 'things that work', and to gradually improve and mainstream on the basis of their socioeconomic and ecological impacts. The relative success of the west African canoe fisheries (Chauveau and Jul-Larsen 2000) and the Lake Victoria fisheries (Kolding et al. 2008) are cases in point. These have not followed externally planned trajectories but have built themselves up on the basis of a wide array of local assets, whether technical, social or organisational.

Table 11.3 Summary of drivers, trends and implications for the fish-based farming system

Driver of farming system evolution	*Trends and implications*
Demography	High population growth rates to continue for several decades with further reduction in farm size and catch per fisher with expansion of destructive migratory fisheries and increasing demand from urban centres
Natural resources and climate	Increased variability, extreme events and uncertainty leading to declining system extent and productivity
Energy	Construction of large numbers of hydropower dams affecting system extent and productivity. Increased use of wood fuel leading to deforestation and land degradation
Human capital/knowledge sharing/gender	Education levels remain low and further marginalisation of poorest fisher-farmers and women, e.g. through mesh-size regulations based on beliefs, not on sustainability criteria can be expected. There is a lack of exchange between traditional and technical knowledge
Technology and science	Expansion of unsustainable agriculture into marginal areas and floodplains with exclusion of traditional users and decline in ecosystem service delivery
Markets and trade	Globalisation, land and water grabbing, increased power of speculative capital, rising inequity leading to increased vulnerability and political volatility
Policies and institutions	Lack of understanding of the ecological bases and sociocultural contexts of the production systems leading to ineffective interventions

Macroeconomic advances do not necessarily 'trickle down' or lead to greater equity. Vulnerable groups (e.g. women-led households) need specific attention, often through collective action within common property regimes. In the past, cooperatives (neither required nor understood) were created top-down and failed. Unfortunately, interesting initiatives that were initially successful, such as the reduction of dynamite fishing in the Tanga area in Tanzania, proved to be very donor-dependent and collapsed when external support and follow-up were withdrawn (Samoilys and Kanyange 2008). More recent and better thought-out attempts to reverse the negative trends, for example in the management of coral reefs, have involved organising coastal communities to become self-regulating.

System and subsystem performance

Sustainably harvesting the fish-based farming system to benefit human well-being, while maintaining the system's structural and functional integrity (Weeratunge et al. 2013) should in principle be possible as the system is highly productive and resilient. Unfortunately, sharing the benefits equitably so that everybody, including women and other vulnerable groups, can move together towards a better future is hampered by many political, economic, social and environmental constraints, locally, regionally and globally (Béné and Friend 2011).

In the fish-based farming system, there has been technical progress but not improved quality of life for the greater number. Fisher-farmers are not paid enough for what they produce partly because they have little or no negotiating power with those who transport and market their perishable produce. They are overburdened by nuisance taxes and face many administrative hurdles. Elders in the villages doubt whether they have seen improvement since the 1960s, with the exception perhaps of a lowered disease burden (treated mosquito nets), sturdy bicycles (capable of transporting over 100 kg over several tens of kilometres along bush paths) and, increasingly, motor cycles, cheap second hand clothing and the ubiquitous flip-flop sandals (which are conveniently recycled as floaters for gill nets). Still, mobile phones are now used to seek traders to buy the catch even while still in the canoe and also to enquire about market prices and weather patterns for sowing.

The sustainability and equity issues faced in the fish-based farming system do not only come from the 'big bad world far away'. The burgeoning African cities also draw away ecosystem services that the fisher-farmers directly depend on; the politically vocal, urban classes are more effective in pressurising decision makers for more water (Komakech et al. 2012), more electricity, more cheap food, more cheap charcoal, more cheap furniture and more protected areas for leisure. The rural populations rarely receive adequate compensation for what is taken away from them, for example the downstream impacts of hydropower dams on floodplain, deltaic and coastal fisheries.

Assessing system performance requires indicators that focus on human well-being and ecosystem service delivery (Pinto et al. 2014; Ringold et al. 2013) across the spectrum of activities in the fish-based farming system. These will of necessity be context specific or 'place based' as there are many sociocultural differences, historical pathways and adaptations to the specific ecosystem where activities emerged. Jointly developing and monitoring these indicators with the stakeholders will help the technical staff from government or management authorities to understand the real issues affecting system performance.

The sandy coast fisheries have performed comparatively well for decades, but over-exploitation has become an issue and nursery areas are affected by land use change and infrastructure development. Human well-being indicators such as income, health and education remain low, often lower than the country's averages, while the demography is very dynamic. Behind the strip of flamboyant beach hotels along the shores of the Indian Ocean there is a more prosaic reality. In the fisher-farmer villages, in spite of adequate rainfall and a favourable LGP, agriculture is confronted with shallow soils on fossil coral rag or leached sandy soils. Various tree crops can be grown, including coconuts, but many plantations are senescent. Mango, banana, cashew, jackfruit and citrus trees can be profitable, but trade is affected by overproduction peaks and inadequate capacity to transport produce and transform it. Rice is grown in seasonally flooded depressions, and other cereals such as maize, sorghum and millet are grown on higher ground. Around the homestead or in fields cleared in secondary forest, crops such as cassava, legumes, vegetables, fruits such as pineapple, and spices are grown. In proximity to tourist resorts these find ready markets. However, beach tourism and rapid urbanisation push land prices beyond what locals can afford, and access to fish landing points can become difficult as beachfront properties expand. Similarly, access to fresh water is increasingly an issue as demand increases and shallow aquifers are overexploited and become saline (Bakari et al. 2012). This trend is likely to be compounded by sea level rise. Cement quarries that strip-mine the fossil coral are another competitive land use. For the fisher-farmers, the remittances from family members engaged in various types of off-farm activity, including from migrants to affluent countries and urban centres, are a substantial source of income, allowing access to credit and equipment (e.g. rural electrification, drinking water supply).

Coral reef fisheries represent an estimated 10 per cent of the world's fish catches (Smith 1978) from about 0.1 per cent of sea bottom area (Spalding et al. 2001), and they are therefore productive but also highly exploited and vulnerable. De Groot et al. (2012) estimated the value of coral reefs is up to US$350,000 per hectare per year, mainly linked to their tourism potential. Their other ecosystem services, including protection against erosion and nursery functions, are mostly non-tradable public benefits, but replacement value is often only understood after the reefs have been destroyed.

Coral-reef fish-based farming subsystems are typically caught in a socioecological trap, even in places where reefs are still productive (Steneck 2009). In areas with *low* socioeconomic development and intact traditional governance, fishers simply do not earn enough to acquire the tools for overexploitation. The reefs could sustain a higher fishing effort, but there are no marketing opportunities. Life is comparatively good but operates at subsistence level. Monetary poverty makes improved education unattainable. In areas of *intermediate* development, where traditional institutions have collapsed and 'modern' ones are ineffective, overfishing and destructive techniques are rife. Here the human well-being indicators are in the red, and it is hard to see how to move them towards the green as the resource base itself is compromised. At the other end of the spectrum, in areas with *high* socioeconomic development, reefs are again in better condition as institutions are stronger and there are incentives for regulation, e.g. by the effective management of Marine Protected Areas (MPAs) that bring in tourist revenue. More non-fishing livelihoods are available and there is access to motorised vessels allowing fishing further off-shore (Cinner et al. 2009), thus reducing the pressure on the reefs. The impact of MPAs is highly variable across different governance and management regimes, but a minimum area of 5 km^2 and high compliance with the restrictions are the key success factors (McClanahan et al. 2009).

There is a strong correlation between excessive fishing pressure and reef degradation, with the most fundamental and deleterious shift being a change from a dominance of hard coral to algae or sea urchins. Little is known about how these phase shifts occur, but there is now some pragmatic understanding of reef function and its fisheries-related tipping points (McClanahan et al. 2011). To avoid overgrowth by algae it is essential to keep fishable biomass above 500 kg/ha, ideally above 1000 kg and certainly above 300 kg. Below that threshold fish-dependent livelihoods are compromised.

With a total production of 1 million tonnes per year, the Lake Victoria fisheries are now the largest freshwater lake fisheries in the world, operating in the world's second biggest, but comparatively shallow, freshwater lake (68,000 km^2 but maximum depth less than 100 m). In Africa's lakes, the number of fishers stabilises at production levels of about 3 tonnes per fisher per year (Kolding and van Zwieten 2011). When catches consistently fall below that level, most fishers will shift to other activities either seasonally or permanently. Post-harvest losses of fish, partially through insect infestation, are substantial (Akande and Diei-Ouadi 2010), but pesticide use to combat this may pose health risks for those who apply it and those who consume the fish.

Strategic priorities for the system

Table 11.4 summarises the strategic priorities for the fish-based farming system. As interventions in the farming part of the system are treated in other chapters, the emphasis here is on the fisheries-oriented aspects, in particular maintaining structural and functional integrity, especially by maintaining flood pulse characteristics, including through managed flood releases from dams. Some key issues are discussed below.

There is a need to identify the science, technology, knowledge and human capacity needs for the system. Science is a method to acquire reliable knowledge, ideally used to solve problems identified by the people who are confronted with them. These people should conduct or at least actively participate in the research, in collaboration with people

Table 11.4 Strategic priorities for the fish-based farming system

Drivers	*Intervention*	*Implementers*
Natural resources and climate	Maintain and enhance adequate flood pulses and ecosystem integrity especially for nursery areas. Plan for worst case scenarios	Government, private sector, NGOs, development partners
Energy	Design and manage hydro-electric dams for environmental flows to maintain downstream socioecosystems	Dam designers and managers
Science and technology	Co-construct context-specific knowledge; pilot and mainstream incremental technological improvements especially in fish processing	Scientific and engineering community, NGOs, local government with holistic rural extension workers
Markets and trade	Lift nuisance taxes and address marketing constraints such as transport and processing. Ensure land and water security to resource user communities	Government
Policies and institutions	Changeover from GDP-oriented thinking to context-specific, ecosystem-based co-management arrangements targeting human well-being	Government, NGOs, development partners

familiar with the scientific method, in order to explore and test potential solutions. This co-constructed knowledge, drawing on both local experience and the scientific method, can then be made available in the appropriate format such as feedback sessions with role play (Duvail et al. 2014) to those who need that knowledge to make the changes required, e.g. the local leadership.

The need for some serious advances in fish processing technology under tropical conditions has already been emphasised. The reduction of post-harvest losses probably represents one of the biggest potential gains in productivity in small-scale fisheries. Post-harvest losses are immense, and current processing techniques either consume lots of wood or have health issues (insecticide sprays). Simple solar ovens do seem to work, especially in the drier areas, and reduce wood consumption in places where it is in short supply. Research into appropriate technology for each of the subsystems, in close collaboration with the operators, should be given a high priority. In choosing technologies, consumer preferences need to be taken into account and prices need to be kept low to keep protein affordable for the vulnerable. Still, in theory, the engineering required should be less complex than sending a life-seeking probe to Mars or creating a Higgs boson. Possibly a question of priorities, therefore.

Aquaculture offers opportunities to diversity and intensify. Africa only contributes about 2 per cent of global aquaculture production, but the practice is rapidly expanding (FAO 2012). Care should be taken to avoid the introduction of inappropriate species and to promote production of fish that are low rather than high in the food chain (e.g. tilapia); control the conversion of edible fish into fishmeal; and, in particular, make sure that aquaculture does not subtract from the natural systems by encroaching on the productive margins of existing water bodies. Small-scale testing, incremental technological improvements and household level roll-out may be the more sustainable approach and beneficial to many rather than the few (Allison 2011). Rather than search for sophistication, culture of the ubiquitous oil-rich and nutritious catfish *Clarias gariepinus*, which can feed on just about everything, survives in almost any habitat and is the perfect fish to be smoked, offers opportunities in simple village ponds seeded from the wild.

Planning and management also need to address natural resource issues in the fish-based system. Eutrophication, as observed in Lake Victoria, is a comparatively new threat likely to become important elsewhere. Irrigation systems should be designed to add to and not subtract from the natural system, to maintain input-effective recession agriculture and other flood-based biodiversity, ecosystems and livelihoods. Climate change uncertainties should engender planning for wide error margins for infrastructure in or around floodplains.

Co-management, based as much as possible on traditional governance systems, has a better chance of being effective in banning proven destructive techniques and safeguarding nursery areas and reproductive seasons. It is vital that the technical support and regulatory roles of government be strictly separated to maintain mutual trust. Repressive interventions should be based on joint analysis of the need and agreement on the approach. Mesh-size regulations in particular should be much more flexible and adapted to local conditions. Enforcing national mesh-size regulations across different ecosystems is counterproductive, and ideally these should be locally adapted and accepted through community bylaws with the government stepping in only at the request of the local co-management institution.

Much can be learned from projects initiated by NGOs, but interventions should preferably be embedded in local government and operate over medium-scale timeframes and not act as temporary substitutes for the state. Support through holistic (non-sectoral) and non-dogmatic rural extension workers with a thorough understanding of the local context and favouring incremental improvements in technology should be prioritised. Ideally this will be guided by a set of principles for identifying and deliberating options for governance reform through inclusive multi-stakeholder dialogue, evidence-based analysis, support for livelihood security and human rights, and addressing cross-sectoral and cross-scale interactions (Ratner and Allison 2012).

Africa requires more energy and more food, and the preferred options are now hydropower and (large-scale) irrigation. Both of these, if implemented without taking account of what is required to keep the fish-based farming system and its multiple social and ecological benefits intact, constitute a major challenge that needs to be addressed.

Hydropower is not a problem per se, but the way it will impact on the fish-based farming system depends on the choices that are made. Most of the optimal dam sites in Africa have already been equipped but unfortunately often without the design or operations to allow or implement adequate managed flood releases (Acreman et al. 2000) to maintain downstream ecosystems, in particular floodplains. Notable exceptions are the Senegal Valley, the Kafue flats on the Zambezi and the Waza-Logone in northern Cameroon. On a much smaller scale such releases have been used to rehabilitate a dam-impacted delta (Duvail and Hamerlynck 2003). New dams should have systems in place that ensure that they can and will produce managed flood releases.

After the World Commission on Dams (2000) report there was a slow-down in the funding for large dams, and the recommendations for environmental and social impact prevention and mitigation were quite stringent. This constraint has now largely been lifted with the advent of new donors and the private sector setting its own standards. The series of Gibe dams on the Omo River in Ethiopia threaten not only the fisheries, livestock keeping and deltaic farming around Lake Turkana but also the existence of the lake itself (Avery 2013). The Niger floodplains, vital for millions of people, are also threatened (Zwarts et al. 2005), and many other dams are being planned or are under construction on Africa's major river systems. Impacts will be tremendous unless environmental flows for multiple objectives are implemented (Acreman et al. 2014).

Where fresh water is available, including through improved harvesting techniques, intensification can be achieved through small-scale irrigation using small pumps. There has been uncontrolled development of furrow irrigation in many floodplains, affecting downstream users and blocking livestock and wildlife migration with increased risk for both farmer-pastoralist and farmer-wildlife conflict. Diversification, especially to high added-value crops (e.g. spices, trees), remains a reasonable option to improve livelihoods (Table 11.5).

Table 11.5 Relative importance of household livelihood improvement strategies

Poverty escape strategy	*Extremely poor (2000)*	*Extremely poor (2015)*	*Less poor (2015)*	*Total population (2015)*
% of total ag pop	–	48	52	100
Intensification	1	2	3	2.5
Diversification	3	3	3	3
Increased farm size	0	0	1	0.5
Off-farm employment	4	3	3	3
Exit from agriculture	2	2	0	1

Sources: See Chapter 1, 'Farm household decisions and strategies' and Chapter 2, 'Household strategies'.

Logically irrigation should supplement the fish-based farming system, not subtract from it. These schemes should, therefore, preferably be sited outside of the naturally flooding areas. Areas that are currently embanked but do not have performing irrigation schemes could be restored by changing dam management regimes or reopening embankments to allow natural flooding and recession agriculture. Because of multiple ecosystem services that natural or restored floodplains provide (Maltby and Acreman 2011), the net economic value of traditional multi-use floodplain management systems usually exceeds what irrigation schemes can provide. The economic calculations that supposedly show profitability of irrigation are often derived from high intensity situations with conditions that are unlikely to ever exist in real-life situations.

System conclusions

Small-scale fisheries are a key component of livelihood activities for a substantial proportion of the rural populations of Africa and are practised part time with a variety of gear by large numbers of men, women and children. These people also engage in farming, livestock keeping, forestry, hunting and gathering. The fisheries provide much-needed cash and protein to the 'farming' households and also support a significant number of land-based jobs in processing, transporting and marketing the produce, often over long distances. The comparatively cheap and, in comparison to bush-meat, sustainable protein that these fisheries produce is essential to the well-being of the majority of the vulnerable people of Africa and near impossible to replace by any other source.

There is nascent awareness in governments and development partners that investment in environmental infrastructure is required to maintain and enhance ecosystem service delivery and improve both biological and societal resilience. A holistic approach can become a much needed counterweight to two main threats to the system: hydropower storage dams that do not consider downstream socioecological systems and large-scale conversion of floodplains for irrigation. Such approaches are being tested at the appropriate transnational scale, for example by the West African Fisheries Commission that works in close collaboration with the Regional Partnership for Marine and Coastal Conservation in West Africa (PRCM) (Box 11.4). This programme, funded by a consortium of donor agencies and implemented by an array of international and local NGOs and CBOs in collaboration with other partners, includes a range of interventions at the conservation/sustainable use interface from which useful lessons can be extracted and mainstreamed.

A shift away from sectoral to ecosystem thinking is essential, to analyse the basis on which these production systems depend, especially adequate flood pulses, and to implement measures that can bring the systems back to sustainable production and ecosystem service levels with due consideration of the human well-being aspects. Empowerment of communities for increased control over their resources, including the establishment of co-management arrangements, will be required in many settings. Many of these interventions, including the development of household-based aquaculture, could benefit from the return of the rural extension worker. However, these need to be trained from a multiple livelihood perspective, with a strong ecosystem thinking capacity and skills in good governance and local institution building.

Box 11.4 A laudable attempt at regional integration and bottom-up planning in West Africa

Under the auspices of the intergovernmental Sub-regional Fisheries Commission, an innovative partnership has been developed in a series of west African coastal countries (Cape Verde, the Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone), covering both sandy coast and deltaic fisheries. This Regional Partnership for Marine and Coastal Conservation in west Africa (www.prcmarine.org/en) comprises environmental NGOs, foundations and bilateral aid agencies working together using a holistic and multi-level approach to improve environmental governance, conservation and sustainable management of the shared regional fish stocks, fauna and flora. Interventions range from support for the establishment of Indigenous and Community Conserved Territories and Areas (www.iccaconsortium.org) by fisher-farmer communities, to traditional mechanisms for the control of effort (species taboos, closed areas and seasons). Their key objective is improving human well-being through conservation (not primarily targeting conservation outcomes), through the facilitation of a network of managers of marine protected areas, public forums, support for research proposals vetted by a scientific and technical council, policy-influencing, capacity building, stakeholder forums and advocacy including to lobby Members of Parliament in the different countries. This could be a model for other subsystems and transnational areas (e.g. Lake Victoria fisheries, the western Indian Ocean reef, deltaic and mangrove systems).

Notes

1 Defined as the freedom of choice and action to achieve basic material needs, health, security and good social relations (Scholes et al. 2005).

2 Artisanal fisheries (a term used interchangeably with small-scale or traditional fisheries, even though the scale can actually be quite large and that they have often evolved quite far from what would be strictly traditional, e.g. the use of nylon instead of natural fibre) refers to various low-technology, low-capital, fishing practices undertaken by individual households (though sometimes organised into cooperatives or associations).

3 In many societies cars are a status symbol, and the Mercedes Benz is a particularly powerful one across Africa, leading to terms like the Mama Benz for the comparatively rich, fish-trading women of the Gulf of Guinea and Wabenzi (literally 'the people of the benz') in the Swahili-influenced cultures in east and central Africa.

4 Schematically, living beings can be split into long-lived slow reproducing species that are adapted to stable and predictable environments, and short-lived fast reproducing species (i.e. opportunists) typical of dynamic and highly variable environments. Such species will produce very high numbers of young, most of whom will perish even in the absence of harvesting. Extracting a large proportion of such a population before it reproduces, e.g. by fishing out juveniles, will therefore not necessarily affect the capacity of the next generation to maintain the species.

References

Abbot, J.I.O. and Homewood, K. (1999) 'A history of change: causes of miombo woodland decline in a protected area in Malawi', *Journal of Applied Ecology*, vol. 36, pp. 422–433.

Abbott, J.G. and Campbell, L.M. (2009) 'Environmental histories and emerging fisheries management of the Upper Zambezi River Floodplain', *Conservation and Society*, vol. 7, pp. 83–99.

Acreman, M.C., Farquharson, F.A.K., McCartney, M.P., Sullivan, C., Campbell, K., Hodgson, N., Morton, J., Smith, D., Birley, M., Lazenby, J., Wingfield, R. and Barbier, E.B. (2000) *Managed Flood Releases from Reservoirs: Issues and Guidance*. Report to DFID and the World Commission on Dams, Centre for Ecology and Hydrology, Wallingford.

Acreman, M.C., Overton, I.C., King, J., Wood, P.J., Cowx, I.G., Dunbar, M.J., Kendy, E. and Young, W.J. (2014) 'The changing role of ecohydrological science in guiding environmental flows', *Hydrological Sciences Journal*, vol. 59, no. 3, pp. 433–450.

Adamczewski, A., Hertzog, T., Dosso, M., Jouve, P. and Jamin, J.-Y. (2011) 'L'irrigation peut-elle se substituer aux cultures de décrue ? La dépression du lac Horo (Nord Mali)', *Cahiers Agricultures*, vol. 20, no. 1, pp. 97–104.

Akande, G. and Diei-Ouadi, Y. (2010) *Post-Harvest Losses in Small-Scale Fisheries: Case Studies in Five Sub-Saharan African Countries*. FAO Fisheries and Aquaculture Technical Paper, No. 550, FAO.

Akyeampong, E. (2007) 'Indigenous knowledge and maritime fishing in West Africa: the case of Ghana', *Tribes and Tribals*, vol. 1, pp. 173–182.

Allison, E.H. (2011) *Aquaculture, Fisheries, Poverty and Food Security*. Working Paper 2011–65, The WorldFish Center, Penang.

Andrefouet, S., Guillaume, M.M., Delval, A., Rasoamanendrika, F.M.A., Blanchot, J. and Bruggemann, J.H. (2013) 'Fifty years of changes in reef flat habitats of the Grand Récif of Toliara (SW Madagascar) and the impact of gleaning', *Coral Reefs*, vol. 32, no. 3, pp. 757–768.

Atta-Mills, J., Alder, J. and Sumaila, U.R. (2004) 'The decline of a regional fishing nation: the case of Ghana and West Africa', *Natural Resources Forum*, vol. 28, pp. 13–21.

Avery, S. (2013) *What Future for Lake Turkana? The Impact of Hydropower and Irrigation on the World's Largest Desert Lake*. University of Oxford African Studies Centre.

Bakari, S.S., Aagaard, P., Vogt, R.D., Ruden, F., Johansen, I. and Vuai, S.A. (2012) 'Delineation of groundwater provenance in a coastal aquifer using statistical and isotopic methods, Southeast Tanzania', *Environmental Earth Sciences*, vol. 66, no. 3, pp. 889–902.

Barbier, B., Ouedraogo, H., Dembélé, Y., Yacouba, H., Barry, B. and Jamin, J.Y. (2011) 'L'agriculture irriguée dans le Sahel ouest-africain', *Cahiers Agricultures*, vol. 20, no. 1, pp. 24–33.

Beale, C.M., Rensberg, S.V., Bond, W.J., Coughenour, M., Fynn, R., Gaylard, A., Grant, R., Harris B., Jones, T., Mduma, S., Owen-Smith, N. and Sinclair, A.R. (2013) 'Ten lessons for the conservation of African savannah ecosystems', *Biological Conservation*, vol. 167, pp. 224–232.

Béné, C. and Friend, R.M. (2011) 'Poverty in small-scale fisheries old issue, new analysis', *Progress in Development Studies*, vol. 11, no. 2, pp. 119–144.

Béné, C., Hersoug, B. and Allison, E.H. (2010a) 'Not by rent alone: analysing the pro-poor functions of small-scale fisheries in developing countries', *Development Policy Review*, vol. 28, no. 3, pp. 325–358.

Béné, C., Lawton, R. and Allison, E.H. (2010b) 'Trade matters in the fight against poverty: narratives, perceptions, and (lack of) evidence in the case of fish trade in Africa', *World Development*, vol. 38, no. 7, pp. 933–954.

Béné, C., Neiland, A., Jolley, T., Ovie, S., Sule, O., Ladu, B., Mindjimba, K., Belal, E., Tiotsop, F., Baba, M. Dara, L., Zakara, A. and Quensiere, J. (2003) 'Inland fisheries, poverty, and rural livelihoods in the Lake Chad Basin', *Journal of Asian and African Studies*, vol. 38, no. 1, pp. 17–51.

Béné, C., Steel, E., Luadia, B. K. and Gordon, A. (2009) 'Fish as the "bank in the water": evidence from chronic-poor communities in Congo', *Food Policy*, vol. 34, no. 1, pp. 108–118.

Bennett, E. (2005) 'Gender, fisheries and development', *Marine Policy*, vol. 29, pp. 451–459.

Brashares, J.S., Arcese, P., Sam, M.K., Coppoillo, P.B., Sinclair, A.R.E. and Balmford, A. (2004) 'Bushmeat hunting, wildlife declines, and fish supply in West Africa', *Science*, vol. 306, no. 5699, pp. 1180–1183.

Chauveau, J.-P. and Jul-Larsen, E. (2000) 'Du paradigme halieutique à l'anthropologie des dynamiques institutionnelles', in Chauveau, J.-P., Jul-Larsen, E. and Chaboud, C. (eds) *Les pêches piroguières en Afrique de l'Ouest. Dynamiques institutionnelles: pouvoirs, mobilités, marches*. Karthala, pp. 9–85.

Cinner, J.E., McClanahan, T.R., Daw, T.M., Graham, N.A.J., Maina, J., Wilson, S.K. and Hughes, T.P. (2009) 'Linking social and ecological systems to sustain coral reef fisheries', *Current Biology*, vol. 19, pp. 206–212.

Cinner, J.E., McClanahan, T.R., Graham, N.A.J., Daw, T.M., Maina, J., Dtead, S.M., Wamukota, A., Brown, K. and Bodin, Ö. (2012) 'Vulnerability of coastal communities to key impacts of climate change on coral reefs fisheries', *Global Environmental Change*, vol. 22, pp. 12–20.

Comas, J., Connor, D., Isselmou, M.E.M., Mateos, L. and Gómez-Macpherson, H. (2012) 'Why has small-scale irrigation not responded to expectations with traditional subsistence farmers along the Senegal River in Mauritania?' *Agricultural Systems*, vol. 110, pp. 152–161.

Cormier-Salem, M.C. (ed.) (1999) *Rivières du Sud: Sociétés et mangroves ouest-africaines*. IRD Éditions.

Crona, B. and Rosendo, S. (2011) 'Outside the law? Analyzing policy gaps in addressing fishers' migration in East Africa', *Marine Policy*, vol. 35, pp. 379–388.

De Graaf, G.J., Grainger, R.J., Westlund, L., Willmann, R., Mills, D., Kelleher, K. and Koranteng, K. (2011) 'The status of routine fishery data collection in Southeast Asia, central America, the South Pacific, and West Africa, with special reference to small-scale fisheries', *ICES Journal of Marine Science*, vol. 68, no. 8, pp. 1743–1750.

De Groot, R., Brander, L., Van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., Ten Brink, P. and Van Beukering, P. (2012) 'Global estimates of the value of ecosystems and their services in monetary units', *Ecosystem Services*, vol. 1, no. 1, pp. 50–61.

Deininger, K.W. and Byerlee, D. (2011) *Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits?* World Bank.

De la Croix, K., Dao, A., Ferry, L. Landy, F. Muther, N. and Martin, D. (2014) 'Les systèmes de pêches collectives fluviales somono dans le Manden (Mali): Un révélateur territorial et social unique en sursis sur le Niger supérieur', in Ferry L. and Mietton M. (eds) *Chemins et territoires de l'eau dans les pays de la ceinture tropicale. Ressources et patrimoines, Dynamiques Environnementales*, vol. 32, pp. 125–143.

Dickmann, M., Ficatier, M. and Schmidt, M. (2009) *Le Barrage de Manantali. Evaluation ex-post conjointe*. Rapport de synthèse Coopération financière avec l'Organisation pour la Mise en Valeur du fleuve Sénégal (OMVS), Banque allemande de développement (KfW), Banque européenne d'investissement (BEI), Agence française de développement (AFD).

Duvail, S. and Hamerlynck, O. (2003) 'Hydraulic modelling as a tool for the joint management of a restored wetland: sharing the benefits of managed flood releases from the Diama dam reservoir', *Hydrology and Earth System Sciences*, vol. 7, no. 1, pp. 133–146.

Duvail, S. and Hamerlynck, O. (2007) 'The Rufiji River flood: plague or blessing?' *International Journal of Biometeorology*, vol. 52, pp. 33–42.

Duvail, S., Hamerlynck, O., Paron, P., Hervé, D., Nyingi, D.W. and Leone, M. (2017) 'The changing hydro-ecological dynamics of rivers and deltas of the Western Indian Ocean: Anthropogenic and environmental drivers, local adaptation and policy response'. *Comptes Rendus Geoscience*, vol. 349, no 6, pp. 269–279.

Duvail, S., Médard, C., Hamerlynck, O. and Nyingi, D.W. (2012) 'Land and water "grabbing" in an East African coastal wetland: the Tana Delta case study', *Water Alternatives*, vol. 5, no. 2, pp. 322–343.

Duvail, S., Mwakalinga, A., Eijkelenburg, A., Hamerlynck O., Kindinda, K. and Majule, A. (2014) 'Jointly thinking the post-dam future: exchange of local and scientific knowledge on the lakes of the Lower Rufiji, Tanzania', *Hydrological Sciences Journal*, vol. 59, no. 3–4, pp. 713–730.

Ellis, F. (1998) 'Household strategies and rural livelihood diversification', *The Journal of Development Studies*, vol. 35, no. 1, pp 1–38.

Eriksson, H. (2012) 'Managing sea cucumber fisheries and aquaculture: studies of social-ecological systems in the Western Indian Ocean'. Unpublished PhD thesis, Stockholm University.

FAO (2012) *The Status of World Fisheries and Aquaculture 2012*. Food and Agriculture Organisation of the United Nations.

FAOSTAT (undated) FAO database, FAO, Rome. www.fao.org/faostat/en/#data.

Feka, N.Z. and Manzano, M.G. (2008) 'The implications of wood exploitation for fish smoking on mangrove ecosystem conservation in the south west province, Cameroon', *Tropical Conservation Science*, vol. 1, no. 3, pp. 222–241.

Fröcklin, S., De la Torre-Castro, M., Lindström, L., Jiddawi, N.S. and Msuya, F.E. (2012) 'Seaweed mariculture as a development project in Zanzibar, East Africa: a price too high to pay?' *Aquaculture*, vol. 356, pp. 30–39.

Geheb, K. and Binns, T. (1997) '"Fishing farmers" or "farming fishermen"? The quest for household income and nutritional security on the Kenyan shores of Lake Victoria', *African Affairs*, vol. 96, no. 382, pp. 73–93.

Geheb, K. and Crean, K. (2003) 'Community-level access and control in the management of Lake Victoria's fisheries', *Journal of Environmental Management*, vol. 67, no. 2, pp. 99–106.

Hall, R. (2011) 'Land grabbing in Southern Africa: the many faces of the investor rush', *Review of African Political Economy*, vol. 38, no. 128, pp. 193–214.

Hamerlynck, O. and Duvail, S. (2003) *The Rehabilitation of the Delta of the Senegal River in Mauritania: Fielding the Ecosystem Approach*. IUCN Gland.

Hamerlynck, O., Duvail, S., Vandepitte, L., Kindinda, K., Nyingi, D.W., Paul, J.L., Yanda, P.Z., Mwakalinga, A.B., Mgaya, Y.D. and Snoeks, J. (2011) 'To connect or not to connect? Floods, fisheries and livelihoods in the Lower Rufiji floodplain lakes, Tanzania', *Hydrological Sciences Journal*, vol. 56, no. 8, pp. 1436–1451.

Hamerlynck, O., Moulaye Zeine, S.A., Mutua J.Y., Mukhwana, L.V. and Yena, M. (2016) 'Reflooding the Faguibine System in Northern Mali: potential benefits and challenges', *African Journal of Aquatic Science*, vol. 41, no. 1, pp. 109–117.

Hardin, G. (1968) 'The tragedy of the commons', *Science*, vol. 162, no. 3859, pp. 1243–1248.

Harrison, L.E. and Huntington, S.P. (2000) *Culture Matters: How Values Shape Human Progress*. Basic Books.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A. and Hatziolos, M.E. (2007) 'Coral reefs under ocean acidification under rapid climate change', *Science*, vol. 318, pp. 1737–1742.

Jacob, J.-P. (2003) *Fishing Rights on the Floodplains of Gwendégué, Winye Country, Central Western Burkina Faso*. IIED Issue Paper No. 121.

Kipkemboi, J., van Dam, A.A., Ikiara, M.M. and Denny, P. (2007) 'Integration of smallholder wetland aquaculture–agriculture systems (fingerponds) into riparian farming systems on the shores of Lake Victoria, Kenya: socio-economics and livelihoods', *The Geographical Journal*, vol. 173, pp. 257–272.

Kolding, J. and van Zwieten, P.A.M. (2011) 'The tragedy of our legacy: how do global management discourses affect small scale fisheries in the South', *Forum for Development Studies*, vol. 38, no. 3, pp. 267–297.

Kolding, J. and van Zwieten, P.A.M. (2012) 'Relative lake level fluctuations and their influence on productivity and resilience in tropical lakes and reservoirs', *Fisheries Research*, vol. 115, pp. 99–109.

Kolding, J. and van Zwieten, P.A.M. (2014) 'Sustainable fishing in inland waters', *Journal of Limnology*, vol. 73, pp. 128–144.

Kolding, J., van Zwieten, P., Mkumbo, O., Silsbe, G. and Hecky, R. (2008) 'Are the Lake Victoria fisheries threatened by exploitation or eutrophication? Towards an ecosystem-based approach to management', in G. Bianchi and H.R. Skjoldal (eds) *The Ecosystem Approach to Fisheries*. CABI, pp. 309–350.

Komakech, H.C., van Der Zaag, P. and van Koppen, B. (2012) 'The last will be first: water transfers from agriculture to cities in the Pangani river basin, Tanzania', *Water Alternatives*, vol. 5, no. 3, pp. 700–720.

Maltby, E. and Acreman, M.C. (2011) 'Ecosystem services of wetlands: pathfinder for a new paradigm', *Hydrological Sciences Journal*, vol. 56, no. 8, pp. 1341–1359.

Margulis, M.E., McKeon, N. and Borras, S.M. Jr. (2013) 'Land grabbing and global governance: critical perspectives', *Globalizations*, vol. 10, no. 1, pp. 1–23.

Marquette, C.M., Koranteng, K.A., Overå, R. and Aryeetey, E.B.D. (2002) 'Small-scale fisheries, population dynamics, and resource use in Africa: the case of Moree, Ghana', *AMBIO: A Journal of the Human Environment*, vol. 31, no. 4, pp. 324–336.

Matsuoka, T., Nakashima, T. and Nagasawa, N. (2005) 'A review of ghost fishing: scientific approaches to evaluation and solutions', *Fisheries Science*, vol. 71, pp. 691–702.

McClanahan, T.R., Graham, N.A., MacNeil, M.A., Muthiga, N.A., Cinner, J.E., Bruggemann, J.H. and Wilson, S.K. (2011) 'Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries', *Proceedings of the National Academy of Sciences*, vol. 108, no. 41, pp. 17230–17233.

McClanahan, T.R., Graham, N.A.J., Wilson, S., Letourner, Y. and Fisher, R. (2009) 'Effects of fisheries closure size, age, and history of compliance on coral reef fish communities in the western Indian Ocean', *Marine Ecology Progress Series*, vol. 396, pp. 99–109.

Mehta, L., Veldwisch, G.J. and Franco, J. (2012) 'Introduction to the special issue: Water grabbing? Focus on the (re)appropriation of finite water resources', *Water Alternatives*, vol, 5, no. 2, pp. 193–207.

Mmopelwa, G. and Ngwenya, B.N. (2010) 'Constraints and potentials of the fish market in the Okavango Delta, Botswana', *African Journal of Agricultural Research*, vol. 5, no. 23, pp. 3176–3184.

Mölsä, H., Reynolds, J.E., Coenen, E.J. and Lindqvist, O.V. (1999) 'Fisheries research towards resource management on Lake Tanganyika', *Hydrobiologia*, vol. 407, pp. 1–24.

Müller, C., Cramer, W., Hare, W.L. and Lotze-Campen, H. (2011) 'Climate change risks for African agriculture', *Proceedings of the National Academy of Sciences*, vol. 108, no. 11, pp. 4313–4315.

Munga, C., Ndegwa, S., Fulanda, B., Manyala, J., Kimani, E., Ohtomi, J. and Vanreusel, A. (2012) 'Bottom shrimp trawling impacts on species distribution and fishery dynamics: Ungwana Bay fishery Kenya before and after the 2006 trawl ban', *Fisheries Science*, vol. 78, no. 2, pp. 209–219.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A.B. and Kent, J. (2000) 'Biodiversity hotspots for conservation priorities', *Nature*, vol. 403, pp. 853–858.

Nelson, G.C., Bennett, E., Berhe, A.A., Cassman, K., DeFries, R.S., Dietz, T., Dobermann, A., Dobson, A., Janetos, A., Levy, M.A., Marco, D., Nakicenovic, N., O'Neill, B., Norgaard, R., Petschel-Held, G., Ojima, D., Pingali, P., Watson, R. and Zurek, M. (2006) *Anthropogenic Drivers of Ecosystem Change: an Overview*. Columbia University Academic Commons, http://dx.doi.org/10.7916/D8125RDD.

Njock, J.C. and Westlund, L. (2010) 'Migration, resource management and global change: experiences from fishing communities in West and Central Africa', *Marine Policy*, vol. 34, no. 4, pp. 752–760.

Nunan, F. (2010) 'Mobility and fisherfolk livelihoods on Lake Victoria: implications for vulnerability and risk', *Geoforum*, vol. 41, no. 5, pp. 776–785.

Odada, E.O., Olago, D.O., Kulindwa, K., Ntiba, M. and Wandiga, S. (2004) 'Mitigation of environmental problems in Lake Victoria, East Africa: causal chain and policy options analyses', *AMBIO: A Journal of the Human Environment*, vol. 33, no. 1, pp. 13–23.

Ostrom, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

Parnell, S. and Walawege, R. (2011) 'Sub-Saharan African urbanisation and global environmental change', *Global Environmental Change*, vol. 21, pp. S12–S20.

Paul, J.-L., Duvail, S. and Hamerlynck, O. (2011) 'Appropriation des ressources "naturelles" et criminalisation des communautés paysannes. Le cas du Rufiji, Tanzanie', *Civilisations*, vol. 60, no. 1, pp. 143–175.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R. and Zeller, D. (2002) 'Towards sustainability in world fisheries', *Nature*, vol. 418, pp. 689–695.

Pinto, R., De Jonge, V.N. and Marques, J.C. (2014) 'Linking biodiversity indicators, ecosystem functioning, provision of services and human well-being in estuarine systems: application of a conceptual framework', *Ecological Indicators*, vol. 36, pp. 644–655.

Ratner, B.D. and Allison, E.H. (2012) 'Wealth, rights, and resilience: an agenda for governance reform in small-scale fisheries', *Development Policy Review*, vol. 30, no. 4, pp. 371–398.

Richmond, M.D., Wilson, J.D.K., Mgaya, Y.D. and Le Vay, L. (2002) 'An analysis of smallholder opportunities in fisheries, coastal and related enterprises in the floodplain and delta areas of the Rufiji River, Tanzania', *Rufiji Environment Management Project. REMP Technical Report, No. 25*.

Ringold, P.L., Boyd, J., Landers, D. and Weber, M. (2013) 'What data should we collect? A framework for identifying indicators of ecosystem contributions to human well-being', *Frontiers in Ecology and the Environment*, vol. 11, pp. 98–105.

Robertson, S.A. and Luke, W.R.Q (1993) *Kenya Coastal Forests: The Report of the NMK/WWF Coast Forest Survey*. WWF Project 3256, Coast Forest Status, Conservation and Management.

Samoilys M.A. and Kanyange N.W. (2008) *Natural Resource Dependence, Livelihoods and Development: Perceptions from Tanga, Tanzania*. IUCN.

Scholes, R., Hassan, R. and Ash, N.J. (2005) *Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Current State and Trends*. Island Press.

Seeley, J.A. and Allison, E.H. (2005) 'HIV/AIDS in fishing communities: challenges to delivering antiretroviral therapy to vulnerable groups', *AIDS Care: Psychological and Socio-medical Aspects of AIDS/HIV*, vol. 17, no. 6, pp. 688–697.

Shanahan, T.M., Overpeck, J.T., Anchukaitis, K.J., Beck, J.W., Cole, J.E., Dettman, D.L., Peck, J.A., Scholz, C.A. and King, J.W. (2009) 'Atlantic forcing of persistent drought in West Africa', *Science*, vol. 324, pp. 377–380.

Smith, S.V. (1978) 'Coral-reef area and the contributions of reefs to processes and resources of the world's oceans', *Nature*, vol. 273, no. 5659, pp. 225–226.

Spalding, M.D., Ravilious, C. and Green, E.P. (2001) *World Atlas of Coral Reefs*. University of California Press.

Steneck, R.S. (2009) 'Marine conservation: moving beyond Malthus', *Current Biology*, vol. 19, no. 3, pp. R117–R119.

Thiollay, J.M. (2006) 'Large bird declines with increasing human pressure in savanna woodlands (Burkina Faso)', *Biodiversity & Conservation*, vol. 15, no. 7, pp. 2085–2108.

Tockner, K. and Stanford, J.A. (2002) 'Riverine floodplains: present state and future trends', *Environmental Conservation*, vol. 29, pp. 308–330.

Turpie, J., Smith, B., Emerton, L. and Barnes, B. (1999) *Economic Value of the Zambezi Basin Wetlands*. IUCN Southern Africa.

Turpie, J.K. (2000) 'The use and value of natural resources of the Rufiji floodplain and delta, Tanzania', *Rufiji Environment Management Project Technical Report 17*, Dar es Salaam.

Tweddle, D. (2010) 'Overview of the Zambezi River System: its history, fish fauna, fisheries, and conservation', *Aquatic Ecosystem Health & Management*, vol. 13, no. 3, pp. 224–240.

United Nations, Department of Economic and Social Affairs, Population Division (2013) *World Population Prospects: The 2012 Revision, Volume I: Comprehensive Tables ST/ESA/SER.A/336*.

van den Bossche, P. and Delespaux, V. (2011) 'Options for the control of tsetse-transmitted livestock trypanosomosis. An epidemiological perspective', *Veterinary Parasitology*, vol. 181, no. 1, pp. 37–42.

Wamukota, A.W., Cinner, J.E. and McClanahan, T.R. (2012) 'Co-management of coral reef fisheries: a critical evaluation of the literature', *Marine Policy*, vol. 36, no. 2, pp. 481–488.

Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E.H., Nayak, P.K. and Badjeck, M.-C. (2013) 'Small-scale fisheries through the wellbeing lens', *Fish and Fisheries*, vol. 15, no. 2, pp. 255–279.

Welcomme, R. (2008) 'World prospects for floodplain fisheries', *Ecohydrology & Hydrobiology*, vol. 8, nos. 2–4, pp. 169–182.

Welcomme, R.L., Cowx, I.G., Coates, D., Béné, C., Funge-Smith, S., Halls, A. and Lorenzen, K. (2010) 'Inland capture fisheries', *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 365, no. 1554, pp. 2881–2896.

Weyl, O.L., Ribbink, A.J. and Tweddle, D. (2010) 'Lake Malawi: fishes, fisheries, biodiversity, health and habitat', *Aquatic Ecosystem Health & Management*, vol. 13, no. 3, pp. 241–254.

Woodhouse, P. (2012) 'Foreign agricultural land acquisition and the visibility of water resource impacts in Sub-Saharan Africa', *Water Alternatives*, vol. 5, no. 2, pp. 208–222.

World Bank (2009) *Awakening Africa's Sleeping Giant: Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond – Directions in Development*. World Bank and FAO.

World Commission on Dams (2000) *Dams and Development: A New Framework for Decision-Making*. London.

Zwarts, L., Beukering, P.V., Kone, B. and Wymenga, E. (2005) *The Niger, a Lifeline: Effective Water Management in the Upper Niger Basin*. RIZA, Lelystad.

Zwieten, P.V., Béné, C., Kolding, J., Brummett, R. and Valbo Jorgensen, J. (eds) (2011) *Review of Tropical Reservoirs and Their Fisheries in Developing Countries: The Cases of the Lake Nasser, Lake Volta and Indo-Gangetic Basin Reservoirs*. FAO Fisheries and Aquaculture Technical Paper 557, FAO.

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