Annals of Arid Zone 50(3&4): 189-207, 2011

Learning from Stakeholders' Adaptations to Environmental Change and Variability

Michael Mortimore*

Drylands Research, Cutters' Cottage, Glovers' Close, Milborne Port, Sherborne, DT9 5ER, UK

Abstract: There is much to learn from stakeholders' adaptations in seeking a new paradigm of dryland development. The case is based on eleven paradoxes: (1) specialised scientific knowledge, formerly accepted as the guide to policy, now needs to engage in partnerships with local stakeholders and to aim for interdisciplinary understanding of complex systems; (2) the population factor, formerly blamed for land degradation ('desertification') is now known to work in more complex ways, and positive outcomes can be associated with high densities; (3) climate scientists focus on models for predicting trends while dryland peoples set their priority on managing rainfall variability; (4) recent analyses suggest that demand factors have been underrated, as opposed to supply constraints, in achieving food security; (5) the policy choice between promoting small-scale family farming or large scale commercial agriculture is unresolved and has enormous implications; (6) natural resources are frequently blamed for conflict in drylands, but it has more complex system-wide causes; (7) the emergence of new and growing markets in drylands challenges the assumption that they have little to sell; (8) protecting biodiversity is now a global priority, for good reasons, whereas GM crops and new technologies threaten to destroy or reduce it; (9) technologies aimed at maximising production need to be re-oriented towards sustainability; (10) in a free market system, promoting investment is a priority and needs better analysis; and (11) even as agriculture climbs the development agenda once more, spontaneous income diversification out of agriculture (or complementary to it) attracts more attention from dryland peoples. These paradoxes are explored through the illustration of northern Nigerian experience. A more contextual paradigm of dryland management should include all stakeholders and promote greater local ownership of the policy process.

Key words: Adaptation, development opportunities, dryland systems, environmental change, Nigeria, transition.

In order to contribute to enhancing the well-being of dryland peoples and their ecosystems, social and natural scientists need to understand the nature and the context of the fundamental transitions that are presently challenging them. These transitions affect the productivity of dryland ecosystems, the demand for commodities, the natural environment itself (including climate change), and the political economy of global drylands. Adaptation (sometimes called 'adjustment') to this range of challenges is broader and more complex than much literature and debate implies, for example in the often simplified terms 'desertification' and 'coping strategies'. Recent advances in understanding complex systems leave us with no alternative, but to grapple with systems as wholes – or as co-evolving human-environmental systems (Reynolds *et al.,* 2007). To restrict analysis to the societal 'impact' of a particular predictive scenario, e.g. of climate change, cannot recognize adequately that it faces 'double exposure' to both environmental and economic drivers. Nor can it take full account of the interactions between the many social and environmental drivers of change.

How a dryland family responds to a drought or food emergency is a function both of scale and of diversity. It depends not only on internal resources (such as assets, income, labour, land, knowledge and capabilities), but also on external drivers (commodity prices, employment opportunities, governance, civil order, etc.). There is thus a great diversity, both in the nature of the challenges and in the configuration of responses. But the drylands are often characterized at a generic and global level without recognising these differences. Understanding complexity and diversity offers a better way forward than risking a prematurely simplified narrative.

*E-mail: mike@mikemortimore.co.uk

Adaptation stems from knowledge, and so this overview addresses the knowledge and adaptive capacity of stakeholders in the drylands, and in particular, of resource users on the one hand, and the science-policy nexus on the other. This discussion is restricted to the experience of a single dryland region (northern Nigeria), but set in a wider global context. This is for two reasons. First is the difficulty of deriving valid generalisation from the enormous diversity that characterises the global drylands - which cover over 40% of the earth's land surface and are home to a third of its population the World Atlas of Desertification. Second is the need for policy responses at national level. Scientific knowledge must engage with unique national institutional and policy frameworks, if it is to benefit the users and occupiers of the land. It is also at the sub-national level that local knowledge and stakeholder interests can make an impact, or be given 'voice' and participation. This calls for more attention to be paid to the political ecology of land use sustainability, country by country. Neglect of this dimension is one reason why the national action plans prepared under UNCCD auspices have had only limited impact (fn). The people of the drylands, it has been argued, continue to be 'the forgotten billion' (UNDP and UNCCD, 2011).

Transition is the key issue, both in northern Nigeria and more generally in drylands – not 'conservation' or 'rehabilitation' of existing (or past) structures, but finding a pain-free pathway to achieve defined goals. Thus in place of trying to stop or put into reverse trends, such as 'desertification', which are not desirable, I want to focus on the opportunities for beneficial change, building where possible on what has already been achieved, and where stakeholders' knowledge is germane to the transition. The discussion will relate to the following areas (and the listing is not exclusive):

1. sharing and using knowledge,
2. making good use of human resources,
3. managing climatic variability,
4. achieving food security,
5. large-scale versus small-scale 'modernisation',
6. conflict in drylands,
7. new and emerging markets,
8. sustaining and using dryland biodiversity,
9. technology and sustainability,
10. promoting investment, and
11. poverty reduction – only through agriculture?

In moving away from an exclusive preoccupation with negative trends, this discussion reflects revised assessments of dryland development published recently (IUCN, 2009; UNEMG 2011). It may be said that the new approach is opportunistic rather than driven by negative scenarios. The recent and expected profile of change in Nigeria is likely to be followed by other West African countries sharing comparable environmental and demographic challenges (Cour and Snrech, 1998). Where possible, lessons of wider applicability are noted.

Sharing and Using Knowledge

In its findings, the IUCN Challenge Paper identifies upgrading the knowledge base as the first building block for a dryland strategy (IUCN, 2009).

In the past, new knowledge was not always managed well. A stark dichotomy was allowed to grow between indigenous and science-based knowledge; access to new knowledge was often impeded; and projects often promoted inappropriate technologies. These barriers are now recognized. The Integrated Ecosystem Management project, financed by the Global Environmental Facility, in five river basins shared between Niger and Nigeria, aims to build knowledge sharing and local ownership into a framework of governance based on community institutions (UNEP/GEF, 2005).

Stakeholder negotiations are an effective way of sharing knowledge and developing local governance of natural resources. The 'ecosystem approach' has been formalised in a sequence of five steps: (1) identifying and bringing in key stakeholders in the selected ecosystem; (2) understanding the ecosystem structure, functioning and management through research; (3) understanding ecosystem management in economic terms; (4) adapting ecosystem management in space; and (5) developing adaptive capacity over time (Shepherd, 2008). In some interventions in natural resource management, stakeholders negotiate a 'local convention' or suite of byelaws to govern access to,

and benefits from a contested resource, such as a forest reserve.

In the past, a 'diagnostic-prescriptive' framework was widely adopted, whether explicitly or implicitly, in development interventions: experts (from outside) diagnosed the sickness and prescribed treatment which was implemented by the project staff. The analogy with human health has since developed further into the concepts of 'soil health' and 'ecosystem health' (www.terralinua.org). The term is probably synonymous with 'sustainability'. The significance of ecosystem thinking is that it locates agriculture in its wider environmental context, whose neglect precipitated many erosion disasters in the history of farming and grazing animals. Actually it converges with local peoples' own complex livelihood agendas.

An important theoretical perspective is the concept of resilience, which allows for an ecosystem to be unstable and yet resilient (i.e., preserving its basic structure and function even under conditions of variability) (Holling, 1973; 2001). Both 'natural' and 'management' variables may impinge on the system, which is subject to cyclical change. For example, an exploitation phase such as a specific population expansion can lead to a 'collapse' and recovery. But the basic structure and function of the system do not change. Such trajectories suggest parallels with dryland experience – for example, in the Sahel – where human populations function both as specific components of the system and as managers with the power to exacerbate or control the intensity of natural cycles.

From here it is a short step to the idea of co-evolving human and ecological systems, a device that attempts to simplify the relations between a society (managers) and its environment (natural resources) (Reynolds *et al*., 2007). A long-term perspective suggests that the relations between a society and its environment depend on linking mechanisms or institutions whose failure to function in a sustainable way can lead to breakdown in either environmental or human systems. For example, if an agricultural system is based on the 'mining' of essential soil nutrients, without adequate replenishment, the impact of land degradation will sooner or later undermine incomes and well-being. On the other hand, appropriate institutions, policies, and economic incentives can lead to a development pathway of sustainable intensification. Such transformations (including the rehabilitation of degraded land) have been documented in African drylands (Tiffen *et al*., 1994; Mortimore and Adams, 1999; Mazzucato and Niemeijer, 2000; Reij and Thiombiano, 2003)

A Dryland Development Paradigm (DDP) has been proposed, which may (with further development) provide a new understanding of the nature of agricultural or other development interventions and the role of institutions and policy (Reynolds *et al.,* 2007). A dynamic framework recognises transition and change as a long-term ingredient in sustainable co-evolution of the human and ecological systems. A snapshot in time (Fig. 1) shows, within a small space, multiple bio-productive enterprises (each based on a set of economic, social and policy conditions) dependent on soil management (controllable through labour, skills and inputs) and rainfall distribution (not in this case controllable). There is a 'platform' here for marrying science-based and locally-based knowledge, and strengthening local ownership by ecosystem managers.

Fig. 1. A multiple use system in the Kano Close-Settled Zone, Nigeria. The pearl millet is used for food, fodder (residues) and composting; the groundnuts are grown for market and the residues for high grade fodder (the crop also fixes atmospheric nitrogen); weeds are cleaned for feeding to penned animals; and the trees for fruit and other non-timber products, browse for animals, and nutrient cycling through litter decomposition and nitrogen fixation (some species). High densities of livestock are sustained.

The degradation scenario of the Sahel is often constructed in terms of a single, homogenous narrative (chosen from among the familiar litany of over-population, over-cultivation, deforestation, over-grazing, irrigated salinization, etc.). However, scientific opinion is divided between such scenarios and a more nuanced counter-narrative that recognises resilience in the system. (MEA, 2005) The theoretical directions briefly explored above show the scope for a better understanding through embracing a long-term perspective and the concept of transition. But in place of a medical analogue - a diagnostic-prescriptive framework for a 'one-off' restorative intervention – I suggest that a better analogue is that of a life and livelihood frame, recognising the mix of opportunism and determinism that leads to incremental gains or losses in the life-trajectory of an individual. Attention to these incremental changes should lead to participatory developmental pathways that can lead communities somewhere, rather than the sweepingly remote generalisation that has often characterised policy discussion.

Making Good Use of Human Resources

Population is the most misunderstood variable in the drylands debate: blamed for land degradation, low productivity, exceeding 'carrying capacities' and for being too many (sometimes too few) in number. To get away from these stereotypes it is necessary to balance the debate with a better appreciation of humans as a resource – of labor, of skills, of knowledge, of capacity to build institutions for regulating the use of natural ecosystems – as agents of sustainability. But nevertheless, the issues of numbers do matter.

The Nigerian population was 19% urbanised in 1963, 36% in 1991, and according to an FAO estimate, recently approached or passed the critical threshold of 50% urbanised (of a total population of 140.4 million in 2006) (Federal Republic of Nigeria, 2006. Population and Housing Census. Abuja: National Population Commission, 2010). There is no reason to suppose that the drylands are far behind the humid zone in terms of urbanization, as they contain many major and rapidly expanding cities. In food security terms, this means that the lesser half of the population is responsible for feeding the whole (if imports are disregarded). This transition will be no less significant if rates of urbanization should decline with global recession.

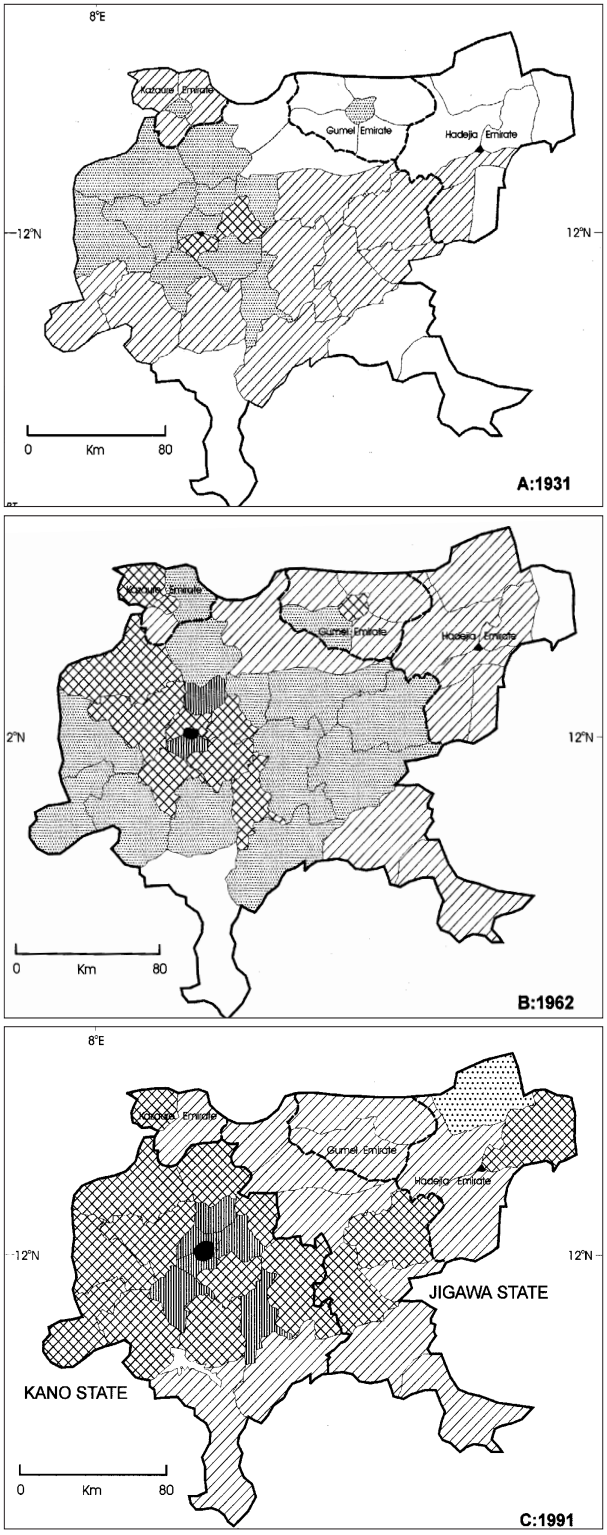

Fig. 2. Population density, Kano and Jigawa, 1931, 1963, 1991per km² (Intervals: <38; 38-75; 76-150; 151-300; >300).

Yet rural population densities have not yet fallen in the Nigerian drylands. This is despite already high rural densities. To take the extreme case, that of Kano, rural densities increased consistently from 1931 through 1963 until 1991, in the vast region known as the Kano Close-Settled Zone (Fig. 2). These patterns have not yet been updated to the Census of 2006. But in 1994, the amount of arable land available per person in farming families in one village in the inner zone was only 0.46 ha (at a density of 223 persons km^{-2}) (Mortimore and Adams, 1999). Both the priority of subsistence, and the pressure of markets, ensure that the still-growing rural population exercises a powerful demand on cultivable land. Subdivision of holdings on inheritance reduces the size of holdings from one generation to the next. Markets for land develop, and the poorest are the most likely to become dispossessed through alienating their small fields (Hill, 1977; Tiffen, 2001). The rural population includes an increasing number of landless people, whether by choice or necessity. Larger holdings, meanwhile, are being accumulated through purchase (Tiffen, 2001).

The Kano Close-Settled Zone was originally defined as having rural population densities exceeding 141 km^{-2}, (Mortimore, 1993) but such levels are now achieved more widely in the Nigerian drylands. It is important to recognise that the land scarcity problem is not only or even mainly driven by subsistence-inadequately described as 'population pressure', or worse, as 'over-population' - but also by urbanization and the market forces associated with it. Hence the close association between rural density and the distance from the major market, visible in Fig. 2.

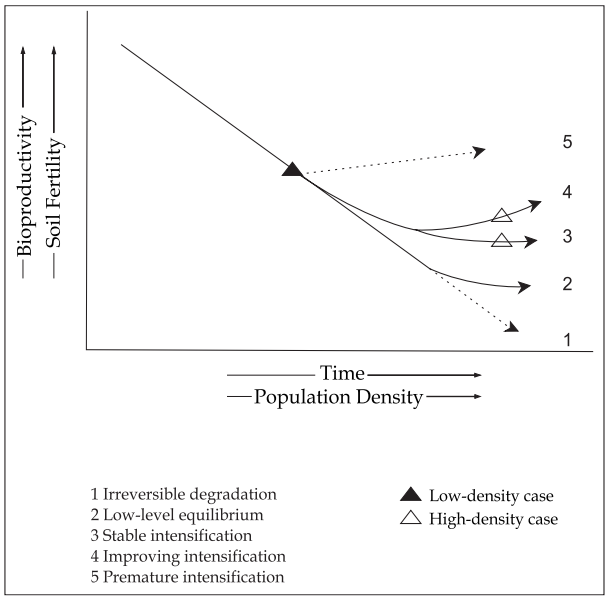

Fig. 3. The transition from degradation to intensification in a farming system.

This has profound implications for agricultural services and research. What can be done on less than half a hectare per person? But we should not overlook what small-scale farmers have achieved with their own limited resources. In a model of the relationship between demand for farmland and productivity (Fig. 3), productivity is shown in a U-shaped curve when plotted against demand (or time, or labour inputs). As land becomes scarce, its value increases, more labor is spent in raising output and soil fertility is better preserved (Harris, 1998; Bolwing *et al*., 2011). Natural fallows cease. A cycle of degradation can be reversed with inputs, mainly organic. Paradoxically, the more people, the less degradation.

The same combination of demographic growth and market opportunities drives livestock populations. There is paradox here, too. The density of standard livestock units (taking into account the relative weight of small and large ruminants) was found in the 1990s to correlate positively with human population densities (Bourn and Wint, 1994). This is despite the disappearance of common access pastures. Thus the viability of livestock keeping depends less on rangeland and more on the valuable residues especially those of sorghum, millet and cowpea. It also depends on fodder from tree browse. The freedom of action of mobile livestock keepers is, however, threatened, both by diminishing rangeland and by the privatisation of crop residues by livestock-owning farmers (Mortimore, 2001). In the arid rangelands, efficiency in grazing is achieved by high labour inputs in maintaining mobility between sparse but valuable patches.

Forestry practice in the drylands of northern Nigeria focused historically on protecting natural woodland, especially on eroded sites, and on plantations on better soils. The seemingly endless expansion of small-scale farming has threatened both the reserves and the plantations. Yet farmers value trees and protect them on their farms, provided that tenure is secure. Moreover, timber volume as well as economic value may

be higher on the farm than in the residual 'forest' reserves, often degraded, of natural woodland (Cline-Cole *et al*., 1990). Here then is another paradox: the more people, the more trees (Reij *et al*., 2006).

I have framed this summary discussion in terms of three paradoxes: the more people, the less degradation, the more livestock and the more trees. The demographic equation in the Nigerian drylands is far from being simple, and challenges the negative prognosis that is widely promoted. Is northern Nigeria representative of drylands in general? The point is that better in-depth analysis of change over time may yield a sounder platform for policy. The future is uncertain: is a demographic transition to lower levels of human fertility certain to take place? How far can intensification go? What scope is there for raising yields and saving labour? Will rural out-migration eventually reduce the labor force and eliminate the viability of smallholder agriculture, livestock keeping and tree management? Adaptive capacity will determine the future, as it has done in the past.

Managing Rainfall Variability

Drylands are defined as areas where the ratio of average precipitation over potential evapo-transpiration (*P/PET*) is less than 0.65. They break down into dry sub-humid (0.50-0.65), semi-arid (0.20-0.50), arid (0.05-0.20), and hyper-arid deserts (<0.05). Including the last, 66% percent of Africa is dryland (Middleton and Thomas, 1992).

The longer term trends in annual rainfall in the West African Sahel are a reminder that climate change is not new to this region; in fact the decline that was experienced between the 1960s and the 1990s was greater than any predicted in global scenarios (Hulme, 1996). Since the 1990s, it has reversed. Such changes in 'sign' or direction are a warning against placing too much confidence in model predictions, based on projections. For the West African Sahel, more or less opposite predictions are available for the future depending on which model is used. However, a majority of models predict an increase in precipitation in the Nigerian area between 1980-99 and 2080-99 (Solomon *et al*., 2007).

Hadley Centre data have been used to model Nigerian future climates (for the Forest, Southern Guinea, Northern Guinea, Sudan and Sahel) (Adejuwon, 2006). Projections to 2100 indicate steady and consistent increases in annual rainfall. The magnitude of the projected increases is highest in the south near the coast and declines with distance from the sea. They concluded that

"In general, there will be increases in crop yield across all ecological zones as the climate changes during the 21st century. In most cases, the increases will continue until mid-century. However, towards the end of the century, the rate of increase will slow down" (Adejuwon, ibid.).

Climate change modelling suffers from a major drawback as a guide to agricultural futures in African (and other) drylands. This is an inability so far to predict local outcomes, or to differentiate between macro-scale and micro-scale scenarios. In fact, besides their aridity, the key characteristic of the African drylands, including those of northern Nigeria, is rainfall variability. This is expressed in long term linear trends or long cycles (tending to 11- or 22-years) in annual rainfall. In the West African Sahel, a highly significant decline between the 1960s and the 1990s resulted in a southward shift of the rainfall isohyets of more than 100 km.

On an annual time-scale, rainfall variability exceeds a coefficient of 30% in many drylands. The graph for Maradi (Niger) illustrates both annual and longer term variability (Fig. 4). Such events cannot be predicted. On an even shorter (within-season) time-scale, variability from one ten-day period to the next calls for adaptive management of farm labor in the major farming operations, especially weeding (Fig. 5). It is of no use weeding a crop that is dying from drought, yet to withdraw labor runs the risk of losing output if the rain comes back.

Pastoralists, on the other hand, cope with variability by constant movement of flocks and herds in response to erratic variations in pasture quality. As stated above, this requires the intensive use of labor, environmental knowledge, and breeding skills by such groups as the WoDaaBe of southern Niger (Kratli, 2008). Intelligence on the whereabouts of specific valued fodder plant communities plays a crucial role.

Forecasting rainfall is embedded in local traditions in West Africa, for example in Burkina

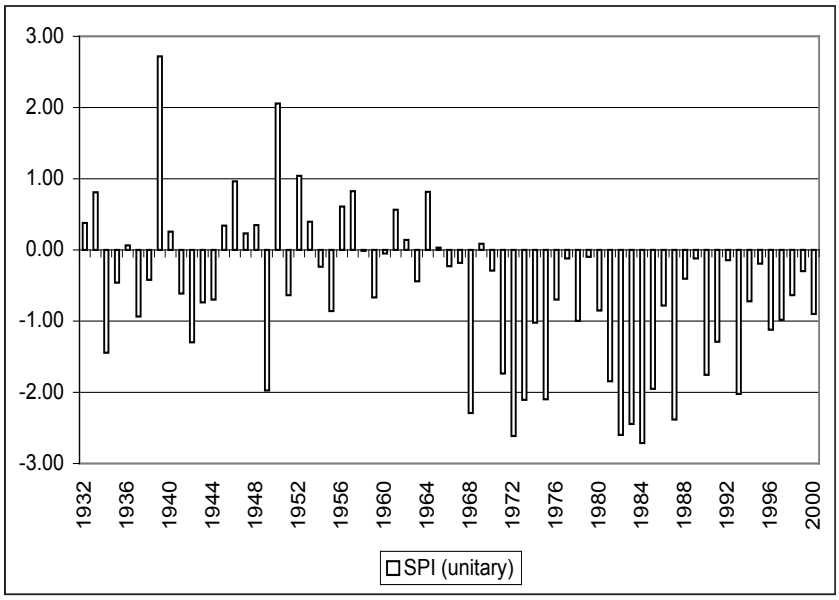

Fig. 4. Maradi: variability of rainfall index, 1932-1998. Source: Tiffen, 2001.

Faso (Roncoli *et al*., 2002). In northern Nigeria, connections are adduced between the Harmattan dust haze during November to February and the ensuing rainy season. Such folk forecasting shows that the key characteristic of dryland climates as perceived by rural resource users is inter-annual rainfall variability. Research in East Africa has shown that farmers' decision making is assisted significantly by improved (i.e., more reliable) seasonal forecasting in the form of a simple scientific assessment such as 'above', 'below', or 'about' average (Cooper, 2008).

As a consequence of aridity and variability, prolonged over geological time, soil fertility and plant biomass production tend to be low compared with more humid regions, except in localised river flood plains or depressions. Water always brings a response in biomass production. The occurrence of higher potential 'patches' in a vast region of low potential reflects both a diversity of weathered soil parent materials and also a geological history of fluctuating desert margins, dune formation and wind erosion. This diversity is greater than a casual observation of the great plains of the Sahel would suggest, and underlies an equally significant diversity of social, cultural and economic systems (Raynaut *et al*., 1997).

However, transcending this diversity is a general pattern of environmental response to climate variables recently revealed in evidence of 're-greening' in the Sahel (Ecklundh and

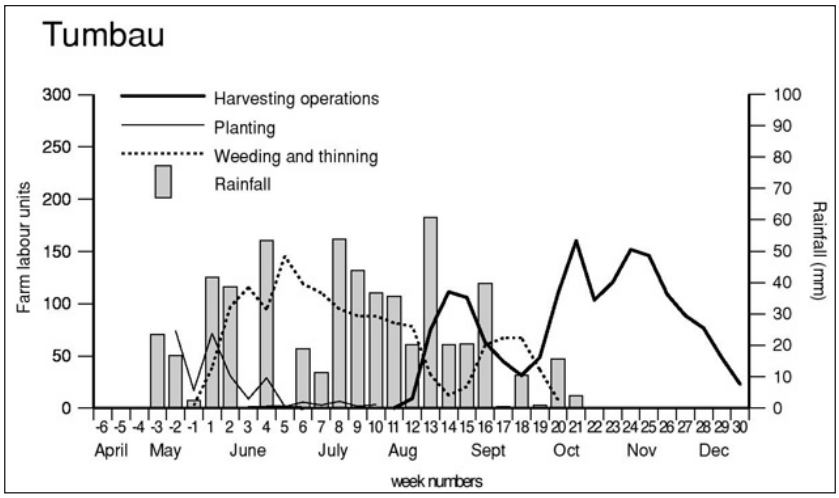

Fig. 5. Labor use in planting, weeding, and harvesting. (Source: Mortimore and Adams, 1999).

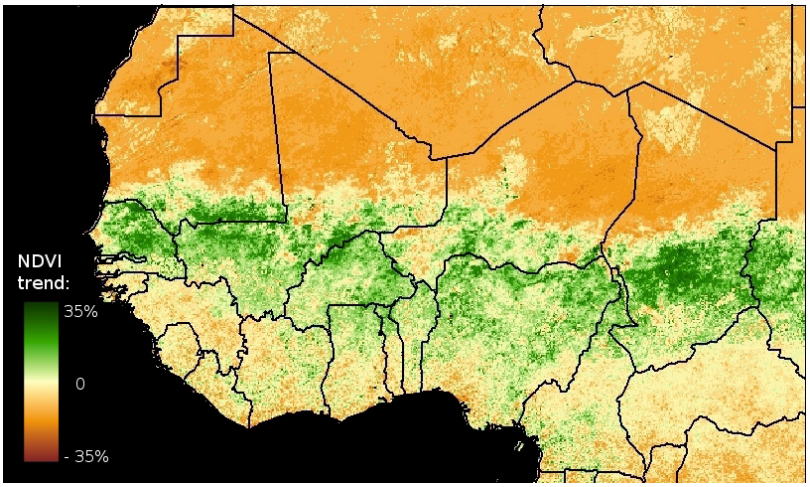

Fig. 6. 'Re-greening' in the Sahel. Source: IUCN, 2009.

Olsson, 2003). Derived from earth satellite data, the vegetation 'greenness' index (NDVI) shows a statistically significant positive trend from 1982 until 2006 (IUCN, 2009) (Fig. 6). The areas benefiting from this 're-greening' are particularly noticeable in the semi-arid zone where population densities are highest and the risk of degradation is normally assumed to be greatest. But they extend into the arid zone northwards and the dry sub-humid (and even the moist sub-humid) zone southwards, notably in Nigeria.

Across the entire Sahelian biome there is a significant correlation with rainfall, as the period of satellite observations corresponds to the recovery from the intense drought cycle of the early 1980s (Fig. 7). The correlation brings us back to the fundamental observation that drylands are a product of the distribution of precipitation. Where the correlation is strongest, the role of non-precipitation factors is the least - and vice-versa. With some exceptions, the strongest correlations are in the most densely populated and cultivated semi-arid zone right across the continent - the very zone where land degradation is often attributed to human mismanagement of ecosystems. The role of land use drivers is thus (to say the least) unclear. However, non-precipitation factors (including management) must account for the irregularities in the rainfall correlations.

The overall findings from these data confirm that the desert edge oscillates with rainfall trends (Tucker *et al*., 1991), and is not primarily driven by management, although this does have a secondary role. Land use policies can therefore make a difference to the detail, but cannot direct the regional trend. Much remains to be understood about the mechanisms involved,

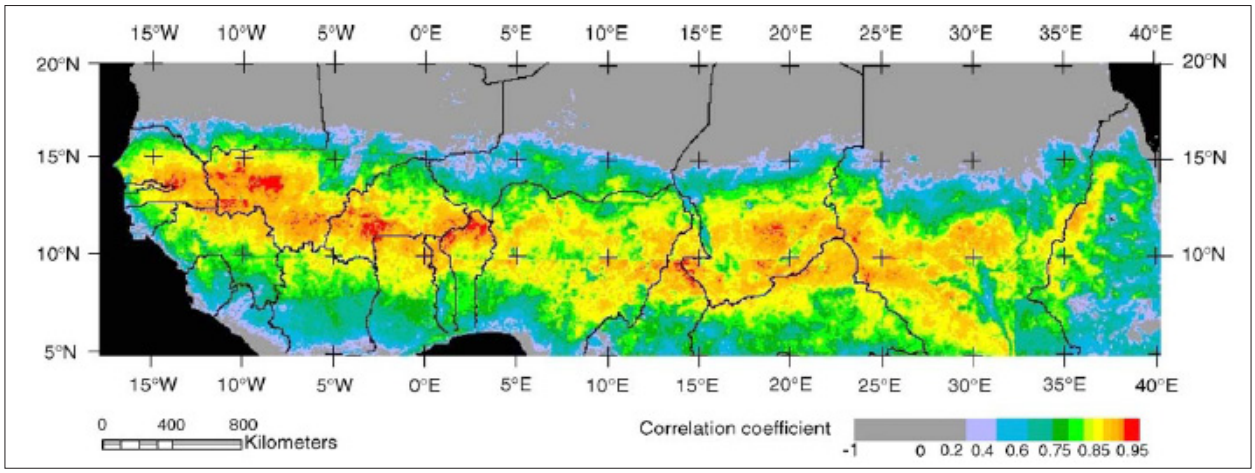

Fig. 7. Correlation of rainfall and NDVI 1982 – 2003 Monthly NDVI and cumulative rainfall of the same plus the two preceding: the more red, the more vegetation is driven by rainfall. Source: Hermann in IUCN (2009).

but the recent vegetation changes in the African Sahel do not support simplistic theories of human causation of deserts (Reynolds *et al*., 2002).

Achieving Food Security

We return to the Nigerian drylands, in order to show how dryland development is specific to a particular country and the political economy in which food security trends are embedded. From the 1970s onwards, an oil boom in Nigeria decoupled food production and demand, by making it possible to import cheap food from abroad – a strategy which still continues. Meanwhile agricultural exports lost their competitive edge in world markets owing to an overvalued currency. It is not surprising that there was 'a pervasive feeling at the time that the country was on the cusp of an agrarian crisis' (Mustapha and Meagher, 2001). One federal intervention followed another yet failed both to bring about the desired 'modernisation' of agriculture and to slow down the exodus of labour to the cities. Projections of food deficits were made by experts – one study predicted a deficit of 6.6 million tons of grain equivalent by 1985. Yet Nigerian farmers 'were to confound these experts and undermine their scientific pretensions' (Forrest, 1993).

After the introduction of structural adjustment policies ('SAP') in 1986, negative perceptions of the performance of the agricultural sector persisted, influenced by the volume of food commodity imports and the high prices of fertilizers. However, food production kept up with the rate of population growth through the 1990s, not only yams and cassava (which did extremely well) but even of millet and sorghum, which increased from as early as 1978, though more slowly.

The performance of the food sector in northern Nigeria cannot be separated from that of its southern, humid zone in national statistics. But in the arid and semi-arid CILSS countries of the Sahel, gross production tended upwards from 1987-88 to 2004-05, though fluctuating from year to year (Faye *et al*., 2001). Certainly imports tended upwards, and the trend of cereal production *per capita* was flat. However, the population grew quite rapidly. Other evidence from FAO statistics suggests that in West Africa, even under conditions of low and erratic rainfall, the production of food commodities kept up with population growth in the long term. During this period, in Nigeria and elsewhere, the food commodity markets, driven by urbanization, were strong (Ariyo *et al*., 2001). But there was (and still is) much poverty, restraining demand. The best construction of these data is that demand rather than supply factors constrain output at the macro-scale, especially where smallholder economies lack export markets for staple foods (Mortimore, 2003). Such a finding, if confirmed, and replicated elsewhere, will call for revision of the popular view that dryland development is constrained fundamentally by supply factors; and that degradation will inevitably win over adaptive capacity.

Large-scale Versus Small-scale Farming

It is a mistake to think of the drylands as empty or unclaimed. Nevertheless, many donor-driven interventions have thought fit to proceed on this assumption, mainly because of ignorance concerning the customary rights of pastoral nomads, collectors/hunters, and the rationales of long-rotation fallowing systems. A key element of a political ecology of the drylands, therefore, is the reassertion of these rights against competitors.

A recent study of the Guinea Savanna (sub-humid) agro-ecological zone of Africa has relevance for semi-arid drylands (World Bank, 2010). This study argues that the Guinea Savanna lands are the greatest under-developed agro-ecological zone in the world, and that current economic forces are set to appropriate them. There are two policy options outlined in the study: first, a 'Brazilian' model that is characterised by extensive forest clearance, large estates, dispossession of smallholders, mono-cropping (soya for export) and dependence on inorganic inputs; second, a 'North-east Thailand' model of sustained policy support - for example, infrastructure, marketing institutions, extension - leading to a prosperous peasantry able to benefit from export markets. In the absence of a policy, the Brazilian model is more likely to occur.

In Nigeria, including its drylands, the policy choice between the 'Brazilian' and the 'Thailand' options is stark and controversial. Large-scale farming, ranching and plantations have been tried intermittently, but the foundation of agrarian policy until now has been small-

scale family farms, geared (in colonial times) towards export commodities. Land tenure law protected the holders of inherited rights under 'customary' law (which included Islamic law and 'family' or lineage land), while 'statutory' rights to unallocated land could be awarded by the government. The extension of a dual system from the North to include the South, in the Land Use Act of 1978, brought the whole country under a unified system. It did not ensure equity, as intended, because state governors could allocate large estates on long leases in unsettled areas, opening the door to large-scale agricultural 'modernisation', and pastoral rights were not protected.

The policy bias in favor of smallholder agriculture ran counter to the popular conception of 'modernization' through labor-saving machinery, chemical inputs and new methods. But low productivity and incomes from farming led to rural-urban migration. Not even substantial incentives (land and loans) could deter young men from abandoning family farms in Kwara State. The State Government then hit on the idea of inviting 13 Zimbabwean farmers – who had been displaced forcibly from their farms there – to begin an 'experiment' (as it was called) in large-scale farming under Nigerian conditions. Each was allocated 1,000 ha on a 25-year lease, offered state help with clearance and infrastructure, and access to bank loans. Internal markets for cassava, soya, maize, sorghum and rice and for dairy produce (UHT milk and yoghurt) and poultry are keys to economic viability. Besides employing about 3,000 local people, the farmers undertook to teach new methods to selected local youths who would be allocated new farms outside the existing village lands. Villages were not disturbed and additional land was made available to replace any lost to the new farms. The experiment began in 2005 and it is too early to reach judgement on its success (Ariyo and Mortimore, 2012). However, it is clear that large-scale commercial farming needs capital, and if this is not provided by inward investment, or from private savings within Nigeria, the government must support the enterprises. Subsidies are likely to be necessary and so its sustainability may depend on the level and continuity of government or corporate support.

The Kwara story is told in some detail because the large scale option is on the ascendancy in many dryland countries in Africa. Foreign corporations are understood to be taking leases on extensive areas for direct production of food commodities - not for the local market, but for export to food-deficit countries such as the Gulf states. The Guinea savanna region is still under-developed, but the same is not true for much of the semi-arid and arid regions where, either for farming or for pastoralism, indigenous claimants to land or grazing abound.

Dryland peoples may not be able to participate fully or fairly in policy formation for the agricultural sector as a whole.

Conflict in the Drylands

Because mobility is fundamental at the local level both to pastoral nomadism and to many agro-pastoral farming systems, conflicts of interest easily arise in the drylands, and may sometimes trigger violence. However, additional underlying factors are usually involved, such as food emergencies, ethnic or cultural resentment, land alienation, frustrated political aspirations, and corrupted governance. Militant groups operating outside the law have reduced Somalia and Darfur to ungovernable and/or depopulated places for years at a time. In northern Nigeria, territorial ambition – through the rejection of what is perceived to be foreign cultural influence - is a prime driver of contemporary terrorism (*Boko Haram*), though it is mostly manifested in the cities rather than in the countryside.

Natural resources assume central significance in outbreaks of violence. But it would be mistaken to assume that dryland ecologies are uniquely vulnerable to conflict over natural resources, just as it is an over-simplification to speak of 'drought refugees'. Many factors are likely to be involved, one of which is the incompetence of governance institutions to regulate rights to resources justly and equitably. The upsurge in African conflicts suggests that development is much more than a technological challenge. The internationalization of conflict (e.g., illegal trans-Mediterranean migration to Europe; piracy on the Somalian coast) is now so serious that political dimensions of the development agenda should take a high profile in the dryland countries. The importance of understanding conflict and substituting negotiation is itself an argument for adopting the holistic systems approach advocated earlier in this article.

On the other hand, there are positive outcomes from resource-sharing negotiations (community-based natural resource management) such as 'local conventions' or byelaws governing the use of contested resources (Vogt and Vogt, 2000). These experiments suggest that there is ample scope for institutional development that can assist the transition from 'indigenous' governance to decentralized and democratic models consistent with changing political and economic conditions.

New and Emerging Markets

Ecosystem services, previously neglected by policy makers, are being linked with new niche markets including export markets in several African dryland countries (IUCN, 2009).For example, mongongo fruits from Zambia are used in body gel products in South Africa and Europe; dairy products are processed in Kwara State for distant markets thanks to UHT technology; gum Arabic is still exported from the Sudan; and frankincense from Ethiopia. The value chains associated with these products add significantly to livelihood opportunities and increasingly justify modern processing, quality control and marketing methods (though their true economic value may not yet enter into national accounting). Market value chains have recently been advocated as a priority for development efforts in the Sahel (Bolwig *et al*., 2011), offering opportunities for enhanced efficiency (in favor of producers), quality control (in favor of consumers) and equitable institutional regulation. In the Nigerian case, production of export commodities from drylands has largely been replaced by production for urban markets via informal chains, and the tempo of periodic markets is constantly increasing, indicating positive trends in participation.

These new directions are not without risk. In Kenya, for example, biofuel production is planned. Economic planners claim that USD 71 million can be saved from the cost of imported petrol and diesel (at 2008 prices) (GTZ, 2008). 15,000 ha of 'new' land (not currently used for food or cash crops) can be planted to sugar cane, together with 24,700 ha of 'new' land under sweet sorghum, and 'a portion' of land diverted from food production, for petrol. For biodiesel, 50,000 ha of land could be planted to castor, coconut, croton, rapeseed, sunflower and jatropha. This, however, is a country where only 15% of the land surface can support rainfed farming. Much attention is being given to the shrub species jatropha which is widely assumed to grow well in drylands, though economic yields in a given situation should not be taken for granted (ref World Bank report). As the example of Kenya shows, the possible impact of biofuel production on food security (through competitive pricing and the diversion of land from food crops) will probably be perverse. Nigeria has more cultivable dryland than Kenya, and less reason to import oil and petrol (though it does so). However, in Kwara State alone, six private sector firms are proposing to grow jatropha on large-scale farms with planned extensions to over 45,000 ha (Ariyo and Mortimore, in prepn.).

Payments for Environmental Services (PES), although familiar in Europe, have been slow to enter the African drylands, partly because of inadequate institutional structures (especially 'secure' private land tenure) and partly because the most common form hitherto – river catchment management for downstream benefits – is restricted to a few possible sites on perennial rivers. But because of the enormous spatial extent of drylands, the sequestration or capture of CO_2 – even at low levels of potential – appears an attractive proposition. According to the FAO, drylands have the potential to sequester more carbon than currently stored as they are far from saturated (Table 1).

Carbon markets under the Clean Development Mechanism (CDM) have been slow to develop in Africa because of problems of eligibility, investment barriers and low rates of return (IISD, 2008). The alternative 'Voluntary' market is new and small. Africa's share in carbon markets is growing, but a question remains as to whether drylands can compete against biomes with higher per hectare potentials.

As with biofuels, land issues are fundamentally important. While some drylands are sparsely populated, remote from cities, and apparently well suited to forestry protection or

Table 1. Total and dryland carbon stocks

Region	Total carbon stocks	Drylands %
Africa	356	59
S Asia	54	49
S America	341	34

Cited in UNEMG, 2011, p. 84

reafforestation for PES, others (including much of the Sahelian Drylands) are already experiencing land shortages. They are relatively intensively managed in smallholdings for subsistence and market production of food crops, often with residue grazing by livestock. Carbon may also be sequestered from intensively cultivated land, whose potential could be increased with agro-forestry techniques. But the administrative costs of a carbon scheme for smallholders would probably far exceed the profits. As with biofuels, there is a major risk of distorting food markets. Rangeland can also sequester carbon, but under conditions of common access or multiple claims, the fair distribution of benefits would be very difficult. There is a sharp distinction to be made between advocated scenarios for carbon markets and reality.

Solar energy generation is at an advanced stage of planning in north African countries under European Union capitalisation and with a view to exporting electricity to southern Europe (www.deserenergyproject.org). Since the deserts are only rarely occupied, food production is less likely to be threatened by these capital-intensive but land economizing investments in hyper-arid areas. Their relatively small extent will minimize damage to agricultural livelihoods in semi-arid and dry sub-humid regions. However, high transport costs between generator and users will hold back solar investments in most drylands.

The foregoing review of the highly dynamic market sector in drylands has intentionally followed a continuum from local to global, encapsulating a reality that is directly relevant to dryland livelihoods. Besides the densely populated and intensively cultivated areas, the West African drylands also include large areas with relatively low intensities of cultivation, or none at all. Whose land is it, and can it be more productively used? While dryland agriculture is facing major policy issues, some involving significant trade-offs, other markets are rapidly developing in land, labour and skills. Strategies in these areas can be risky – for example, West African laborers recruited for the Libyan oil industry and as mercenaries for the ousted regime are currently (2012) returning home empty-handed. It is paradoxical that free markets which have led the western economies for centuries have not attracted more attention from economic planners in poor dryland countries (see Bolwig *et al*., 2011).

Sustaining and using Dryland Biodiversity

For agricultural development, including forestry and livestock, the 'productivist' paradigm that dominated policy until recently was that based on mono-cropping, homogeneous high-yielding varieties, high inputs and labour-saving technology. The Millenium Ecosystem Assessment, and the UN Convention on Biodiversity, have brought many practices into question and promoted the protection of biodiversity. The Economics of Ecosystems and Biodiversity (TEEB) study published in 2010 lends international weight to efforts to value ecosystem services in financial terms, and to cost biodiversity loss (www.teebweb.org). The IUCN Challenge Paper (IUCN, 2009) also takes an ecosystem viewpoint.

Just a few examples from northern Nigeria will suffice to underline the diversity that has survived in drylands:

Crops

During three years of village level studies in four communities in north-eastern Nigeria, inventories were made of named landraces used in the farming system (Fig. 8). Of sorghum, there were 22 landraces in the wettest village, and 18, 13 and 6 per village as average rainfall decreased. Of pearl millet, there were 12, 7, 6 and 3 landraces. Including all crops, there were 76 landraces in the wetter village, 48 and 55 in the intermediate villages, and 23 in the driest (Mortimore and Adams, 1999). To maintain these landraces from year to year, selections are made, carefully stored, and used in the following season. Each is preserved for its distinct properties, such as drought resistance, time to maturity and taste. A

Fig. 8. Sorghum diversity in northern Nigerian villages.

considerable 'living library' of local knowledge is engaged in this process. An analysis of genetic variability in pearl millet showed that in effect, farmers maintained a genetic pool through out-crossing on their own farms. Variability within a named landrace on different farms was greater than the variability between landraces on the same farm (Busso *et al*., 2000).

Animals

Across the Niger border, WoDaaBe pastoralists have developed a cattle management system which allows them to control, stress and facilitate the transmission of functional behavioural patterns within the herd (learning, feeding competence and social organization), which they have learned by studying cattle in their environment (Kratli, 2008). The breeding population of cattle is organized into matrilineal lineages. Less than three per cent of the bulls are used for matching with all of the dams, and variability is fostered. Cows are rarely sired twice by the same bull. Females are culled for reproductive capacity, and poor animals are marketed. Selection is carried out within lineages, and long-lasting lineages are sought after and protected even under economic pressure.

Trees

In a single village with an average annual rainfall of c.450 mm and on a landscape of stabilized dunes under a Sahelian vegetation, a survey found 135 species of economically useful plants, including trees grown on farmland (Mohammed, 1994). They are used for multiple purposes, including medicinal applications, food, fodder, construction and craft materials. Cultivated land extends to 55% of the area and the remainder is reserved for grazing by livestock keepers. Clearance for cultivation took place more than 70 years ago, involving the removal of many mature trees. However, the farmers value trees, both as a general good and as particularly valued species. Such trees are protected on farms, though at low densities in order not to compete with the crops. Management for conservation is understood, and when offered a small amount of assistance, the community organized a woodlot, which needed irrigating from a distant well in its first two years. Indigenous species are valued more than exotics, but the latter (especially *Azadirachta indica*) germinate better and grow faster. Farmed parkland is a long-established land use category in the Kano Close-Settled one also (Cline-Cole, 1990), and in particular the species *Faidherbia albida* is currently enjoying farmer protection on a large scale across several districts of southern Niger (Boubacar, 2006).

These examples show how diversity is not only protected, but fostered in the Sahelian agro-ecosystem. The paradox here is that genetic engineering is near the point of delivering high yielding varieties, which require standardized agronomic techniques, input dependency and suppression of field biodiversity. Development, if based only on productivity goals, could afford to ignore diversity. But now that we understand its function better, in particular in maintaining alternatives, famine foods, and fodder, there is a need to balance policy and to marry indigenous with scientific knowledge. Such sharing may be a precondition for sustainability, not only in the Sahel, but in other drylands.

Technology and Sustainability

Following a succession of international conventions and meetings since 1974, and in particular the formation of the UN Convention to Combat Desertification in 1992 (www.unccd.int/) (which succeeded the Plan of Action to Combat Desertification that in turn was hatched by the UN Conference on Desertification of 1977), sustainability has been advancing steadily up the development agenda. Meanwhile, estimates of unsustainable practices (some of questionable accuracy) have been promoted (Table 2).

As the Millennium Ecosystem Assessment showed in 2005, there are two narratives of change in the drylands (MEA, 2005). In the first, the 'degradation' narrative, drylands are seen as victim to the misuse of the land (overcultivation, overgrazing, deforestation, salinization under irrigation).

Desertification is understood as 'land degradation' caused partly or wholly by human activities, but the agency of climate was recognised after 1992. Hence the use of the term 'combating' by the UNCCD and other agencies, conveying a sense of global urgency, reflected in the use of military terminology. As widely agreed, it is an unfortunate concept, for it removes all precision from the debate and is an inappropriate way of characterising the subtleties of land use management. The second narrative

Table 2. Land and soil degradation in the Sahel (per cent)

Soil degradation	Light	Mod	Strong	Extreme	Total
	13.6	10.0	3.8	0.4	27.9
Water erosion	12.1	3.1	2.3	0.3	17.8
Wind erosion	19.5	12.4	0.6	0.1	32.6
Chemical deterioration	3.2	1.1	0.6	0	4.9
Physical deterioration	2.3	1.1	0.4	0	3.8
"Main causes" of soil degradation					
	Overgrazing	Over cultivation	Over exploitation	Deforestation	Total
	14.8	4.3	6.8	2.0	27.9

Source: World Atlas of Degradation (UNEP, 1992).

is based on detailed field studies in areas where elements of sustainable land use have evolved through time. This counter-narrative learns lessons from local experience with a view to supporting and extending sustainable practices that already exist, with appropriate policies. It takes an opportunistic rather than a 'doomsday' view. Of course, the two narratives merge on some common ground. As mentioned earlier, the IUCN and the forthcoming UN reports on the global drylands focus attention on the potential of the drylands rather than on scenarios of environmental breakdown. Key international documents, including reports from the IUCN (2009), UNEMG (2011), and UNDP/UNCCD (2011), now focus attention on the potential of the drylands rather than on scenarios of environmental breakdown.

Sustainable soil management is of central importance for dryland agriculture. There are two paradoxes here. The first is that having attempted, through project interventions over several decades, to change local practice in favor of 'modern' technologies, the science of agricultural development now pays more attention to local knowledge and practice than it did 50 years ago. Such local practices include the intensive smallholder system of the Kano Close-Settled Zone, reliant on mainly organic fertilization through mixed crop and livestock husbandry. Several other systems where land and livelihoods demand sustainability are described in the literature (Mortimore, 2005). The paradox lies in the fact that these cases stand Malthusian determinism on its head, for they are densely populated. Erosion tends to be greater where there are fewer people (Tiffen *et al*., 1994). The technologies used are labour-intensive, hand technologies. Any departure from these in favor of labor-saving methods increases the risk of soil erosion or degradation.

This dilemma opens the second paradox: conservation agriculture (CA), now being energetically promoted internationally, aims to eliminate (or reduce) tillage as the main cause of soil degradation and erosion:

Conservation agriculture is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (www.fao.org/ag.ca/la.html).

The key principles of conservation agriculture are: minimum tillage, permanent organic soil cover and diversification of crop species (rotations or associations).

Since mechanical tillage originated and developed in response to a need to save labor, the challenge posed by CA is clear. The relations between smallholder agriculture, technology and labor need to be re-thought. It seems likely that solutions to this paradox will be very specific to the farming system in question. CA does not reverse the course of agricultural science, but steers it away from tillage machines towards organic and intensive applications, such as sustainable rice intensification (SRI). Dryland applications of these new ideas, addressing the needs of smallholders with multipurpose systems, are urgently needed.

Promoting Investment

Investment is critically important in drylands, many of which have suffered neglect (IUCN, 2009). It falls into two categories: public and private. In Nigeria, the drylands have

benefited from investments in infrastructure (roads, mobile phone systems, airports, new LGA and State headquarters, educational and health facilities), not a few of which are due to decentralisation of government functions and accountability. Many of these public investments are the fruits of an oil-based economy, and not found in other dryland states; on the other hand, the constitutional model in which power is devolved to 37 states is very expensive to operate.

Often forgotten in discussions of investment is the use of personal savings that smallholders make all the time in their farms, flocks or herds, many of them the fruit of labor rather than financial resources. Sustainable agriculture calls for investment, in soil and water conservation, enclosures, soil fertility treatment, and input purchases. Pastoralists invest in animal health and herd management. Protected trees are a form of investment in a more sustainable landscape. A concrete way of encouraging small-scale investments is thus to offer asset protection in time of drought/food emergency, and experimental projects in drought risk insurance are already operating in Ethiopia. Thus while it may be true that the drylands need more investment, much could be achieved by better protecting what has already been invested.

An analysis of investment in drylands (UNEMG, 2011) argues for a disaggregation of investment opportunities by aims (why invest?), agency (who invests?), typology (what investments?) and beneficiaries (who benefits?). Multiplying out this matrix reveals the diversity of sectors and actors that may be involved. A case is made for getting away from the idea that dryland investment has to be implemented by the public sector because of expected low returns, and instead, adopts a market-oriented framework better suited to increasing global interaction and innovation. The role of policy is to provide incentives.

Some drylands have become 'investment deserts', an observation that is borne out in a comparison with developed, industrialized and urbanized drylands in other countries. Within drylands, private capital tends to be channelled into the cities for building houses and businesses. The 'success stories' of sustainable dryland systems in poor countries are founded on maintaining flows of private micro-investments into profitable enterprises.

Poverty reduction-only through agriculture?

An unacceptably large proportion of dryland people are poor by global standards.The Millennium Development Goals, to be achieved between 1990 and 2015, include five targets that are relevant to natural resource management in the drylands:

1. Halve the proportion of the population with incomes < \$1 day^{-1}
2. Halve the proportion who suffer hunger
3. Prioritise sustainable development in policies, and reverse the loss of environmental resources
4. Halve the numbers without access to safe water
5. Improve the lives of >= 100 million slum dwellers

According to the Drylands Development Centre of the UN, achieving the MDGs in drylands faces four groups of challenges. After some re-ordering, these emerge as follows. The first is climatic and ecological challenges, such as low and variable rainfall, climate change, frequent droughts, and land degradation. The second is economic challenges - poor infrastructure and limited markets – which inhibit investment. The third consists of policy and institutional barriers such as too little voice for poor people in policy making, weak policies on access to natural resources, and little recognition of the links between poverty and environment. Finally (and sometimes most important) is a bundle of disparate issues summed up as 'socio-cultural challenges' such as pastoral ways of life, gender inequalities, and civil conflict (UNDP, 2005).

After a long period of neglect, agriculture is back at the top of the development agenda, including that of the World Bank (World Bank, 2007). Among the reasons for this change of heart are: (1) agricultural growth, especially in smallholder economies, benefits the most people; (2) its benefits trickle down to the poorest; (3) a prosperous agricultural sector creates employment in associated services, processing and marketing activities; and (4)

agricultural exports bring in foreign exchange. Provided that pastoralism is included, this shift in the agenda can bring benefits to all dryland peoples.

However, can or should agriculture be the exclusive foundation of poverty reduction in drylands? To read many project or programme documents, one might think so. Agriculture supports livelihoods at the level of the household. However, exclusive dependence on agriculture is declining with the progressive diversification of livelihood portfolios in response to new income earning opportunities, cheaper travel, increased education, and also to impoverishment from droughts and other disasters. This is not new. In northern Nigeria, seasonal migration is an ancient practice (*cin rani*). Recently, not only has it increased quantitatively, but it is becoming common for young men to absent themselves from the family farm even during the growing season. If the opportunity costs of staying at home to farm become too high, this has a negative impact on productivity, sustainability and farm incomes.

Also at the household level, the women do not generally enjoy equal access to land, nor to income benefits, and may be impoverished if widowed or divorced. While not free to migrate, they have good reason to diversify into small-scale trading based on gathering, cooking, processing or crafting articles for sale. Women are often the guardians of local knowledge on, e.g., famine foods available from the ecosystem. The root of their inequality is insecure rights to land. But the extent of their involvement in field work varies according to customary practices as well as along a 'modernization' gradient. Thus the popular prescription of some development agents to target 'women farmers' needs further refinement to specific cultural and social conditions if it is to have beneficial impact.

Thus even as development agencies have promoted productivity in agriculture, dryland peoples have searched diligently for alternatives, a trend that is now recognised as nearly universal, and not only in drylands. Entrepreurial development is now on the development agenda for poor rural communities. Enhanced income from outside the agriculture sector will increase demand for locally produced food commodities, which in turn will provide incentives for micro-investments.

The 'sustainable livelihoods approach' to development (SLA) was promoted during the 1990s and has drawn attention to the common position of agriculture as one component (if often the most important) in a complex and dynamic livelihood system. One response to this complexity is to insist on covering all the possible impacts of an innovation on multiple system variables. This may prove to be impossible. A better alternative is to practice participatory development in which the intended beneficiaries play a full part in defining the goals, designing the project, executing it and monitoring its success or failure. Local ownership will expose the interactions and stakeholder interests, though it will not necessarily achieve equity in the distribution of benefits.

A recently published study from the UNDP shows that basic services including education and health provision are significantly correlated with equitable economic growth in Third World countries (Mehotra and Delamonica, 2007). Nigeria has moved quickly to establish educational institutions in its dryland region since Independence, but especially since the creation of new states. The global study thus supports the Nigerian strategy. More research based knowledge, too, will contribute to developing the drylands, meeting the MDGs, and (hopefully) to sustainable improvements in well-being.

Conclusion

The argument summarised above is organised around eleven paradoxes. These are summarised in the Abstract. In Nigeria, as in other countries, in-depth analysis of change over time can expose the drivers of change, the challenges for adaptation, and the opportunities for development. They form an essential element of a comprehensive understanding of dryland challenges.

Science and technology have prioritised production, conservation, and other new practices. It is argued that interventions (through policies, programmes or projects) in natural resource management in the drylands need to build on careful analysis of what is already there (knowledge, experience, investments, institutions) and move with the direction of positive change, rather than trying to achieve a revolution. An interdisciplinary approach will

be necessary because of the complexity of the system, and it should build on a robust theory of dryland development rather than merely on an assumed degradation scenario.

It is time for a new paradigm of dryland development. The challenge for the future is multiple: to engineer the incentive structure for profitable and sustainable dryland agriculture, livestock keeping and woodland management; to make the best use of local as well as scientific knowledge; to promote market participation; to maintain a collaborative framework in which shared ownership (including local partners) should both design and carry out projects or programmes. The concepts are generic but the battle will be won at the national scale, within a specific policy and institutional framework.

Acknowledgements

The author is grateful to Stefanie Hermann for the use of Figs. 6 and 7 and to Beryl Turner for Fig. 3. Figs. 3 and 4 are reproduced by permission of Drylands Research, UK, Fig. 5 by permission of Routledge, London, and Figs. 6 and 7 by permission of IUCN (World Conservation Union).

References

Adejuwon, J.O. 2006. Food crop production in Nigeria. II. Potential effects of climate change. *Climate Research* 32: 229-245.

Adejuwon, J.O., Odekunle, T.O. and Adejuwon, S.A. 2006. *Climate Variability and Food Security in Nigeria.* Ile-Ife: Obafemi Awolowo University Press.

Ariyo, J.A. and Mortimore, M. 2012. Youth farming and Nigeria's development dilemma: The Shonga experiment. *IDS Bulletin* 43(6): 58-66.

Ariyo, J.A., Voh, J.P. and Ahmed, B. 2001. Long-term change in food provisioning and marketing in the Kano Region. Drylands Research Working Paper 34 (34) 2001. Crewkerne, United Kingdom, Drylands Research.

Bolwig, S., Rasmussen, K., Hesse, C., Hilhorst, T. and Hansen M.K. 2011. New perspectives on natural resource management in the Sahel. Copenhagen, Department of Geography and Anthropology, University of Copenhagen.

Boubacar, Y. 2000. Évolution des régimes de propriété d'utilisation des ressources naturelles dans la région de Maradi. *Drylands Research Working Paper 29.* Drylands Research, Crewkerne.

Bourn, D. and Wint, W. 1994. Livestock, land use, and agricultural intensification in sub-Saharan Africa. *Pastoral Development Network Working Paper No 37a.* Overseas Development Institute, London, UK.

Busso, C.S., Devos, K.M., Ross, G., Mortimore, M., Adams, W.M., Ambrose, M.J., Alldrick S. and Gale, M.D. 2000. Genetic diversity among landraces of pearl millet (*Pennisetum glaucum)* under farmer management in West Africa. *Genetic Resources and Crop Evolution* 47: 561-568.

Cline-Cole, R.A., Falola, J.A., Main, H.A.C., Mortimore, M., Nichol, J.E. and O'Reilly, F.D., 1990. *Wood Fuel in Kano.* United Nations University Press, Tokyo.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. and Twomlow, S. 2008. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment* 126(1-2): 24-35

Cour, J.M. and Snrech, S. (Eds.) 1998. *Preparing for the Future: A Vision of West Africa in the Year 2020.* Summary Report of the West Africa Long Term Perspectives Study. Paris:Club du Sahel, OECD.

Ecklundh, L. and Olsson, L. 2003. Vegetation index trends for the African Sahel 1982-1999. *Geophysical Research Letters* 30(8): 1430.

Faye, A., Fall, A., Tiffen, M., Mortimore, M. and Nelson, J. 2001. Policy Requirements for Farmer Investment in Semi-Arid Africa: Senegal Series: Djourbel Region: Synthesis. Working Paper 23e. Drylands Research, Crewkerne, UK.

Federal Republic of Nigeria 2006. *Population and Housing Census. Abuja:* National Population Commission, 2010.

Forrest, T. 1993. *Politics and Economic Development in Nigeria.* Boulder, Colorado: Westview Press (cited in Mustapha and Meagher, *ibid.,* p. 36.

GTZ 2008. *A Roadmap for Biofuels in Kenya. Opportunities and Obstacles.* Federal Ministry for Economic Cooperation and Development, Bonn.

Harris, F.M.A. 1998. Farm-level assessment of the nutrient balance in northern Nigeria. *Agriculture, Ecosystems and Environment* 71: 201-214.

Herrmann S.M., Anyamba, A. and Tucker C.J. 2005. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change* 15: 394-404.

Hill, P. 1977. Population, prosperity and poverty. Rural Kano, 1900 and 1970, Cambridge University Press, Cambridge.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4: 1-23.

Holling, C.S. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* 4: 390-405.

Hulme, M. 1996. Climate change within the period of meteorological records. In *The Physical Geography of Africa* (Eds. W.M. Adams, A.S. Goudie and A.R. Orme), pp. 88-102. Oxford University Press, UK.

IISD 2008. *A Summary Report of the Africa Carbon Forum.* International Institute for Sustainable Development: http://www.iisd.ca/africa/acf/

IUCN 2009. *Dryland Opportuinities: A New Paradigm for People, Ecosystems and Development,* p. 13

Kratli, S. 2008. Time to outbreed animal science? A cattle breeding system which exploits structural unpredictability. The WoDaaBe herders in Niger'. *STEPS Working Paper 7.* Brighton: Institute of Development Studies.

Mazzucato, V. and Niemeijer, D. 2000. Rethinking Soil and Water Conservation in a Changing Society, Tropical Resource Management Paper 32, Wageningen University and Research Centre.

Mehotra, S. and Delamonica, E. 2007 *Eliminating Human Poverty. Macroeconomic and Social Policies for Equitable Growth.* Zed Books in Association with International Studies in Poverty Research and the International Social Science Council, London.

Middleton, N. and Thomas, D. 1992. *World Atlas of Desertification,* 2nd Edn. Edward Arnold for the United Nations Environment Programme, London.

Middleton, N. and Thomas, D. (Eds.) 1997. *World Atlas of Desertification, 2nd Ed.* Edward Arnold for UN Environment Programme, London.

MEA (Millennium Ecosystem Assessment) 2005. *Chapter 22: Dryland Ecosystems*, pp. 623-662.

Mohammed, S. 1994. Evaluation of multipurpose uses of trees, shrubs and grasses, conditions of access and smallholder management in a village in the semi-arid north-eastern Nigeria. *M.Sc. Thesis*, Department of Geography, Bayero University, Kano.

Mortimore, M. 1993. The intensification of peri-urban agriculture: The Kano Close-Settled Zone, 1964-1986. In *Population Growth and Agricultural Change in Africa* (Eds. B.L. Turner II, R.W. Kates and G. Hyden) pp. 358-400. Gainsville: University Press of Florida, USA.

Mortimore, M. 2001. Hard questions for pastoral development: A northern Nigerian perspective, In *Elevage et gestion de parcours au Sahel, Implications pour le développement*, (Eds. E. Tielkes, E. Schlecht, and P. Hiernaux), pp. 101-114, Stuttgart, Germany: Verlag Grauer.

Mortimore, M. 2003. The future of family farms in West Africa. What can we learn from long-term data? *Drylands Programme Issue Paper No. 119.* London: IIED

Mortimore, M. 2005. *Why Invest in Drylands?* Global Mechanism for the UNCCD, Rome.

Mortimore, M. and Adams, W.M. 1999. *Working the Sahel: Environment and Society in Northern Nigeria,* p. 105. Routledge, London.

Mustapha, A.R. and Meagher, K. 2001. Agrarian production, public policy and the state in Kano Region, 1900-2000. *Kano-Maradi Study of Long-term Change: Niger-Nigeria Series.Working Paper 35.* Drylands Research, Crewkerne, UK.

Raynaut, C., Grégoire, E., Janin, P., Koechlin, J. and Lavigne Delville, P. 1997. *Societies and Nature in the Sahel*. Routledge, London.

Reij, C., Larwanou, M., and Abdoulaye, M. 2006. Etude de la régénération naturelle dans la région de Zinder (Niger), International Resources Group (IRG), Washington, DC.

Reij, C. and Thiombiano, T. 2003 *Developpement Rural et Environnement au Burkina Faso*. Vrije Universiteit, Amsterdam.

Reynolds, J.F. and Stafford Smith, D.M.e. 2002. Global desertification. Do humans cause deserts? Dahlem University Press, Berlin.

Reynolds, J., Stafford Smith, D.M., Lambin, E.F., Turner, B.L. II, Mortimore, M., Batterbury, S.P.J., Downing, T.E., Dowlatabadi, H., Fernadez, R.J., Herrick, J.E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M. and walker, B. 2007. Global desertification: Building a science for dryland development. *Science* 316: 847-851.

Roncoli, C., Ingram, K., and Kirshen, P. 2002. Reading the rains: Local knowledge and rainfall forecasting in Burkina Faso. *Society and Natural Resources* 15: 409-427.

Shepherd, G. (Ed.) 2008. *The Ecosystem Approach: Learning from Experience.* IUCN, Gland, Switzerland.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.e. 2007. Climate change 2007. The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPPC 2007. *Climate Change 2007. The Physical Science Basis.* Contribution of Working Group 1 to the Fourth Assessment Report of the Inter-Governmental Panel on Climate Change. Cambridge University Press, 859 p.

Tiffen, M. 2001. Profile of demographic change in the Kano-Maradi Region, 1960-2000. 2001. Crewkerne, United Kingdom, Drylands Research. Drylands Research Working Paper.

Tiffen, M., Mortimore, M. and Gichuki, F. 1994. *More People, Less Erosion: Environmental Recovery in Kenya.* John Wiley, Chichester.

Tucker, C.J., Dregne, H.E. and Newcomb, W.W. 1991. Expansion and contraction of the Sahara Desert from 1980 to 1990. *Science* 253(5017): 299-301.

UNDP 2005. *The Global Drylands Imperative. Implementing the Millennium Development Goals in the Drylands of the World.* Drylands Development Centre, UNDP, Nairobi.

UNDP and UNCCD 2011. *The Forgotten Billion: MDG Achievement in the Drylands.* United Nations Development Programme and UN Convention to Combat Desertification.

UNEMG 2011. *Global Drylands: A UN System-wide Response*. Environmental Management Group, United Nations.

UNEP 1992. *World Atlas of Desertification.* Edward Arnold for the UN Environment Programme, London.

UNEP/GEF 2005. *Integrated Ecosystem Management of Trans-Boundary Areas of Niger and Nigeria Phase I.* UN Environment Programme/Global Environmental Facility Project GEF/GFL 2328-2770-4889.

Vogt, G. and Vogt, K. 2000. Hannu biu ke tchudu juna-strength in unity: a case study from Takieta, Niger. (2). 2000. London, IIED/SOS Sahel. Securing the Commons Series.

World Bank 2007. *World Development Report 2008: Agriculture.* The World Bank, Washington, DC.

World Bank 2010. *Awakening Africa's Sleeping Giant. Prospects for Commercial Agriculture in the Guinea Savannah and Beyond.* The World Bank, Washington, DC.

Printed in April 2013