Chapter 3
Changing Paradigms for People-Centred Development in the Sahel

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Abstract Key paradigm changes are discernible in the science of desertification or land degradation in the West African Sahel. These have been characterized as a shift from a ‘desertification’ to a ‘resilience’ paradigm. The first of these positions, based on an equilibrial model of social-ecological systems, refers to a range of measurable changes which are unilinear with a strong likelihood of irreversibility. The second is based on a disequilibrial model which begins with evidence for sustainable practices under local knowledge and management of variability. Whereas the desertification paradigm attempts to correct misuse through exogenous interventions, designed to transform natural resource management by improved technologies, the resilience paradigm, based on optimizing endogenous capacities, offers an evolutionary trajectory of development adapted to the constraints of small-scale farming and pastoralism. Guided by this distinction, the complexity and variability of the social-environmental systems in the Sahel are disaggregated under the following headings: bio-productivity changes as reflected in remote sensing; rangeland management; deforestation (the expansion of cultivation, burning, fuelwood cutting and the transition to sustainable practice); and soil nutrient management. Against the backdrop of rapid demographic change, poverty reduction and adaptive capacity are briefly reviewed. An ‘escape from Malthus’ is being attempted through a smallholder intensification pathway in situ and an income diversification pathway that extends to non-local opportunities. Governments, donors, and other agencies can use these as a platform for policies and interventions.

Keywords Adaptation · Desertification · Dryland farming · Sahel · Variability

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3.1 Change and Complexity in the Sahel

A conception of drylands as a major global biome has now emerged as a policy priority, against a background of the Millennium/Sustainable Development Goals, recognizing that in view of the drylands' spatial extent (41 % of global land surface) and demographic weight (35 % of global human population), the Goals will not be achieved without making substantial progress in the drylands. The global drylands have recently been unwrapped in a series of policy-oriented studies published by international organizations (IUCN 2009; UNDP/UNCCD 2011; UN/EMG 2011; Davies et al. [IUCN] 2012). All place emphasis on natural resource (or ecosystem) management and all draw attention to Sahelian local experience and knowledge.

Relations between society and environment in the West African Sahel region are intimately bound up with the variable rainfall, in space as well as time. They are highly complex in terms of the heterogeneous and interactive nature of social and environmental systems. And they are dynamic, in the sense that subtle and multi-dimensional changes—some slow, some fast—have taken place in the past, and still continue. This ecological and social diversity overlays the deceptive regularity of the moisture gradient from southern (sub-humid) through semi-arid and arid to northern (hyper-arid) biomes.

In terms of the theme of this book, this characterization presents a major challenge to development policy, debate and practice. For a long time, debate has been dominated by global diagnostics such as desert advance, irreversible land degradation, or deforestation. The persistence (and influence) of what we term here the 'desertification paradigm' in scientific, policy and international discourse on the Sahel has hitherto tended to prefer diagnostic-prescriptive framings imposed 'top-down' by governments and external actors. Yet while research studies at micro-scale have presented nuanced analyses of environmental intimacy, complexity and dynamics in specific social-ecological systems, they have not adequately informed the design of policies and interventions at macro-scale, which tend to reflect the viewpoint of the state, informed by science rather than local people (Scott 1998).[1]

3.2 The Desertification Paradigm

Desert advance in regions bordering the southern Sahara is an idea that goes back to early 20th century perceptions (Davis, this volume; Mortimore 1998): 'desséchement' (Hubert 1920); desiccation (Bovill 1921), desert advance (Stebbing

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[1] The literature is too large to review. For examples, Raynaut et al. (1997) set out the interactions between social and agro-ecological systems in the Sahel region, Mortimore and Adams (1999) show the complexity of these relations at micro-scale, and Cour and Snrech (1994) identified the long-term regional dynamics and predicted future trajectories of change up to 2020.

1935), desertification (Aubréville 1949), progressive aridity and 'ensablement' (Chevalier 1950). 'Misuse' of the land by local people (Timberlake 1986) has transformed the less arid into more arid woodland and thus to move the latitudinal vegetation zones southwards over time, with negative implications for productivity. Estimates were made of the rate of desert advance (USAID 1972; Lamprey 1975; Ibrahim 1978). The idea is not yet dead (UNEP 2007).

The seeming culpability of humans was endorsed by the United Nations Conference on Desertification (UNCOD 1977: 3) and according to the (then) Director General of UNEP, six million hectares of land were lost 'totally' each year and, in a further 21 million hectares, productive capacity was 'reduced to the point of zero economic productivity' (Tolba 1986). However, under fire from critics, the inclusion of natural causes (rainfall and drought) and a preference for the less emotive expression 'land degradation' resulted in the definition published in the first edition of the *World Atlas of Desertification* (Thomas and Middleton 1992) being adopted at its inception by the UN Convention to Combat Desertification (UNCCD 1993):

> Desertification is land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities

which included soil erosion caused by wind and/or water; deterioration of the physical, chemical, and biological or economic properties of soil; and long-term loss of natural vegetation (UN Convention to Combat Desertification, Part 1 (Introduction), Article 1, Use of terms).

Popular perceptions are still framed by the first edition of the *Atlas,* and its successor, the second edition (Middleton and Thomas 1997). A fundamental challenge is encountered in separating natural-induced from human-induced processes or causes (Thomas and Middleton 1992, p. 11; Reynolds and Stafford Smith 2001).

The assessment of global land degradation employed in both editions of the *World Atlas of Desertification* relied heavily on GLASOD (Global Assessment of Human-induced Soil Degradation), a survey of homogeneous landscape units compiled from subjective reports by 250 soil scientists (Oldeman and Hakkeling 1990). This assessment concluded that soil degradation affected 224 million hectares of drylands, at four levels of severity (light, moderate, strong and extreme) (Table 3.1). Degradation includes wind and water erosion, chemical, and physical

Table 3.1 GLASOD data on the Sahel (millions of hectares)

	Water erosion	Wind erosion	Soil nutrient depletion	Physical deterioration	Human induced soil degradation
Light	97.5	156.2	25.6	18.7	109.8
Moderate	24.7	99.5	8.8	8.7	80.3
Strong	18.2	4.9	5.0	3.1	30.8
Extreme	2.2	0.8	0	0	3.1

Source Middleton and Thomas (1997)

Note Figures relate to the continental Sahel and include Sudan and parts of eastern Africa (total 802.3 million hectares) deterioration, superimposed on a global vegetation index (GVI) derived from satellite radiometer data (averaged from 1983 to 1990).

The expert assessments were delivered at a point in time, rather than being based on change in key variables over a known period. The severity categories thus indicate states rather than rates of change. The 'global maps are designed to give an overall, if exaggerated, impression of the scale of the soil degradation problem world-wide' (*ibid* 1997: 17). GLASOD defined soil degradation as 'human-induced phenomena which lower the current and/or future capacity of the soil to support human life' (*ibid,* 1: 11). According to Middleton and Thomas (1997: 71), the main causes of soil degradation in the Sahel are: overgrazing (118.8 million hectares), agriculture (34.8), "overexploitation" (54.2), and deforestation (16.3 million hectares).

Over a period of eight decades (1920s–1990s), desertification was consolidated, in an influential expert orthodoxy, as a product of misuse of the land by indigenous farmers and pastoralists, factoring in a changeable climate and underlying population growth (Eckholm and Brown 1977). The implicit basis of the desertification paradigm (WRI 2005: Chap. 22) is the idea of an ecosystem at equilibrium in which a perturbation is normally followed by a natural readjustment back to a stable state. Within this frame, the 'advancing Sahara' hypothesis implied a risk of an irreversible form of land degradation which (if caused by humans) called for urgent interventions with the aim of arresting unsustainable practices and restoring an ecosystem to its baseline state.

The UNCCD has consistently addressed this theory of change in the global drylands, and its current goal is

> to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effects of drought in affected [arid and sub-humid] areas in order to support poverty reduction and environmental sustainability (www.unccd.int).

The desertification paradigm adopted a diagnostic of human agency (Garcia and Escudero 1982; Garcia and Spitz 1986) in a crisis scenario, a prioritization of scientific (as opposed to local) knowledge, a prescription of urgent technical interventions to transform land use practices, and (to achieve this) the mobilization of resources on a grand scale. Its institutionalization in the form of the UNCCD and funding channels for 'desertification control' raised the profile of counter-measures at the expense of independent scientific analysis. However, science and practice are now achieving better convergence in some areas of natural resource management in drylands.[2]

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[2] Reynolds et al. (2007). Work on 'desertification indicators' commissioned from an independent panel of scientists by the UNCCD for the Buenos Aires Conference of the Parties (2009) is published in 'Special Issue on Understanding Dryland Degradation Trends' *Land Degradation and Development* (2011), vol 22/2. Subsequently work on economic issues is ongoing.

3.3 Questioning the Dominant Paradigm: Resilience

In contrast to the ‘desertification paradigm’, which asserts degradation in the natural ecosystem, and its consequences for the social system, and advocates changes in practice based on science, an alternative view focuses on the evidence of adaptive capacities based on local knowledge of small-scale farming and pastoralism. This view points to the failure of many development interventions and yet to the ‘success stories’ of transitions to sustainable practices based on full participation and building on local experience (Safriel et al. 2005). Given the environmental variability with which farmers and pastoralists have to contend, their ‘repertoire’ of livelihood strategies and technologies enables them to adapt to change not necessarily by returning to the status quo (as predicted in an equilibrium model), but to manage state-changes in the social-environmental system (a non-equilibrial model) (Hesse et al. 2013).

Originating in ecological science, the idea of resilience in this usage recognizes that the natural ecosystems in drylands are not characteristically at equilibrium. As their productivity depends directly on variable rainfall, they are better understood as in a state of non-equilibrium and uncertainty. Extreme events—droughts, or floods—may lead to species loss and replacement. But the ecosystem retains its structure and functional integrity (Holling 1973, 2001)—it is said to be unstable but resilient.

The resilience model has been applied to nomadic pastoralism where herd mobility is the principal (but not the only) response to variability in the natural environment (Benhke et al. 1993). Evidence from interviewing Sahelian farmers suggests that such a view fits the strategies employed to manage their livelihoods under conditions of uncertainty. Such flexibility is driven in the first place by drought (Adams and Mortimore 1997) and expressed in an inventory of adaptive strategies for dealing with rainfall variability (Table 3.2): in agronomy, crop selection, wild food sources, timber and non-timber forest products for sale, manufacturing, processing, services and labour hiring within the community or migration on a seasonal or longer term basis for earning incomes further afield. For pastoralists the essence of adaptation is still herd mobility, in response to spatial and temporal variability in pastures and fodder. The advantages of adaptive range management, spatial mobility, herd management and breeding is apparent in every study of Sahelian pastoralism from the past (e.g., Stenning 1959; Dupire 1962) to the present (e.g., Krätli 2008).

In an extension of the model, it is contended that resilient adaptation is also driven by the need to maintain productive resources—soils, woodland, animals—in the longer term (Table 3.3). Managing variability is not always easy to distinguish from sustainable use of natural resources: the first is episodic, the second longer term (‘combating desertification’). But adaptation in the longer term includes a measure of labour intensification, which is a response both to necessity (as ‘saturation’ gradually overwhelms ‘free land’ in the economy of colonization) and to growing market opportunities for staple and niche foods and animal products (in an economy of urbanization). These changes amount to investments—at a micro-scale—in smallholder intensification.

Table 3.2 An inventory of adaptive strategies to variability

Elements of the social-ecological system	Activity change	Beyond the household	Outside the area
Crop farming (rainfed or irrigated)	Re-planting Buy borrow or beg seed Reduce fertilization Change crop mixtures (drought resistant or tolerant varieties) Increase or reduce weeding Cultivate more wetlands Make do with less farm labour	Transfer farm labour to another system Hiring out own labour sell assets (land)	Hiring out own labour through migration to urban or more humid areas
Livestock breeding/keeping	Optimize herd mobility to access spatial-temporal variability of pasture Manage animal health Sell surplus bulls and vulnerable cows Make do with less labour Purchase water	Plant and grow crops (agro-pastoralists) Herding contracts with farmers' livestock Sell breeding/producing stock	Hiring out own labour through migration to urban areas Transhumance
Fishing (where surface water)	More or less depending on the resource	Absorb farm labour (at harvest time)	Set up camps near seasonal floods Urban sales
Forestry/tree management	Protect regenerating useful trees on farms Increase trimming and lopping for fuelwood Plant shade and fruit trees, tree lots, boundaries	Absorb additional labour cutting/selling fuelwood	Sell fuelwood to traders from other areas
Harvesting non-timber forest/wild products	Conserve knowledge of wild foods Increase intensity of collection Extend collecting from more to less preferred edible plant parts Process and cook wild foods	Absorb additional labour	Sell high value wild products to traders

(continued)

Table 3.2 (continued)

Elements of the social-ecological system	Activity change	Beyond the household	Outside the area
Manufacturing local materials	harvest raw materials, especially dum palm fronds increase output of marketable products	absorb additional labour making/selling mats, ropes, baskets	sell manufactures to traders
Service provision	Increase sale of ready foods, confectioneries Visit more local markets	Begging, patron-client relationships	Visit markets outside the area Unskilled employment in towns (e.g., guards) Begging in urban centres
Paid employment	Send more people to find jobs elsewhere		
Trading	Bulking local products for export	Absorb additional labour	Transport and sell livestock or other commodities in urban centres

Sources Various

A recent study by the IUCN argues that the key to sustainable dryland development is to reverse the status of drylands as 'investment deserts' (IUCN 2009). This theme is taken up in an analysis of dryland investment opportunities in a UN System-wide Response (UN 2011), and reiterated in a new report from UNDP-UNCCD (2011). Responses to perceived land degradation, at the smallholder level, are constrained by capital scarcity and for this reason consist of incremental, small-scale processes, whether assisted by donors and governments or autonomously financed using private savings. A large part of the value added may come from family labour, analytically indistinguishable from current operations, though with time an increasing access to financial capital is visible in drylands as in more favoured biomes.

Adaptation can go wrong. Among such strategies there lurk possibilities of maladaptation or dysfunctional adaptation, which leads to increased vulnerability to climate variability or change, including for other stakeholders (Magnan et al., in prep.). Maladaptation is a real possibility where external actors misjudge the impact of interventions by the state and its partners (Scott 1998); or on a local scale, where rights to resources are contested between stakeholders, for example between farmers and graziers. The resilience model accords higher status to local knowledge, practice and capacity in managed dryland ecosystems.

Evidence of such incremental growth into greater resilience in farming ecosystems of the West African Sahel is provided in meso- and micro-scale studies, for example: Senegal (Faye et al. 2001), Burkina Faso (Mazzucato and Niemeijer 2000; Reij and Thiombiano 2003), Niger (Mortimore et al. 2001) and northern Nigeria (Mortimore 1993; Mortimore and Adams 1997). Resilience does not mean

Table 3.3 Adaptation to land degradation

Elements of the social-ecological system	Incremental adaptations through autonomous investments
Crop farming (rainfed or irrigated)	Increase irrigated wetland cultivation (engineering, water management, negotiated use rights) Obtain livestock Increase nutrient cycling through livestock or composting Increase weeding frequency Intercrop grain with legume (N-fixing) crops Reduce plant spacing Soil and water conservation (ridging, terracing) Grazing/manuring contracts with herders Purchase fertilizers (incl. manure) Protect natural regeneration of on-farm trees
Livestock breeding or keeping	Breed for optimal performance in variable conditions (not for maximum milk) Increase mobility/transhumance where better grazing opportunities allow Cut-and-carry feeding during growing season Maximize use of crop residues (own, purchased or contracted) Purchase feedstock
Forestry/tree management	Protect regenerating trees on farmland, boundaries and cattle tracks Community reservation of woodlands and controlled grazing Community managed tree lots
Harvesting non-timber forest/wild products	Community protection of valuable natural resources Community control of exported scarce natural products, esp. fuelwood
Manufacturing local materials	Community protection of valuable natural resources
Paid employment	Send more children to school for qualifications Extend education to higher ages Send more people to find jobs Diversify employment sources Use migrant remittances for productive investments
Trading	Invest in buying and selling

Sources Various

universal improvements in well-being. In the Kano region of northern Nigeria, signs of pressure, some negative, have accompanied the evolution of the social-ecological system (Maconachie 2007). Nor does it offer certainty in predicting the future. Development indicators across a range of householder activities are needed to assess resilience and adaptive capacity. In the Sahel as a whole, a degree of resilience is implied in the evidence that average food production per capita has not fallen below (though it has struggled to keep up with) growth in the human population, despite very high rates of human fertility.[3]

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[3] FAOSTAT, Rome: Food and Agriculture Organization of the UN.

In order to progress this argument, in the following sections, the desertification debate is disaggregated into discourses on bioproductivity (using remote sensing indicators), rangeland management, deforestation (agricultural expansion and biodiversity, burning, and fuelwood cutting), soil nutrient conservation and fertility, and demographic issues (poverty and adaptation).

3.4 Bio-Productivity: The View from Space?

Declining bio-productivity, often claimed to be irreversible, has been central to claims of desertification from the beginning. But empirical, in situ measurements of productivity based on field surveys are limited to small areas and when they are scaled up to larger areas, ecosystems, countries or region, reliability has to be thrown to fortune especially where change over time is targeted. On the other hand, earth satellite data—repeated at regular intervals—offer a compatible basis for estimating environmental change, using the key parts of the spectrum as proxy indicators of biological productivity. Applying this principle, using the Normalized Difference Vegetation Index (NDVI), or ‘greenness index’, to the African Sahel, has produced surprising counter-evidence to the view of progressive degradation. A strongly significant increase was observed between 1982 and 2006 (Fig. 3.1), a trend that is ongoing and has been confirmed in numerous studies (Knauer et al. 2014).[4] The methodology and documentation of these analyses are reviewed by Herrmann and Sop (this volume), Prince et al. (this volume) and Mbow et al. (2015).

Following the Sahel Drought (1972–74), a second major drought cycle (1984–85), and a decline in average annual rainfall of 25 % or more (from the 1960s to the 1990s), the region became (and remains) an archetype of dryland challenges. Many early interventions in natural resource management (e.g., afforestation) failed. Too often they were imposed ‘top-down’ and only inadequately addressed the systemic context (e.g., rainfall variability, mobility in pastoral systems, flexibility in farming systems). Development planning grew naturally from humanitarian relief and assumptions of technology transfer and authoritarian government.

These regional data confirm early findings on the oscillation of the desert edge since the 1980s (Tucker et al. 1991), and confirm a positive correlation between greening and rainfall. Average annual rainfall recovered from an all-time low in the drought cycle of 1984–85 (Eklundh and Olsson 2003; Herrmann et al. 2005; Olsson et al. 2005). The consensus on this recovery—though incomplete and highly variable, between years and seasons (Anyamba and Tucker 2005; Nicholson 2005)

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[4] Remote sensing data has wide-ranging applications including estimating plant parameters (photosynthetically active radiation, leaf area index, plant biomass and primary productivity, evapotranspiration and water content), the assessment of phenology, and crop yield assessment as well as the analysis of vegetation trends since 1982 and of evidence for climate versus management agency (Knauer et al. 2014).

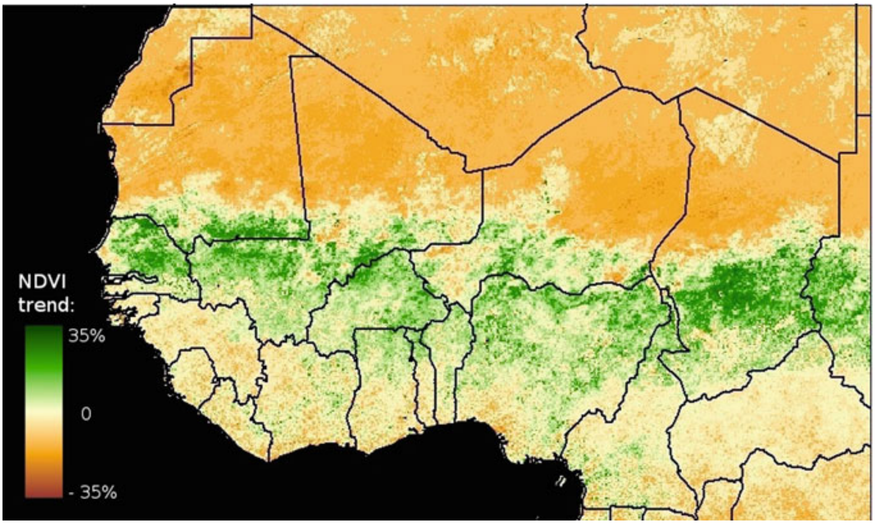

Fig. 3.1 NDVI trend in the West African Sahel, 1982–2006. Monthly NDVI and cumulative rainfall of the same plus the two preceding. *Source* Hermann in IUCN (2009). Technical Note: Linear trends in the NDVI (Normalized Difference Vegetation Index) are shown in percentages. Trends were computed from monthly 8 km resolution AVHRR NDVI time series produced by the GIMMS group, NASA Goddard Space Flight Center, USA, extended from previous work reported in Herrmann et al. (2005) Representations of the 'greenness index' vary in detail depending on the years included and differences in data processing methodology.

confirms the possibility of resilience in Sahelian vegetation in the long term (Hiernaux, this volume; Fig. 3.1). Global trends also appear to be positive (Bai et al. 2008), perhaps reflecting enhanced CO_2 emissions, which would increase biomass production where or when rainfall is not the limiting factor. If this hypothesis is substantiated, the biological productivity of the Sahelian ecosystems, together with the flora, fauna and human communities they support, are globally integrated, in parallel with the linkages discovered between ocean temperatures and Sahelian rainfall (Gianinni, this volume).

The relations between rainfall and vegetation greening are directly affected by the seasonal movements of the West African Monsoon, which vary from year to year, in terms of several parameters including monthly distribution, soil nutrients and moisture, and rainfall use efficiency (RUE: in agriculture, 'crop per drop').[5] These considerations illustrate the complexity and variability of rainfall-greening relationships (Figs. 3.2 and 3.3).

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[5] This is believed to increase with rainfall until a point is reached where other factors (such as soil nutrients) reduce the RUE of total rainfall. In Senegal, according to official statistics, millet and groundnut yields per mm of rainfall RUE increased from 1960 to 1995 against a decline in the rainfall (Faye et al. 2001).

Fig. 3.2 An abandoned millet harvest in north-east Kano State, Nigeria, November 1973 (second year of the Great Sahel Drought).

Fig. 3.3 Bringing in a successful harvest (millet, sorghum, cowpea), eastern Kano State, Nigeria, September 1996 (Note on-farm trees. A year of above-average rainfall).

The positive correlation found between rainfall trends and trends in the greenness index does not necessarily invalidate the thesis of degradation resulting from human activities (including deforestation, grazing, or cultivation). In the regional pattern, regressive relationships are also found locally, possibly reflecting management impact, or soil type. It is likely that some forms of degradation (such as loss of biodiversity, invasion of unwanted species, or declining crop yields) were not picked up by the remote sensing products used or were disguised by the positive effects of increasing rainfall (Knauer et al. 2014)—'net' greening. Much more needs to be done to disentangle the effects of management from those of climate. "What these findings imply in terms of vegetation changes on the ground, however, remains mostly unaddressed in these satellite-based studies" (Herrmann and Sop, this volume). "Many uncertainties exist in regression models" (Mbow et al. 2015).

The use of data from earth satellites offers the possibility of detecting degradation (or sustainability) at landscape scale and monitoring its progression, not only with repeated remote sensing, but by means of integrated social and economic indicators (Nkonya et al. 2010). Remotely sensed data is also useful for monitoring interventions at this scale, and over a long period, such as soil and water conservation in the central plateau of Burkina Faso (stone lines and *zaï* planting holes); and protected natural regeneration in Maradi and Zinder regions of Niger (Reij et al. 2005; Sendzimir et al. 2011). Determining agency for such transformations at a landscape scale is not a simple matter of attributing 'success' to a single intervention. Multiple drivers of change are responsible, including local and science-based knowledge. In Maradi and Zinder, 500,000 ha are claimed to have benefited from protected natural regeneration.

The use of satellite data to estimate bio-productivity has three major drawbacks. First, plant biomass may offer only an imperfect proxy for economic value: for example where invasive plants, useless for grazing, affect the observed values; where standing stocks of timber which grow incrementally may be under-estimated; or where fallow cycles are interspersed with cultivation. On Sahelian farms, biomass production per year (including grain, residues, weeds and compost)—produced in only 3–4 months—may be comparable to that in bush fallows (Mortimore and Turner 2005); so extending agricultural clearance may not be accurately represented as degradation. Second, there is little understanding of what plant formations yield a given NDVI value at a micro-scale, impeding the assessment of change. Third, the history of land use in a given pixel is not known and would be costly to find out; but necessary for the complete understanding of the trends observed. This is relevant to understanding local exceptions to the overall greening trend.

Herrmann (this volume) uses collective recall of pastoralists to build a profile of tree degradation in Senegal; Hiernaux (this volume) finds vegetational resilience through long-term monitoring of grazing land in Burkina Faso and western Niger; and Hof et al. (2006), using ground measurements in conjunction with remote sensing in a grazing reserve in northwest Nigeria, found no evidence of widespread land degradation. Thus, more research is needed to align remotely sensed trends with in situ land use histories.[6]

3.5 Rangeland: Blame the Rain?

Received wisdom from observers of the Sahel Drought of 1969–74 had it that desertification was primarily caused by over-exploitation of natural ecosystems (Mensching and Ibrahim 1977; Garcia 1981; Dregne 1983). By this logic, grazing increasing numbers of animals on a fixed amount of land encounters a bio-productivity threshold and thereafter destroys or modifies pasture communities, resulting in reduced carrying capacity. The dramatic increase in animal mortality and loss of condition that accompanies or follows major drought events in Sahelian rangelands is thus held to indicate ‘overgrazing’ or ‘over-stocking’. Indicators of desertification were considered important from the beginning (Reining 1978). On rangeland, they may include: removal or thinning of grassland communities leaving bare soil surfaces open to erosion; formation of sand dunes or re-activation of stabilized dunes; localized damage around wells and boreholes; changes in the species composition of grasslands in favour of less palatable or preferred species, reducing the supply of fodder per unit area; and the loss of biodiversity (indigenous trees, shrubs or grasses) from savanna.

Such a view was questioned on the ground that insufficient weight was given to hydrological factors, in particular a declining trend in rainfall from the 1960s to the 1990s (Hulme 1992; Hess et al. 1995; Tiffen and Mortimore 2002). If rainfall variability is taken fully into account, it follows that land use was not solely to blame. On the contrary, crop and livestock production systems proved more sustainable than expected: they did not ‘collapse’ (a word commonly used). Since rainfall cannot be manipulated, but land use systems can be, this divergence of view (which is still debated) has important implications for policy. ‘Useful’ moisture (that which contributes to the growth of crops or fodder in a given cropping or grazing system) can be and is manipulated by choices of crop landraces, planting times, and weeding regimes (in dryland farming) or of mobility decisions favouring patches of good growth, desired species and access to water (in pastoralist practice). Rainfall measured in millimeters is only a proxy for moisture that contributes to economic production (see Krätli and Schareika 2012).

Linking degradation exclusively with overstocking and mismanagement sidesteps the impact of rainfall variability (with a coefficient of variability characteristically over 25 %). Carrying capacity is not stable but violently variable. Pastoralism in arid and semi-arid rangelands is based on herd mobility, and is

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[6] The use of an increasing number of different remote sensing products and analytical processing of data is controversial beyond the scope of this discussion.

opportunistic in responding to this variability (Sandford 1983). The condition of livestock depends on fodder successfully accessed, thus indirectly on rainfall, rather than the status of pastures depending on grazing pressure. Animals are lost during and after drought, but herds are rebuilt during wetter years. Debates on this theme (Benhke et al. 1993; Scoones 1994), have given recognition to opportunistic management of non-equilibrial resources, based on systematic seasonal mobility of the herds, as the most gainful strategy for livestock-dependent peoples. Increasing livestock densities in response to good rainfall, and accepting losses in the bad years, does not necessarily lead to degradation. Pastoralism may be understood as a system for conserving, rather than destroying rangeland resources, described as ‘living off uncertainty’ (Krätli and Schareika 2012).

Governments have been very slow to recognize the ecological and economic rationale of pastoral mobility and its implication—that over-grazing is caused by impeding movements with barriers, boundaries and regulation, rather than by allowing moving herds to redistribute grazing pressure and thereby better conserve the ecosystems (WISP 2007). Mobile grazing, though essential, may cease to be viable when pastures are appropriated by other land users (e.g., government projects, farmers, plantations), especially where riverine ‘reserve pastures’ are lost. Straight lines on maps (Scott 1998) cannot reflect the complexity, variability and dynamics of range management as practised by small scale herders (Hof et al. 2006). There is urgent need for land use policies to take account of this reality.

3.6 Deforestation: Destruction or Transition?

This term covers four interlinked dimensions which require separate analysis. Each depends on major data sets whose evolution has driven the perceptions and policies in this sector. The first is the expansion of cultivation at the expense of dry woodland. The second is woodland management and in particular the disputed practice of burning. Third is the energy sector’s reliance on the fuelwood industry. Fourth is the transition to sustainable woodland management.

3.6.1 Expansion of Cultivation

Air photography (since the 1940s) and earth satellite data (since the 1980s), have provided a basis for quantifying land use conversions up to half a century (Table 3.4, Figs. 3.2 and 3.3).

Maradi (Niger) is representative of the Sahel, and the period covered includes the historical peak in rural migration and settlement. Since the end years shown in the table, semi-arid and dry sub-humid zones have approached ‘saturation’—where all cultivable land (unless restrained by forest reserves) is claimed. This, moreover, is accompanied by a significant decline in the average size of holdings. Expanding

Table 3.4 Expansion of cultivated land, mid-late 20th century

Area	Baseline year	Percent	End year	Percent
Djourbel, Bambey Departments, Senegal	1954	82.2	1999	93.3
Maradi Department, Niger	1975	59.0	1996	73.0
Kano State, Nigeria[a]	1950	77.6	1981	88.4
Jigawa State, Nigeria[a]	1950	35.6	1981	54.6
Yobe State, Nigeria[b]	1950	18.9	1990	16.1

[a] One Village Area

[b] Average of two Village Areas

Sources Ba et al. (2001), Mahamane (2001), Mortimore et al. (2001, 2005)

smallholder agriculture, as recorded in these data sets, and extending throughout the Sahel, is sufficiently widespread to play a role not only locally but also in global transformations (climate change, food security and poverty).

The high visibility of agricultural transformation ensured that deforestation figured large in perception and in policy. The colonial forestry departments perceived their mandate as the protection of trees and woodland from reckless indigenous practices, basing their regulatory strategies on 'scientific' knowledge held in opposition to presumed native understanding (Cline-Cole 1997; Ribot 1995). This was to be achieved by reserving forests, banning burning, and requiring permission to fell trees, even on farms, and enforcing its rules with quasi-military forest guards. From natural woodland (or even secondary forest) to open treeless farmland is still commonly equated with reduced biomass and biodiversity, exposure to wind or water erosion, and low crop yields under smallholder 'subsistence' farming. A hostile policy environment—rather than one informed by local knowledge and needs—has not yet completely disappeared from government agendas.

The authoritarian heritage of forest regulatory systems stands in contrast to the policies inherited from colonial governments with regard to access to land itself. Faced with the growth of rural populations, the need to supply export and (later) urban markets, and the functional efficiency of existing institutions, the colonial regimes adopted a dualistic approach to land administration, with formal statutory laws for urban, corporate and government land but customary tenure that recognized local 'custom' administered by locally recognized authorities within their respective territories (e.g., Mortimore 1997).

Customary law is now under pressure from increasing demand (Cotula 2007). Access to land has become a burning issue (Lavigne-Delville et al. 2002). Legislative reform in virtually every West African country since independence has strengthened central control and reduced safeguards against the mis-use of land laws to grant title to commercial or private interests at the expense of smallholders (for example Nigeria's Land Use Act of 1978). Meanwhile resistance against codifying rights to family land, traditionally responsive to changing social realities, has led to a plethora of informal contracts which may actually increase the efficiency of labour to land ratios, both in the forest zone (Berry 1993), and the Sahel

(Chauvaux et al. 2006). These contracts include cultivation of land under tree crops, rights to plant tree crops on village lands, rights to lend land and guardians' rights to valued common land (Cotula et al. 2006). In many places (such as Senegal: Lo and Dione 2000), customary contracts continue in defiance of central legislation.

While adaptive change—in the form of spontaneous, informal contracts—responds to economic and social pressures, a simple market model oversimplifies the complexity at the village level (Benjaminsen and Lund 2003). The remaining forests have come under new pressure from large-scale capital, as, using the myth of unused or unoccupied spaces, central governments have issued leases to foreign corporations or indigenous entrepreneurs for large-scale commercial agriculture. These are justified in terms of national economic priorities (fuels such as Jatropha, export agriculture such as sugar, meat and grain to new markets). A rapidly expanding literature follows the global 'land grabbing' trend especially in Africa. In West Africa, however, the expansion of smallholder agriculture still poses a greater threat to the livelihoods of pastoralists (Hof et al. 2006; Ariyo and Mortimore 2012; Mortimore 2001).

These tensions form the context of agricultural expansion and the management of remaining woodlands in the Sahel. However, negotiated conventions between stakeholders in forest areas offer a solution to persistent conflicts of interest. The Takiéta Joint Forest Management Project helps local people to manage a common resource in an inclusive way. It covers an area of 6,720 ha in SE Niger (Vogt and Vogt 2000). The aim is to create an effective local management structure and strategy through facilitation and genuine participation. Forest boundaries were first redefined. Legal residents were subjected to agreed conditions of access. Dialogue was commenced between user groups on the future of the reserve and costs of management. A Local Management Structure was created with consensual support. Maps (including soils, pastures and vegetation), inventories and knowledge of the resource were put together. Rules for forest use were agreed and user feedback to the draft planning document were taken into account. Following a workshop, management commenced in 2000. The Takiéta experience has since been replicated.

3.6.2 Burning

This practice was the principal method used in clearing forest for agriculture, and almost universally regarded as destructive in ecological and value terms. The history of attempts to control or prevent burning by West African farmers is a vivid example of the clash between indigenous and external knowledge systems that originated in authoritarian colonialism (Cline-Cole 1997).

Burning—which is done to control spontaneous regeneration on farmland or to clear away unwanted vegetation on new fields or after a fallow cycle—has been accused of causing wind and water erosion, reducing soil moisture and organic carbon, and damaging biodiversity. Little attention was paid to the rationale for burning, which was and still is the core technology for transforming woodland into farmland in rotational cultivation systems where labour is limiting and financial capital scarce. Foresters called burning 'indiscriminate'. Colonial forestry departments tried hard to stop burning, and notwithstanding the ineffectiveness of bans, most governments still try to regulate, if not to prevent, the practice.

Such efforts are wasted. In the sub-humid region of south-west Mali, recent research shows that up to 57 % of the landscape may be burned in a year (Laris and Wardell 2006). Draconian regulations to limit burning have been challenged on the basis of work in the subhumid zone of Guinea (Fairhead and Leach 1996). Burning is less damaging if done early in the dry season. It is a management strategy—and not 'indiscriminate'—most common in woodland areas with low population densities, and least common where densities are high and aridity greatest. The differentiation amongst more and less fire-resistant species may contribute to the spatial and temporal diversity of the ecosystem. Burn-scar mapping shows that burning occurs in patches, and it has been argued that the resulting mosaic of burnt and unburnt patches benefits biodiversity, conserving a mix of species. Recognizing the value of indigenous knowledge, a decentralization to local communities of powers and policy on burning practice has been tried with good effect (Laris and Wardell 2006).

3.6.3 *Fuelwood Cutting*

More than 90 % of energy used for cooking and domestic use in rural areas, and a substantial (though variable) fraction in urban areas, depends on fuelwood or charcoal. Overall densities of trees on farms, the availability of preferred fuelwood species, and the rate of natural germination and regeneration of indigenous trees were all expected to decline to vanishing point on the basis of 'projections' made around mid-century (Trevallion 1966; Moss and Morgan 1981). Beneficial properties of trees in re-fertilizing soil and protection from wind erosion would be lost, while exponential growth of urban consumers would inflate prices and create an ever-expanding 'desert' aureole surrounding growing towns. This scenario was commonly promoted across the African Sahel. Colonial and post-colonial forestry departments used it as a justification for centralizing the control of forest resources (Cline-Cole et al. 1990b).

Statistics of fuelwood cutting and consumption are difficult to compile. Exaggeration has been rife. For example, estimates of the future impact of wood cutting on the dry forests surrounding Bamako were found to be unjustifiably pessimistic (Foley 2001). Revisions changed the expected impact by an order of magnitude. Methods used to estimate natural forest regeneration are underdeveloped though regeneration is robust. A lack of knowledge on standing stock, mean annual increment and inter-specific variability in dry forests impeded the findings of a major study of wood supply and demand in northern Nigeria (Silviconsult 1991).

In northern Nigeria, a dual sector model is best placed for understanding the fuelwood industry (Cline-Cole et al. 1990a, b). In rural areas, reckless deforestation for fuelwood cutting is a myth wherever an individual's land rights are recognized. Studies conducted at the micro-scale have confirmed that farmers (and settled agro-pastoralists) conserve the trees they own. Every tree is selected for the economic value of its non-timber forest products (IUCN 2009), as well as the branchwood, which is used by householders for cooking and heating. This 'rural consumption model' is self-supporting—or aims to be so—but wood may be sold when income is urgently needed.

An 'urban consumption model', on the other hand, is supported by markets and takes no thought for the future. In northern Nigeria, the fuelwood demand for cooking and heating escalated during the twentieth century (Hyman 1993). It follows demographic trends (increasing populations and rapid urbanization), and competes with alternative energy sources (kerosene, bottled gas and electricity) whose uncompetitive prices, and irregular supplies, are major constraints on their uptake. However, rates of household consumption tend to decline with increasing price, especially in urban areas (Cline-Cole et al. 1990a; Hyman 1993). Higher prices should incentivize the purchase of improved stoves, which have received large promotion from World Bank funded projects in Niger and other countries (Noppen et al. 2004).

In closely settled areas with farm trees, the opportunity costs of foregoing the value of non-timber forest products, and the environmental value of standing stock (e.g., shade, soil nutrients) ensure that urban demand for fuelwood is transferred to residual natural forests. In Nigeria, weakly regulated or illegal woodcutting takes place in vulnerable natural forests, including state forest reserves. Rather than a 'fuelwood desert' the patterning of fuelwood landscapes is better characterized as a 'fuelwood perimeter' located in the woody interstices between villages.

Instead of enforcing regulations which are seen as antithetical to local interests, recent reforms in governance institutions (decentralization) have moved forest policy towards local participation. Sustainable futures now rest, in place of privileging access for favoured entrepreneurs and taxing trade movements, in the transfer of ownership, policing and sales quotas to local community organizations (Noppen et al. 2004). Expected benefits are poverty reduction (cash in hand), forest conservation (community monitoring), local development (forest management funds), private sector development, and planning capacity. However, decentralization has failed so far to deliver the expected benefits (Hesse et al. 2013).

3.6.4 Sustainability

The use of the term 'deforestation' commonly implies irreversible destruction or loss of value. A vast literature surrounds the subject at the global scale. However from a dryland smallholder's perspective, the conversion of woodland (most often already degraded secondary woodland) to small-scale farming creates a productive asset for multiple cropping which also includes NTFPs of a wide range of fruit, fodder, food, medicinal and other useful plants, as well as capturing synergies from indigenous agroforestry (e.g., complementary shade regimes, nitrogen fixation, and soil fertilization through animal droppings)(Davies et al. 2012).[7] Such capitalization is achieved largely through labour investments over long periods, enabling small but significant nutritional and economic benefits in small-scale farming livelihoods. Interviews in northern Nigeria and southern Niger bear out the value in which biodiversity is held (Mortimore et al. 2008), and biodiversity conservation is seen as a poverty reduction strategy (Roe et al. 2013), in which burning may yet have a place, and in which tree pollarding preserves wanted species without impeding the growth of crops.

Farmed parkland is not a new feature. It was observed in Kano in the mid-19th century (Barth 1857), in Senegal in the 1950s (Pelissier 1953), in Zaria in the 1970s (Pullan 1974), and in Kano in the 1980s (Cline-Cole et al. 1990a). Its impact on the landscape is visually impressive and apparently permanent. The density of mature trees on farmland (12–15/ha) was maintained throughout two major drought episodes (1973–74 and 1984–85), when pressure of food insecurity threatened to reduce tree stocks through fuelwood cutting for sale in nearby urban markets. It is sustained by protecting natural regeneration of native species, and supplemented by planting exotic shade and fruit trees on private farms and inside compounds. In the Kano region, 75 tree species are preserved under an average annual rainfall of 600 mm. Under an average annual rainfall of 360 mm, 135 useful tree, shrub, grass and herb species were inventoried, including 67 wild food varieties (Mohammed 1994 cited in Harris and Mohammed 2003).

Ecological sustainability in the Sahel must make economic sense to farmers and pastoralists, and a condition for this is secure access and enjoyment rights. Even so, with price inflation, fuelwood cutting could become irresistibly profitable in the Kano markets, overwhelming the value of biodiversity (Maconachie 2007). This is not a new suggestion, and in the absence of longitudinal data, the sustainability of dryland ecosystems may easily be underestimated. However, while overall tree densities may be sustained, the age or species structure of the trees may indicate imbalances significant for regeneration. For example, in the Serer villages of Senegal, the unwanted shrub *Guiera senegalensis* accounts for 57 % of the regenerating individuals, and the loss of more valued species is reported (Sadio et al. 2000; Lericollais 1999).

Recently, eastern Niger has witnessed a dramatic growth in protected regeneration of indigenous trees on farms, especially *Faidherbia albida* whose leaves and pods become available in the dry season while falling in the wet, when growing

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[7] This view would be difficult to demonstrate in measured economic terms because a wide range of non-marketed benefits and costs is involved in both space and time. Environmental economics provides methods for turning many costs and benefits into monetary terms. However, combining monetary and non-monetary items in the same equation must overlook the fact that decisions about resource use may not be made either in ‘cash’ or ‘non-cash’ terms, but on social, cultural or other qualitative grounds.

crops can make use of their nitrogen-enhancing effect on the soil (Boubacar, this volume; Sendzimir et al. 2011; Reij et al. 2009; WRI 2008). This trend was facilitated by a conjunction of drivers including the reform of land and tree ownership rights under the Rural Code. Large numbers of farmers are claimed to benefit from this Farmer-Managed Natural Regeneration. While an institutional framework supporting tenure security of land and trees is a necessary condition of sustainable tree management, local factors such as market incentives and livelihood opportunities are the sufficient conditions for its realization. The impact of motivated and consistent extension through NGOs and donor programmes in supporting and improving traditional practice may have been critical (Jouet et al. 1996; Reij et al. 2005). With regard to its future, the impact of very high densities of regenerating trees on the farming system, and the beneficial impact on poverty in Niger (Gubbels 2011), need research.

The mature farmed parklands suggest a theory of transition that proceeds from initial clearance of farmland from forest, through toleration of selected volunteer species along farm boundaries, to their active protection on cropland. If markets have driven conservation in highly valued farmed parklands, the same forces put pressure on remaining areas of natural forest and on forest reserves which are surrounded by competing stakeholder interests (e.g., hunting, wood cutting, grazing and farming incursions, often illegal). A process view of deforestation challenges some orthodoxies of forest management. But smallholders' impact, while considerable, is now small, slow and incremental; most of the colonial waves of migration in search of new lands are completed and the exhaustion of the supply of free land (saturation) is driving a new logic of smallholder intensification, in which increased inputs of labour, capital and fertilization conjoin with the protection of tree regeneration.

3.7 Soil Nutrient Depletion—Man-Made Deserts?

The biological productivity of an ecosystem depends on the health of its soils and on soil moisture during the growing period. Although the management of fertility status in soils is often presented in terms of key chemical nutrients (nitrogen, N, phosphorus, P and potassium, K), being easily manipulated in the short term through inorganic fertilizer amendments, other properties are vitally important in the longer term, including some trace elements, salinity, physical attributes (texture, depth and structure), and organic carbon content (C). In Africa, a dominant narrative of soil degradation and erosion has been influential in debates about dryland management, a key theme being nutrient depletion on farmland.

Early surveys claimed that 332 million hectares (25.8 % of the continent's surface) are affected by soil degradation in the arid, semi-arid and dry sub-humid agro-ecological zones.This work, carried out by ISRIC (Oldeman and Hakkeling 1990) and the Winrand Staring Centre (Stoorvogel and Smaling 1990), was used by the First Edition of the World Atlas of Desertification (UNEP 1992). Extended estimates were later published of the annual depletion of chemical nutrients (Stoorvogel and Smaling 1990), which were promoted by the World Bank and other agencies. These put net combined N, P and K losses at 60–100 kg/ha/yr and increasing (Henao and Banaante 1999; World Bank 2001). All but three African countries were said to be losing >30 kg of N, P and K/h/yr.

This narrative continues to guide policy makers, for example at the Abuja Fertilizer Summit, at which governments committed themselves to higher targets for fertilizer procurement and distribution (African Union 2006). According to this narrative, chemical fertilizers assume the role of palliatives for under-productive African agriculture, though their acquisition is highly dependent on international trade, expensive quarrying and processing, or high consumption of non-renewable energy. Fertilizer use has to be subsidized to make it economically viable; consequently the political economy of fertilizer distribution may be an obstruction to its equitable use.

Critiques of the nutrient depletion scenario focused on the conceptualization and methodologies used in measuring, scaling up and projecting from micro-scale site observations to regional and continental scales (Scoones and Toulmin 1998; Faerge and Magid 2004). Key chemical nutrients cannot alone (that is, without essential micro-nutrients) recreate a sustainably fertile soil, or replenish the critically important stock of organic carbon. What solutions can be found for soil degradation?

The Sahel falls behind more humid regions in its agricultural productivity (Breman and de Wit 1983). But a paradox of Sahelian agricultural systems is their persistence over decades under conditions of population growth and unreliable rainfall. The achievements of small-scale farmers challenge the grand theory of failing African agriculture, and provide a platform for current advances in productivity supported by science and policy (Djurfeldt et al. 2011). Nutrient cycling is the key to soil fertility in relatively closed systems supporting a subsistence household economy (Drinkwater et al. 1998). Mixed crop-livestock systems rotate cultivated fields with fallows and transfer nutrients to cultivation through grazing animals (Powell et al. 2004; Thomas et al. 2006). Where land scarcity eliminates field rotation, crop residues, dry composting, inter-cropping and multiple weeding strategies bolster the supply of organic matter (Harris 1999; Mortimore and Harris 2005). In some more intensive systems, with higher rainfall, crop residues can support higher stocking densities even without rangeland (Harris and Yusuf 2001).

Farmers recognize that organic as well as inorganic fertilization is necessary to approach the potentials shown on research stations. But there is never enough, giving rise to sharp differences between plots. These are shown in micro-scale case studies. At four locations in Maradi (Niger), field sampling showed that by investing in a mix of organic manure and dry compost, and very small doses of inorganic fertilizer (when affordable), a farmer can restore organic matter to levels comparable to uncultivated soil (Issaka 2001). This implies that cultivation has not irreversibly degraded the soil.

Research-based soil fertility strategies build on indigenous knowledge and practices. Scarce and costly inorganic fertilizers can be optimized by mixing ‘micro-doses’ with organic matter (building on local practice) and ‘hill placement’ on the individual stands (Dimes et al. 2005; Aune et al. 2005). Crop rotations and mixtures (especially of grain and legumes) also mimic indigenous practices. Where conditions are suitable, water harvesting with ridges and basins improves moisture conditions, notably the successful uptake of the *zaï* technique for concentrating scarce surface water and nutrients (Traoré et al. 2005; Mando et al. 2006). Nitrogen-fixing trees are promoted on farms (Thomas et al. 2006).

Conservation agriculture, based on zero or minimum tillage (Aune et al. 2005; Milder et al. 2011) and a range of sustainable land management (SLM) technologies (see WOCAT 2007) is largely unproven under Sahelian conditions of low bio-productivity and integrated crop-livestock systems. Claims that it increases yields, reduces labour requirements, improves soil fertility and reduces erosion have been challenged on the basis of weak or inconsistent evidence (Giller et al. 2009). The need for agrochemical inputs is also unclear in many accounts.

‘Ecological intensification’—which includes intercropping systems, integrated pest management, and organic farming—has broadened the scope of extension efforts globally, estimated to have benefited 40 million smallholders (Pretty et al. 2011). ‘Sustainable intensification’ is an imperative across ecological, genetic and socio-economic spheres (Montpellier Panel 2013). Currently, increasing attention is being paid to biological attributes, soil organisms and the carbon cycle (Uphoff et al. 2006). This new (or ‘second’) paradigm advocates ‘more knowledge of and reliance on biological processes’ (Uphoff et al. 2006, pp. 12, 693, 698). It replaces dependence on external inputs—a paradigm characterized as ‘Overcome soil constraints through the application of fertilizers and amendments to meet plant requirements’—with ‘Rely more on biological processes by adapting germplasm to adverse soil conditions, enhancing soil biological activity, and optimizing nutrient cycling to minimize external inputs and maximize the efficiency of their use’. The most striking feature of the change proposed is a shift from relying on exogenous inputs to an emphasis on endogenous processes within the system—and this no longer the perceived closed system of ‘subsistence farming’ but a system open to environmental change and the political economy.

A shift from sectoral (commodity-based) research and development to systems approaches translates integrated soil fertility management (ISFM)—no longer perceived mainly in terms of affording chemical amendments—into part of a ‘complex adaptive system’ (Schiere et al. 2006). It includes a range of interacting drivers and components such as soil and water conservation, ecosystem services, markets, fertilization (organic plus inorganic), integrated pest management, markets, institutions and policy (Bationo et al. 2005; Vanlauwe et al. 2006). Such a change challenges the scientist to integrate research-based knowledge with that of the Sahelian farmer. In place of a policy strategy built on averages and assuming homogeneity in the farmers’ response, the system offers space for multiple pathways (Scoones and Wolmer 2000), and variance becomes a virtue, not a nuisance (Schiere et al. 2006).

The management of soil processes—whether sustainable or degrading—is central to desertification, and justifies this excursion into the changing narratives that link people, their knowledge, and environment. Soil bio-productivity is literally a matter of life and death, and the challenges for technology are plain for all to see: invest through participatory research on organic matter management, dry composting, rain-water harvesting, conservation agriculture, crop rotations and mixtures, micro-dose fertilization and other strategies. Nutrient cycling is site-specific.

3.8 Conclusion: Escaping Malthus?

In the preceding sections of this chapter a case is made for revising the conventional wisdom that supports a desertification paradigm for the Sahel. If a new paradigm of adaptive resilience is justified by the science, what should be concluded about poverty, population growth and the future?

3.8.1 Poverty

The six countries of the Sahel (Nigeria must be excluded here because half its area and population lie outside the ecological Sahel) score behind others, even in Africa, on indicators of poverty, vulnerability and well-being (Dobie and Goumandakoye 2005). In these six (The Gambia, Senegal, Mali, Burkina Faso, Niger and Chad), an average 44 % of their populations live below the international poverty line (US $1.25/day). The UNDP's Multi Dimensional Poverty Index gives them an average value of 0.473, which can be compared with South Africa (0.057), Ghana (0.144) and Kenya (0.229) (UNDP 2011).

The Sahel has a combination of increasing rural population densities, erratic rainfall, infertile soils, deforestation and poverty which appears, on the face of it, to pose a classic neo-Malthusian crisis and, given a population doubling-time as low as 22 years (on recent fertility rates), an extremely urgent one. Furthermore, there is evidence that the demographic transition to lower fertility is faltering in some African countries including those of the Sahel (Economist 2014; for Niger, see Boubacar, this volume). For many observers, an intuitive barrier struggles to accommodate a projected 500 million Sahelians. In the Horn of Africa, the case for a neo-Malthusian crisis in pastoralism, and its dependent human populations, is provocatively argued by Sandford (2011). In western Africa, the Sahel has been shedding its pastoral population for generations (Baier 1980). Following the great Sahel famine of 1972–74, many observers were quick to conclude such a crisis, not only for pastoral populations but also for farmers (Mortimore 1998).

Overall, per capita food production in Sahelian countries has stagnated (according to FAO statistics (Mortimore 2003; FAOSTAT 2014). But according to these data, neither did it decline (1961–2001), and a virtual doubling of rural population indicates that total production increased substantially. The answer to this anomaly appears to lie in economic differentiation which condemns a third of the population, lacking enough land, labour or capital, to chronic food insecurity (Gubbels 2011). They depend on food commodity markets even in years of good rainfall. Under conditions of variable rainfall, yields and harvests, weak demand on account of poverty leaves no space for building reserves for the bad year when prices ‘sky-rocket’. The most vulnerable of this population are young children. The co-existence of poverty with evidence of adaptive resilience suggests that poverty depresses demand and restricts the investment necessary to achieve sustainable NRM.

Using earth satellite data and population projections, Abdi et al. (2014) modeled increases or decreases in net primary production (NPP) ‘supply’ and ‘demand’ during the period 2000–2010 for 22 Sahelian and neighbouring countries. NPP is produced not only on cropland, where production is estimated using FAO crop yield statistics in conjunction with land use classes, but also in woodland, forest (absent in some countries), and savanna grassland. Given a rate of natural increase of 2.8 % per year, the regional population grew from 367 million in 2000 to 471 million in 2010. Assuming that 80 % of crop calories are used for food, estimated NPP ‘demand’ per capita increased from 19 to 41 % of the ‘supply’, suggesting a threat to food security. However, only two countries saw negative change in total NPP, which registered significant increases in cropland, woodland and grassland overall, probably due to improved rainfall.

3.8.2 Adaptation

Variability characterizes both the ‘given’ elements of the Sahelian environments and the adaptive responses documented by many observers. In a new and fundamental argument for a shift in paradigm (Krätli 2015), a case is made for ‘valuing variability’ as an asset of smallholder farmers as well as pastoralists adept in managing incumbent risk through applying local environmental knowledge. Such a model can resolve the contradictions between ‘top-down’ and ‘bottom-up’ development strategies and capitalize on the tenacity evident in these social-environmental systems.

Given the variability of a non-equilibrial environment, as shown in the droughts of 1972–74 and 1983–84, the adaptive capacities of Sahelian peoples were underestimated (Mortimore 1989, 2001, 2010). Early projections of mortality in hundreds of thousands—there are no statistics—were not realized (Caldwell 1975), and notwithstanding food security crises in subsequent years, and persistent calls for food aid, the Sahelian farming systems have not collapsed but today support (though inadequately) twice as many people (Tiffen and Mortimore 2002). Adaptation (for farming families) took place at four levels:

- Adjustment of labour on-farm (sowing, weeding, harvesting) to short-term variability of rainfall (Fig. 3.4)
- Use of famine foods from wild plants to supplement or replace cereal grains

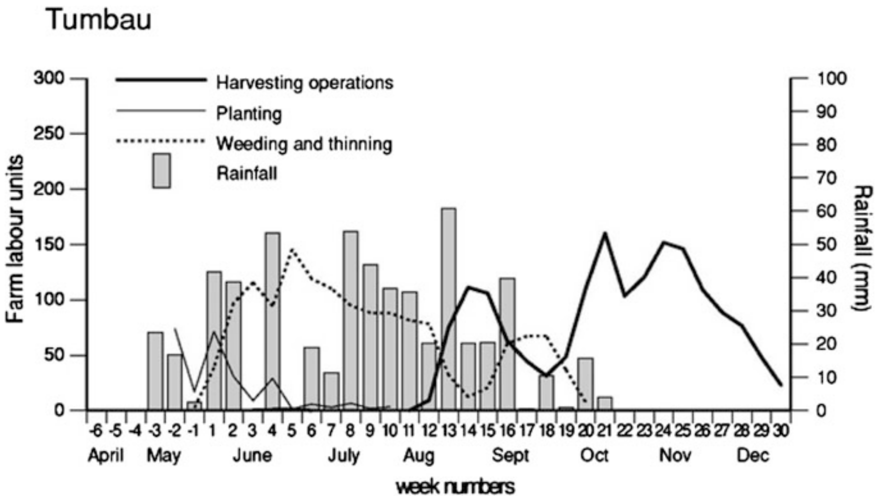

Fig. 3.4 Adapting farm labour inputs to planting, weeding and harvesting under variable rainfall in Kano, Nigeria (units of one week). *Source* Mortimore and Adams 1999.

- Searching for alternative income sources locally
- Migration (short term) seeking employment or trade in towns

Excepting the first, these strategies were also employed by WoDaaBe pastoralists, whose herd's survival depended on the speed and distance of their movements (Bernus 1977a, b). Flexibility, diversity and mobility enabled such adaptation which took most observers by surprise. They are documented over the long term and notwithstanding setbacks and contradictions, they suggest a process of economic and social development through adaptation and diversification as in Senegal and Niger (Faye et al. 2001; Mortimore et al. 2001). It is not possible to consider adaptation to desertification separately from adaptation to drought, since actions taken in the context of short-term food insecurity aggregate over time into a management process.

These capacities, demonstrated at the local level, suggest that a two-step escape route from a Malthusian outcome has been exploited by households in Sahelian social-ecological systems: first a 'smallholder labour-intensification' pathway from rotational subsistence farming to multiple purpose crop-livestock-tree cultures, and second an income diversification pathway that exploits regional income opportunities as well as local. For pastoralists, the first step is to protect the right to do what is already known well. Mobile herding and breeding systems are labour-intensive. Many pastoralists embark on the second step, which may evolve into sedentarization.

For the first step, research and practice based on labour intensification needs to include the stated goal of strengthening capacities to manage non-equilibrial environments, whether those exploited by pastoralists or those cultivated by farmers and agro-pastoralists.[8] This goal must include negotiating rights of access and benefits among contesting stakeholders, and strategies for sustainable use of natural resources. Insurance schemes against risk of loss (of crops or animals) are attracting attention (Hesse et al. 2013), and lessons are being learnt including the need for index-linked insurance to be embedded in a wider portfolio of credit, inputs and risk management. They may also offer social protection for those whose adaptive options have run out (Hazell and Hess 2007). Insurance is becoming more of a priority with contemporary changes such as land 'saturation', market penetration, state interventions in land and water, and conflict.

For the second step, barriers to movement (whether of herds or of migrants) need removal and such regulation as necessary to guarantee mobility when and where needed. This is not always in the forefront of government's concerns. Its necessity arises from increasing regional economic integration, both national and international. Both rural-urban and cross-border movements will increase. Short term movements and circulation are on the increase. Dryland inhabitants have a stake in urbanization as well as their right of cross-border movement under the terms of the Economic Union of West African States (ECOWAS).

Conventional development theory and practice perceives non-equilibrial environments—especially those of the West African Sahel—as a management challenge, subject to increasing demographic, climatic and economic pressures. Public, private and external investment holds the key to reversing poverty and—in time—rebalancing the Sahelian social-environmental systems. Such a view returns to an equilibrial understanding of change. Knowledge systems offer new investment options and scope (UN/EMG 2012).

However, a non-equilibrial model urges that greater attention be paid to local, as well as science-based, knowledge and social capital in engaging realistically with variability and uncertainty in adaptive food production systems, multiple risk management options, mobility, and other parameters at the small or household scale —in essence 'giving small-scale producers a second chance' (Krätli 2015).

This chapter has traced the evolution of development practice and the beginning of a paradigmatic shift towards a better match between environmental change and its management in the West African Sahel. Many questions remain unanswered. Meanwhile the challenge intensifies.

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