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Representing environments in flux: case studies from East Africa

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The dominant view in the ecology and anthropology of the 1950s saw populations harmoniously interacting in self-regulating systems; climax forests and stable societies were the ruling hypotheses. Now, however, ecology and social sciences are investigating nature and culture in flux. The flux paradigms of nature and culture describe a human–ecological relationship that is non-equilibrial, historically contingent and constantly negotiated at both material and ideological levels by unequal actors. In this paper, we examine the effect of changing ecological and cultural paradigms on interpretations of environmental change in three areas of East Africa: the North Pare Mountains, Tanzania, the Mkomazi Game Reserve, Tanzania and the Tsavo National Park, Kenya. We explore how discursive and materialist approaches can complement one another, by expanding the domains of ecological inquiry and demanding that analysts cross-check their data for unquestioned assumptions regarding stability, variability and spatial and temporal scales. Rather than testing a ruling hypothesis, we suggest that ecologists and social scientists work with multiple hypotheses, with the aim of understanding the interplay between ecological, environmental and social influences.

Key words: *Africa, flux, ecology, nature, culture, non-equilibrium*

Introduction

The study of African environments has been transformed in the last 15 years as old certainties of degradation and decline have given way to more nuanced interpretations of landscape change, people's role in ecological change and the consequences of environmental change for people's livelihoods (Fairhead and Leach 1996; Leach and Mearns 1996b; Mortimore 1998; McCann 1999; Kull 2000; Brockington 2002). Recent studies have emphasized the importance of learning from local accounts of environmental change, the pervasiveness of elite discourses of degradation and the potential harm that can be done to local groups and smallholders if erroneous narratives drive environmental policies.

At the same time, it is also clear that work on environmental change needs to take more careful stock of who benefits, and who loses, from both environmental degradation and amelioration (Murton 1999; Birch-Thomsen *et al*. 2001). It has also not always been possible to predict or explain political contestation over environmental affairs (Leach and Fairhead 2000). Finally, it is clear that there are a great many degradation narratives which still dominate interpretations of African environmental change in a variety of situations.

In this paper, we take stock of these developments with particular attention to our understanding

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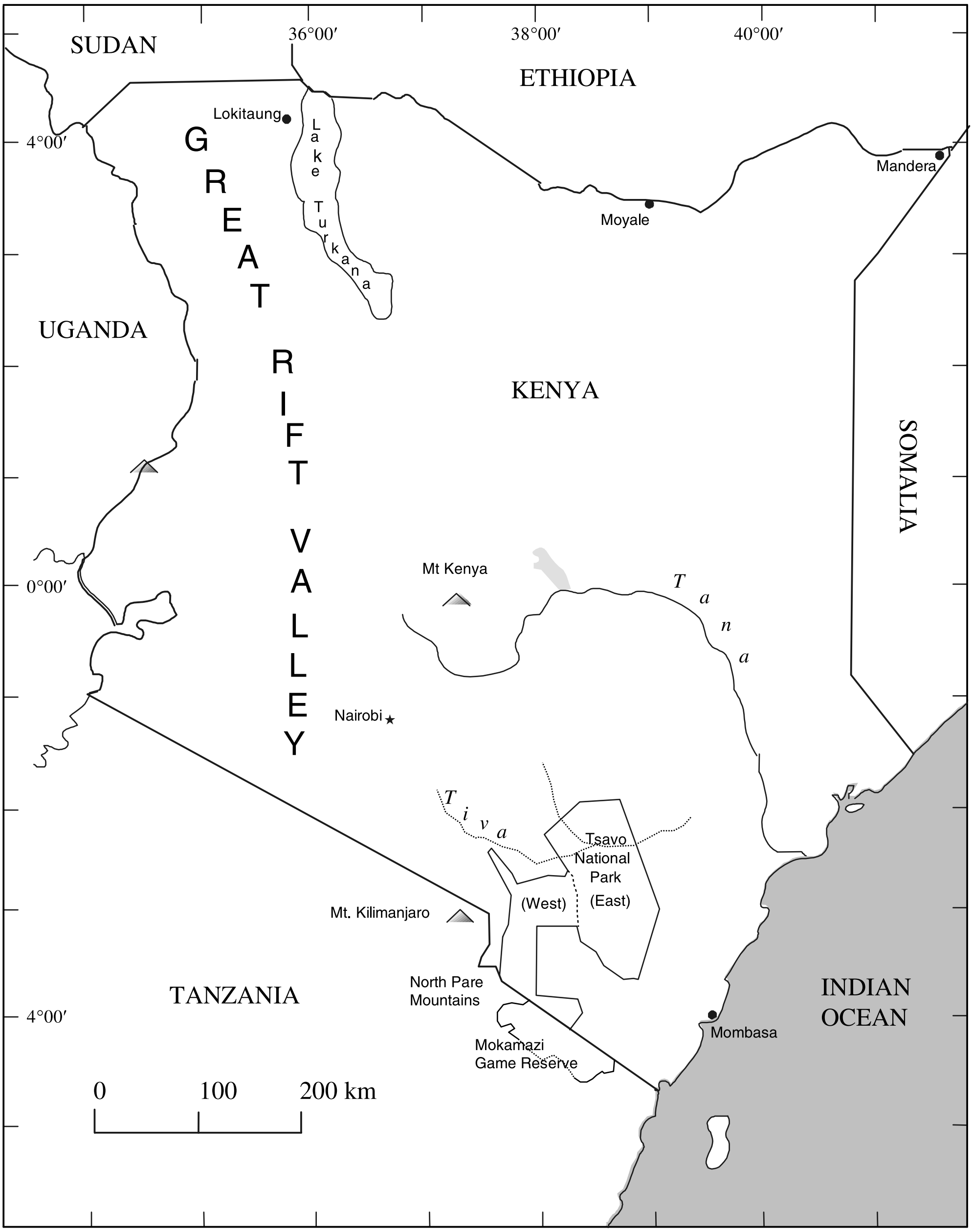

Figure 1 Location of North Pare, Mkomazi Game Reserve and Tsavo National Park
Source: Adapted from Gillson (2002)

of nature and our interpretation of discourse. We will consider how changes in our conceptual models of nature have driven environmental interpretations and how powerful discourses are exploited by elites and locals alike to forge degradation narratives. To do this we will briefly discuss three case studies of contested environmental change drawn from contiguous locations in eastern Africa; the North Pare Mountains, in Tanzania (see Figure 1), the Mkomazi Game Reserve, also in

Tanzania, and the adjacent Tsavo National Park in Kenya.

We have chosen these three case studies mainly because it is useful to have a common historical experience – or at least a reasonably similar one, when discussing trends in the causes of vegetation and landscape change. The common elements in the history of these places make it easier to interpret the role of power and politics in influencing the origins and development of narratives of vegetation and environmental change. There are coherent stories to be attempted for particular regions. Even if one story cannot be told, in the end we will still learn from the attempt.

At the same time, we warn against attributing too much importance to the spatial proximity of our interest. Elements of the common past may help experts familiar with the region to evaluate the significance of similarities and differences in these case studies. However, it is perhaps more honest to say that our cooperation has simply been enhanced by our geographical proximity. Our alliance is the product of an epistemic community enhanced and facilitated by its common geography, not a coalescence driven out of the necessity of understanding the interrelationships that connect these different places. Geography does not here delineate the appropriate boundaries within which we study nature, but it does structure these boundaries within researcher's society.

We will tell in this paper, then, three related stories. They are similar to each other in the time that they cover, and in the political economic context of the nature of the concerns about the environment that are raised. They are also complementary, in that they capture three different aspects of the recent transformations of our understanding of environmental change in Africa, covering, respectively, deforestation and reafforestation (North Pare), rangelands and desertification (Mkomazi) and wildlife and nature (Tsavo).

We will argue that interpretations are partly the product of changing understandings of the nature of nature – whether it is in balance or flux. These ideas are also the product of elite discourses, the consequences of powerful people asserting certain interpretations of environmental change and others resisting or coopting these interpretations. We will briefly discuss how methodologies from ecology and the social sciences can complement one another, and the ways in which different sources of data need to be combined to understand environmental change.

Case studies

The North Pare deforestation narrative[1]

North Pare is a mountain block that towers 2112 metres over the dusty plains of Mwanga District in northeastern Tanzania. The mountains rake moisture from the prevailing winds during the area's two rainy seasons, so that the southeastern slopes of North Pare are green and wet. The highest peaks are covered with a high altitude closed-canopy rainforest, and the highland valleys are intensively cultivated with eucalyptus, coffee, bananas, beans, maize and sweet potatoes.

Development agency experts and government officials agree that North Pare has lost whatever degree of harmony that the area's people once had with nature. North Pare's population increased more than tenfold over the twentieth century (from roughly 10 000 to more than 120 000 people, see Sheridan 2002), and the pressure on the mountains' limited resource base has become acute. European development agencies (The Netherlands' SNV and Germany's GTZ) cooperated in the 1990s to reverse what they perceived as an ongoing Malthusian process of population-driven deforestation, as this quotation from a Tanzanian newspaper indicates:

> The rapid growth and the high density of population in the arable parts of the North Pare Mountains have been identified as factors encouraging soil degradation. The team leader of the Tanzania Forestry Action Plan (TFAP) North Pare project . . . said in an interview that other factors identified include the fragmentation of land, gradual disappearance of forests and consequently a decrease in the district's water reserves. (*The Guardian* 1997)

The agencies' solution to these interwoven problems was to impose participatory, 'bottom-up' rural development programmes in the areas with highest population densities. These programmes included tree-planting campaigns, the rehabilitation of pre-colonial irrigation systems and the creation of Land Use Planning Committees at various levels of the local political hierarchy.

A very different scenario emerges, however, from a close analysis of travellers' reports, missionary documents, photographic evidence, colonial archival documents and oral histories. Although North Pare began the twentieth century as a largely unforested area with low population density[2] (likely because of its status as a precolonial centre of iron and pottery production and the effects of war and famine in the last two decades of the nineteenth century, see Sheridan 2001), administrative elites have consistently used Malthusian narratives of deforestation to justify coercive interventions.

The Europeans who visited North Pare in the late nineteenth century described a largely treeless landscape. After climbing up the western side of North Pare in 1889, a German explorer described the high ridgeline as having 'a few bushes and herbs, but no trees' (Meyer 1891, 210). Meyer saw forests only in the nearly uninhabited northwestern quarter of the mountains and on the outer flanks of the massif.

> Elsewhere, everything has been burned down for clearings, or, as on the higher zones of the mountains, the slopes are covered with low bushes, grass, or ferns. (Meyer 1891, 223)

'Low' is a relative term here – Meyer later wrote that the peaks of North Pare were 'bare, deforested, and covered with a thick, man-high layer of ferns and brush' (1909, 218). Soon after, a missionary reported that 'there are few forests, and most of the hills and mountains are bare' in North Pare (Althaus 1894, 451). Oscar Baumann's description of North Pare from his 1890 visit brings this picture into sharper focus, and marks the first appearance of the assumption that forest patches are relics of a primeval forest:

> the actual inhabited and cultivated area, which was originally well forested, and which still stands in scattered thick groups of trees, has now for a long time been developed [for agriculture]. Among these the homes of the natives are scattered. Above this area stretches a zone of low, lush grass, overgrown with ferns and heathers, which cover the highest areas of both North and Middle Pare. (Baumann 1891, 200)

Baumann's 'thick groups of trees' can only be the more than 600 sacred forests that now comprise 8 per cent of the land in Mwanga District. These forests, which average about 0.75 hectares, function as sites for ancestor veneration and initiation ceremonies by kin groups. Each forest contains only indigenous trees, and all have strict terms of access and use. Each forest is managed by an elderly male head of a clan or lineage, who is responsible for sacrificing beer and meat to the ancestors upon a supplicant's request. The fundamental rule of forest management is that no one can cut or remove anything from a sacred forest – not even a single leaf (Sheridan 2000). During fieldwork in 1997–8, development agency staff echoed Baumann's assessment by pointing to these miniature forests as evidence for an ongoing crisis of deforestation.

Oral histories of landscape transformation in North Pare agree with the documentary sources. Many elderly informants described the landscape of their youth as having been *vichaka tu* (Kiswahili, 'just shrubs'), except for the sacred forests. Table 1 presents the species they identified as common components of this *vichaka*. In addition to the shrubs and weeds on this list, many informants added the broad categories of 'ferns' and 'grasses'. Elderly women pointed out that the shrubs on this list would have grown into trees if they had not repeatedly cut branches for fuelwood, which kept the plants from developing main trunks. 'Long ago,' one woman said, 'it was easy to see far over the whole mountain because there weren't many trees like today . . . the whole country was just shrubs and little plants.'

Although government officials and development agency staff now insist that North Pare is currently experiencing deforestation, these historical data

Table 1 Species composition of highlands summits, North Pare, *c*.1910

Name of plant (Chasu)	Kiswahili name	Species classification	Notes
Ichungalugwi	Unknown	Unidentified	Herbaceous weed
Iririko	Unknown	*Veronica amygdalina*	Whitish-green herbaceous weed, inedible by livestock
Malama ya Chasu	Mzambarau mwitu	*Syzigium guineense*	Shrub, 1–2 m high
Mwasho	Unknown	*Nuxia fluoribunda*	Shrub
Ng'ande	Mwangati	*Juniperus excelsa*	Shrub, 1–3 m high, good fuelwood
Njitwe	Mkeng'eta	*Dodonea angustifolia viscosa*	Shrub, good fuelwood

Source: Sheridan fieldnotes

show that a lack of trees pre-dated the demographic expansion of the twentieth century.

Other than the introduction of elephant grass for fodder, the most important contribution of British colonial land use policies to the North Pare environment was agroforestry. Population growth and a rising standard of living increased the need for fuelwood, timber and poles, and fast-growing exotic trees met that demand. Eucalyptus grows three to four times faster than the indigenous species of North Pare. By the end of the British colonial era, North Pare had far more forest cover than had been the case under German rule, albeit much of it was composed of exotic species with ecological effects quite different from indigenous species.

The North Pare deforestation narrative became a taken-for-granted reality under British colonial rule. The colonial state used a narrative of imminent land degradation to justify its increasingly coercive grip on African land use. The narrative had four components: shifting cultivation, soil erosion, declining water availability and deforestation. North Pare in the 1930s was a prime example of this Territory-wide problem, as this passage from the 1930 *Handbook of Tanganyika* suggests:

> there is still abundant evidence that not much more than two centuries ago forests covered the mountains and parts of the coastal zone to a much greater extent than at present . . . It is obvious that the forest covering once extended far down the mountain sides and out on to the plains. Remnants of rain forest in small groups or single stems are found among low secondary bush and cultivated land in the mountains between surviving blocks of that forest type. Encroachment on the forests by the native tribes for their shifting cultivation was rapidly depleting the mountain tops of their invaluable tree cover . . . when the Germans first established themselves in this part of Africa. (Sayers 1930, 226)

The British response to this situation was to revive the Forest Reserves that had been established by the German administration and plant eucalyptus all around their borders as a fire control measure.

The construction of forestry policy in Pare elided two quite different scenarios into one narrative of deforestation. In the 1930s, a forestry officer wrote that 'North Pare has little or no forest (non-protected) left and in South Pare large areas are still being cut out' (TNA MF 11a). South Pare has much larger forests than the North (the Chome Forest Reserve in South Pare, for example, is over ten times bigger than Kindoroko Forest Reserve in North Pare), so colonial attention to deforestation in Pare District focused on the south. Forestry policy, however, had to be consistent throughout the District, so the 1938 Rules for Forest Conservation fought the threat of deforestation by preventing people from cutting trees, grazing livestock, clearing shrubs and using fire to prepare their fields. As was the case for soil conservation and water source protection, these laws centralized power in the chiefs, who could fine someone up to Tsh 200/= (or three months in jail) for cutting down a tree[3] (TNA 204/e). Although the chiefs of Pare rarely enforced these laws until the 1950s, the 1938 Rules redefined deforestation as an ongoing process in North Pare rather than a precolonial condition. Much of the deforestation that colonial officials decried resulted from North Pare's transformation from a set of semi-autonomous chiefdoms into a cash-cropping peasantry. The 1953 annual report for Pare District, for example, cited the expansion of coffee cultivation as the major cause of deforestation (TNA 19/6/1/III/242). This narrative of deforestation is a persistent colonial cultural model that continues to shape land use policy in North Pare.

Repeated exhortation by chiefs, colonial officers and missionaries made tree planting in North Pare increasingly popular under colonial rule. At first, only Native Authority officials, schools and missions planted them, but ordinary farmers began to embrace the concept in the early 1950s. The Pare Mass Literacy Scheme supervised the planting of half a million trees in North Pare in 1951 (TNA 19/6/1/III/201), and its director was convinced that 'the people are genuinely sold on the idea of tree planting' (TNA 304/962/vol. 19). Most of what had been sold, however, was the free labour of children and rights to common property areas. In 1950, the Native Authorities gave each primary school its own hilltop to cover with trees. Most of the school logbooks that I consulted noted this event as the creation of new school property. By 1955, the nature of tree planting had shifted from schoolchildren collectively planting eucalyptus on bare, heavily eroded hilltops to individual planting on private farms (TNA 304/962/15). Exotic trees were in high enough demand that theft of seedlings became common (TNA 204/a), and much of the reason for this demand lay in the trees' status as strategic assets in negotiations over legitimate entitlements to land.

Although demand for building materials and fuelwood certainly contributed to the spread of tree planting, insecure land tenure was an equally important reason for planting trees in colonial North Pare. Access to land came from the chiefs and clan leaders, and maintaining access to that land required farmers to keep the land in constant use without fallow periods. If a patrilineage had uncultivated land (because it was being reserved for male children or male labour migrants), planting trees was a good strategy to show current use with a crop more valuable than cassava. Under widespread conditions of male out-migration and labour shortage, tree cropping was an effective way to lower the tenurial insecurity that resulted from the tension between individual rights to crops and collective rights to land. Eucalyptus stumps coppice after they are cut, and these new shoots demonstrate that the land is still in use without requiring the farmer's additional labour. Exotic seedlings therefore sprouted up along the boundaries of many farm plots. As one old man expressed the state of land and tree tenure in colonial Pare,

> To own an area it was necessary to build a house there or to plant trees. The area that was planted with trees and then left alone got the name of the person who planted those trees . . . and all the time that a person was living in a particular area he could grow trees and that was sign enough of land tenure. (Interview 11 November 1997)

Tree planting is almost always a male prerogative in North Pare, so the colonial state's introduction of agroforestry combined with indigenous patriarchal relations of resource tenure to enhance men's control and women's dependence. This trend continues to the present day, and the North Pare landscape is now an amalgam of exotic trees, sacred forests, cultivated fields and mixed banana/coffee groves.

The meaning of this landscape depends on the social position of the observer.

1 For technical and administrative elites in the business of implementing development plans, the area's indigenous trees are the remnants of a closed-canopy high-altitude forest decimated by rapid population growth. Historical continuity, power, jobs and money make deforestation the dominant narrative.
2 For North Pare residents, the area's indigenous tree cover held steady, while the exotic and agroforestry tree cover increased over the twentieth century through various forms of individual and collective management. This is, however, more a disorganized set of anecdotes than a narrative. Only the very elderly recall the landscape of 'just shrubs' and most residents have detailed knowledge of tree growth for only their own plots. Powerlessness and the lack of an institutional structure prevent these bits of knowledge from coalescing into a narrative.
3 For an ecological social scientist, the task of synthesizing ethnographic, historical and ecological data leads to the construction of a counter-narrative to challenge the accuracy of the dominant narrative (Roe 1991). In this view, ecological features are inseparable from the socio-political contexts that give them significance.

The Mkomazi degradation story[4]

A large area of the semi-arid plains in north-east Tanzania is contained within the Mkomazi Game Reserve. It occupies over 3000 square kilometres, mostly comprised of rangeland between 500 and 800 metres above sea level, but with some outlying hills from the Pare mountains which border it on the western side. To the north and east is the Tsavo National Park. Rainfall is generally low, between 500 and 600 millimetres per year; the common vegetation on the plains is a mix of grassland and *Acacia–Commiphora* bush and woodland.

The environment of the plains has been hotly contested for more than 60 years. The presence of Mkomazi (which was established in 1951) has added to the intensity of the debates, and ensured a good archival record of lobbying over the security and sanctity of its environment. The debate has frequently focused upon one thing – the impact of cattle on rangeland vegetation.[5] The main actors tend to have taken three positions:

1 Livestock-keeping is deleterious to the environment; it causes over-grazing, soil erosion and desertification. This has been championed by government officials before and after independence who were concerned with both human development and wildlife protection. They have consistently recommended the permanent removal of large numbers of cattle from the plains.
2 The similar position (voiced generally, but not exclusively, by less mobile, more agro-pastoral herders) that there are too many stock, and that immigration should be prevented. These concerns have tended to be voiced after localized increases in cattle brought in from neighbouring districts. This position differs from the first in that it does not contain complaints about the long-term degradation of the range.
3 Rangelands provide good grazing for livestock, and stocking rates do not need to be reduced. This was

voiced by other herders, especially the more mobile, more pastoral peoples. It is manifest in their repeated decisions to move stock onto these rangelands, as well as their retrospective accounts of the quality of this grazing.

All these positions are marked by their conviction of certainty. The consequences of each idea is unambiguous. Cattle need to be moved away (the government), their presence needs to be regulated (less mobile herders), the rangelands' quality demands their use (more mobile herders). There is, more recently, a fourth position to add to these three which is distinguished from them by its uncertainty:

4 Vegetation dynamics in semi-arid rangelands are unpredictable and not well known. From this position it is not possible to determine what the exact nature of the impact of cattle on vegetation actually is.

This fourth position contravenes the first in both its substance and certainty. It is not an easy position to argue, particularly in East Africa (Brockington forthcoming). The power and dominance of degradationist thinking should not be underestimated, yet neither should the weaknesses and inconsistencies of its arguments. Research into the vegetation dynamics of semi-arid and arid lands, and whose findings are applicable to Mkomazi, suggest that vegetation change may not be driven by the density of cattle populations (Ellis and Swift 1988; Westoby *et al.* 1989; Behnke *et al.* 1993; Sullivan 1996; Illius and O'Connor 1999; Sullivan and Rohde 2002). The evidence at Mkomazi, reviewed below, does make the herders' ideas seem more intelligible than the degradationist thinking. However, it does not replace the old certainties of degradation with new ones, and does not condone herders' certainty.

The evidence is not detailed, since no good research has been carried out on the nature of the interaction between livestock and vegetation change on these rangelands. However, at the general landscape scale there are serious inconsistencies in the degradationist school of thinking which demand scepticism. Three prominent doubts need to be considered.

The first is the weaknesses of the science used to describe Mkomazi's degradation. The most comprehensive expression of degradationist thinking was a report written by Dr Anderson, a soil chemist and research officer with the Ministry of Agriculture, Forests and Wildlife, in which he evaluated the best use of the Mkomazi Game Reserve (Anderson 1967). Anderson stated that the appropriate stocking rates for the Reserve were eight acres per cow and 25 acres per animal where grazing had been destroyed. He gave the cattle numbers using the Reserve as 3000–5000 and the Reserve's size as 600 000 acres. Given that about one-quarter of the Reserve was in use, this gives an actual stocking rate close to 30 acres per animal. However, Anderson also underestimated the size of the Reserve (it is closer to 800 000 acres), which would give an actual stocking rate, according to Anderson's figures, of nearly 40 acres per animal. These stocking rates are well within the official recommended limits, yet, despite the apparent abundance of grazing Anderson asserted that cattle were 'a very destructive force on the ecosystem' (1967, 15). This work is not careful science. It is reminiscent of an environmental narrative that persists independently of the evidence available (Leach and Mearns 1996a). The weaknesses of this report, which laid out the case for degradation so carefully, suggest fragility in the foundations of degradation thinking.

The most obvious error in the report is the substantial underestimation of the number of cattle that were using the Reserve. These were more likely to have been between 20 000 and 40 000 at the time he was writing. Twenty thousand cattle, concentrated in one-quarter of the Reserve, would give a stocking rate of one animal in 10 acres and would give Anderson just cause for concern.[6] However, this does not mean that Anderson got his numbers wrong, but his interpretation right. Rather, it introduces a second inconsistency in degradation thinking. For despite government officials' constant complaint that stocking rates were unsustainable, the rangelands continued to sustain a far greater number of cattle than they thought possible, as the record of 24 years of cattle numbers shows (Table 2). At the landscape

Table 2 Cattle numbers around Eastern Mkomazi

Year	Cattle
1960	21 984
1965	38 561
1967	45 245
1978	28 219
1984	48 233

Sources: 1960, 1967 data, Lushoto District Office wall chart; 1965 data, Anderson (1967); 1978, 1984 data, census printouts held in District Office scale, ideas of widespread rangeland degradation cannot explain how livestock numbers flourished on such a persistently degraded and over-used resource.

These large numbers of cattle must have had some effect on the environment. Satellite data suggest that parts of the Reserve showed significant sections of bare ground (Canney 2001; Brockington 2003). But the permanence of this is not entirely clear. The statements of conservationists following the clearance of cattle from the Reserve in the late 1980s suggest that their impact was short lived; barely three years after the removal of people and livestock, they were celebrating Mkomazi as 'brought from the brink of collapse and restored to its former glory' (Watson 1991, 14).

This is the third inconsistency in degradationist thinking. It is premised on cattle having a long-term, permanent impact on the environment (else the word degradation means nothing), yet that impact has proven remarkably elusive. Six years after the evictions were complete, a team of scientists set about monitoring the Reserve's biodiversity (Coe *et al.* 1999). Their findings showed that Mkomazi was rich in birds, insects and vegetation, on a par with savannas elsewhere (Homewood and Brockington 1999). It was not possible from their data to work out what the impact of cattle might have been, even though they had been present only recently and continued illegally to use the Reserve after the evictions.

The weaknesses and inconsistencies in degradation thinking apparent at Mkomazi create the space to reconsider herders' views about the environment's dynamics. Some herders complained that the influxes of unwelcome herds caused problems for their grazing. They complained either of visitors' animals 'finishing' the grass, or of disruptions to the system of grazing reserve that provided dry season grazing for calves, sick animals and smallstock.[7] In both instances, it is not apparent that the herders are complaining about long-term degradation, rather the letters seem to refer to the loss of one season's biomass. These letters appear only occasionally, and after severe stock encroachment.

Likewise, the statements of herders who saw Mkomazi as a valuable grazing ground with sweet and salty grasses in the right abundance, and who moved in large numbers of stock as restrictions on their use lapsed in the 1960s, 1970s and 1980s, also make more sense if cattle were not as deleterious to the environment as long supposed. The arrival of new herds certainly caused frictions and tensions, but it is not clear that they caused widespread degradation.

But it does not follow that herders' knowledge is truer, and more accurate, than that of Western scientists. A better basis to compare these claims is required to reach that judgement. There is evidence that vegetation dynamics of pastures at the wetter end of the semi-arid spectrum are likely to be linked to herbivore density. Parts of Mkomazi's rangelands do lie in that wetter spectrum. Grazing was associated with the occurrence of bare ground (Canney 2001). We do not really have a good detailed record of what herders saw happening to the plains while they used them, nor how they interpreted these changes, to compare with the official science.

We are left therefore with uncertainty. I have argued elsewhere, with Kathy Homewood, that the most appropriate hypothesis to refute vegetation change at Mkomazi is that stock numbers never quite reach densities sufficient for vegetation dynamics to be driven by cattle numbers (Brockington and Homewood 1996 2001; Brockington 2002). The natural variability of the rainfall will result in droughts and shortage that will limit livestock numbers before densities become great enough to affect vegetation on a large scale.

But this is not our prediction of what we will know. Our suspicion is that we will never know what was going on. We cannot envisage circumstances where sufficiently careful research was carried out on such a variable and uncertain ecosystem to make it possible accurately to test between these different interpretations.

The Tsavo elephant story[8]

Tsavo National Park occupies an area of approximately 20 000 square kilometres of lowland savanna in south-east Kenya, bordering with Tanzania. The climate of the area is semi-arid, with an unpredictable, bimodal rainfall distribution of between 200 and 700 millimetres per annum (Wijngaarden 1985; Kasiki 1998). There is a gentle east–west slope to the generally low-lying topography: erosional plains towards the west of the ecosystem lie at altitudes 300–600 metres above sea level, while sedimentary plains are to the east of the 300 metre contour line (Wijngaarden 1985). The vegetation is dominated by *Acacia–Commiphora* savanna, in which the density of trees and shrubs varies significantly over time and space.

The Tsavo National Park was designated in 1948, partly because colonial administrators assumed that the land was useless for anything else, due to its low and erratic rainfall (Kasiki 1998). Ecologists of the time believed that the vegetation of the region was in equilibrium with environmental factors such as climate and soil. It was assumed that these environmental determinants would not change over time, and therefore that tree abundance was stable. These ideas were in accordance with prevailing 'balance of nature' ideas, typified by Clements' theories of succession and the concept of the climatic climax (Clements 1916), which encapsulated the idea of stable, unchanging plant communities determined by environmental factors. It was assumed that vegetation determined the 'carrying capacity' of the park for herbivores, and that animal populations were in equilibrium with the plant community.

However, by the 1960s, ecologists were concerned that woody vegetation in the park was declining; the abundance of *Acacia* and *Commiphora* was decreasing, and there was an increase in areas of open, grass-dominated habitat (Napier-Bax and Sheldrick 1963). A ban on hunting/poaching of elephants had been enforced strictly over the preceding decade, and the decline in tree cover was attributed to the growing elephant population. Debates over the 'Tsavo elephant problem' became the focus of international attention. There were three main ecological explanations for the observed changes in vegetation: an equilibrium-based explanation which was based on Clementsian ideas of vegetation succession and carrying capacity (the 'Compression Hypothesis') (Glover 1963; Laws 1970; Myers 1973); a non-equilibrium explanation which involved predictable cyclical change in vegetation structure 'Woodland–Grassland Hypothesis' (Caughley 1976); and a further, non-equilibrium explanation in which vegetation change was caused by an interplay between disturbances by fire and herbivores (e.g. Buss 1961; Napier-Bax and Sheldrick 1963).

1 The Compression Hypothesis was based on the assumption that the Tsavo ecosystem had been in an equilibrium state when the Park was established in 1948 (Glover 1963; Laws 1970; Myers 1973). It was proposed that the subsequent compression of the elephant population into the boundaries of the Park had increased the pressure on vegetation to levels that were endangering tree cover. The causes of compression were thought to be human population growth in the surrounding areas, which restricted migration and dispersal, combined with an effective anti-poaching campaign instigated in the 1950s, which had reduced elephant mortality. Some authors predicted that desertification was the likely outcome unless elephants were culled (Laws 1970).
2 The Woodland–Grassland hypothesis was an opposing view, based on non-equilibrium assumptions (Caughley 1976). This model predicted that interactions between elephant and tree populations would generate stable limit cycles. Growing elephant populations cause a decline in tree abundance, reducing the availability of browse and triggering density-dependent regulation of the elephant population (for example, by increased calving interval, delayed sexual maturity and increased mortality). This decline in the elephant population would reduce browsing pressure, allowing tree cover to regenerate, which in turn would increase the availability of browse and allow elephant populations to grow. According to this model, the observed loss of tree cover was a temporary stage of the cycle and was not perceived as a threat to the survival of the ecosystem (Caughley 1976). The model was non-equilibrium (as distinct from disequilibrium) because, although density-dependent population regulation would cause populations to tend towards an equilibrium point, the equilibrium would never be reached because of the time-lag between changes in tree density and the response of the elephant population.
3 The situation was further complicated by disputes over the role of fire in vegetation change; further explanations attributed fire as a primary or secondary cause of the transition from woodland to grassland. Proponents of both the Compression and Woodland–Grassland Hypotheses agreed that elephants alone had caused changes in vegetation structure and that the role of fire was unimportant. In contrast, Harthoorn (1966) argued that the changes from woodland to grassland could have been caused by fire alone. He also suggested that natural regulatory mechanisms would limit the elephant population before a transition to grassland occurred. Similarly, Buss (1961) attributed fire as the primary cause of the change from woodland to grassland, with elephants in a secondary, catalysing role. An intermediate view was that elephants and fire caused the transition to grassland in different regions of the Park, and that in some areas the two factors interacted; fire was more likely to spread through the more open vegetation which resulted from elephant damage vegetation (Napier-Bax and Sheldrick 1963).

Ecologists found it difficult to agree on a management response to declining tree cover because there was no agreed model of savanna ecology on which to base management decisions. Proponents of the Compression Hypothesis maintained that the observed loss of tree cover was unprecedented, and elephant populations must be culled to prevent destruction of the habitat. Advocates of the Woodland–Grassland Hypothesis suggested that the loss of tree cover was cyclical, and that no management intervention was necessary. Some scientists were also concerned about the ethical implications of elephant culling, and the perceptions of the increasingly important tourism sector. Ecologists, led by David Sheldrick, then warden of Tsavo East, decided that there was not enough evidence in support of the Compression Hypothesis. A *laissez-faire* approach to management was adopted, there was to be no elephant culling and vegetation change was to be monitored in the long term; 'elephant exclosures' were established in order to directly measure the impact of elephants on vegetation.

However, in 1975, poaching of elephants resurged in the Tsavo region, and the opportunity to observe the effects of non-intervention was lost. The elephant population of Tsavo National Park was reduced from 17 487 to 5363 between 1972 and 1988, a decline of 75 per cent (Douglas-Hamilton *et al.* 1994). From 1989 until the late 1990s, poaching declined to insignificant levels, largely due to lack of demand for ivory following the ban on international trade (Milner-Gulland and Mace 1998). At the last official count in 1997, the elephant population of Tsavo was 7371 (Barnes *et al.* 1999). However, in the past few years, there have been sporadic incidents of poaching, possibly linked to recent moves to re-open a limited trade in ivory from some southern African countries.

Tools for questioning the degradation discourse

Conceptual models

The three case studies from Pare, Mkomazi and Tsavo illustrate how assumed (Pare and Mkomazi) or observed (Tsavo) changes in vegetation were interpreted differently, depending on the assumptions that are made about nature. Whether vegetation change was interpreted as degradation (negative interpretation), a phase in a dynamic system (neutral or positive interpretations) or incompletely understood, depended on underlying assumptions about nature. It is only by examining these assumptions that we are able to understand how and why different perspectives might have developed.

The most common assumption, which underlies all negative interpretations of vegetation change in Pare, Mkomazi and Tsavo, is that of the 'balance of nature'. So engrained is the idea of natural stability in Western thought that until recently it has remained as a background assumption, rarely made explicit and little scrutinized (Egerton 1973). Greek philosophy and science assumed that nature was constant, and this idea was later taken as evidence of a benevolent creator by Roman and Christian thinkers. Renaissance ecological thought was organized around the notion of a Great Chain of Being, which placed all biophysical phenomena and creatures on a continuum between chaos and divine perfection. The mechanistic view of the universe which derived from Newtonian physics defined a model for science, which was applied to the emerging discipline of ecology, regardless of its applicability to complex biological systems (Pahl-Wostl 1995). This development was reinforced by the advent of industrialism, after which machine metaphors (e.g. great wheels, clockwork, etc.) came to dominate Western understandings of nature (Glacken 1967).

It was not until the eighteenth century that Carl Linnaeus attempted to define the balance of nature in terms of an equality between births and deaths ('the economy of nature'). The idea of balance was later formalized in ecology by the mathematical concept of equilibrium (Verhulst 1838 cited in Behnke *et al.* 1993) and, in the early twentieth century, ecologists formulated equilibrium-based theories which continue to influence applied ecology and conservation biology to the present day. Two of the most influential of these equilibrium ideas are Clements' theory of succession (Clements 1916), and the logistic model of population growth (Verhulst 1838 cited in Behnke *et al.* 1993; Pearl and Reed 1920 cited in Krebs 1994). Clement's theory predicted that vegetation would reach a stable assemblage, known as a 'climatic climax', whose composition was determined by climatic factors such as temperature and rainfall. Clements' ideas were developed further by Tansley (1939) and Whittaker (1953). These later models incorporated greater environmental complexity; Tansley proposed that several climax communities could exist under a given set of climatic conditions, and that the composition of the climax community would be influenced by local factors such as soil type. Whittaker proposed a continuum of climax communities, reflecting environmental variation along gradients. However, these later theories basically adhered to the idea of an environmentally determined equilibrium between plant communities and the available resources.

Herbivores were not considered to have a significant impact on vegetation structure because it was assumed that animal populations were at equilibrium with their environment (Vera 2000). The logistic equation describes the growth of a population over time when it is supplied with resources at a constant rate (Verhulst 1838 cited in Behnke *et al.* 1993; Pearl and Reed 1920 cited in Krebs 1994). Initially, population size is small and resources are not limiting; mortality is low and each organism can reproduce at its maximum rate. The population size and the rate of population growth increase until individuals have to compete for resources. The addition of each subsequent individual to the population further reduces the rate of population growth. Eventually, recruitment of new individuals is exactly equal to mortality and the rate of population growth falls to zero (Pearl and Reed 1920 cited in Krebs 1994). At this point, the population size has reached a maximum, known as the carrying capacity, which is determined by the resources available (Odum 1953). At the carrying capacity, the population is assumed to be in equilibrium with the environment.

Clement's theory of succession, the logistic model of population growth and the concept of carrying capacity underlie three interpretations of vegetation change in Pare, Mkomazi and Tsavo. In Pare, the existence of small areas of forest is assumed to indicate remnants of the climax community which 'should' exist in this area, were it not for human population increase. In Mkomazi, one interpretation assumes that stock densities have exceeded the carrying capacity of the rangelands, and are causing negative changes to the vegetation. In Tsavo, when tree abundance declined and elephant numbers increased, some ecologists proposed that the ecosystem, previously at equilibrium, had been unbalanced by human activities which disrupted dispersal of elephants and caused their populations to exceed the carrying capacity of the Park. Thus, the underlying paradigm of the balance of nature has led to an assumptions of previous stability, and negative interpretations of present-day environmental change in terms of the disruption of equilibrium conditions.

The balance of nature has remained as a background assumption or paradigm on which other hypotheses were founded. Never labelled as a hypothesis itself, the balance of nature paradigm has escaped rigorous testing, and has persisted since the time of Herodotus, despite a growing body of observations with which it is incompatible (Egerton 1973). It is therefore rarely stated explicitly; authors and policymakers are more likely to refer to Clement's theory of succession and climatic climax than to acknowledge that this theory is built upon a balance of nature paradigm.

If different assumptions of nature are made, however, alternative interpretations of environmental change emerge; there are several explanations of the observations from Pare, Mkomazi and Tsavo that are not based on the balance of nature paradigm. To look at the case studies in another way, if the balance of nature is considered to be a working hypothesis, the observations from Pare, Mkomazi and Tsavo can provide a means of testing this hypothesis; observations from all three sites would appear to suggest that these ecosystems are not at equilibrium, and would support the recent shift in ecological thinking from a balance of nature (equilibrium) to a 'flux of nature' (non-equilibrium) paradigm (Pickett and Ostfeld 1995).

Non-equilibrium theories do not assume that ecosystems tend towards a single, stable equilibrium. While they do not preclude the possibility of stability, non-equilibrium theories suggest that stability is scale-dependent. Moreover, these theories can include processes that would tend towards equilibrium (such as density-dependent negative feedbacks, for example), but acknowledge that an equilibrium is unlikely to result from these feedbacks, because of interactions with other environmental and biological factors. Non-equilibrium theories focus on the processes that generate spatial and temporal heterogeneity, including the interactions between organisms (biotic instability), environmental stochasticity (variability) and disturbance.

As long ago as 1930, Charles Elton had emphasized the important role of biotic instability in creating non-equilibrium conditions:

> 'The balance of nature' does not exist, and perhaps never has existed. The numbers of wild animals are constantly varying to a greater or less extent, and the variations are usually irregular in period and always irregular in amplitude. Each variation in the numbers of one species causes direct and indirect repercussions on the numbers of the others, and since many of the latter are themselves independently varying in numbers, the resultant confusion is remarkable. (Elton 1930, 17)

Similarly, ecologists and biogeographers had long ago recognized that climate, one of the cornerstones of Clements' theory of succession, varies over a range of timescales, from geological (glacial–interglacial), to centennial (for example, global climatic anomalies such as the Medieval Warm Period and Little Ice Age), decadal (e.g. recent concern over anthropogenically induced global warming, effects of El Ninõ Southern Oscillation) to annual or seasonal (the unpredictability of seasonal rainfall patterns in semi-arid areas). Therefore, it is highly unlikely that any plant community could reach equilibrium with climatic factors, and ecosystems are likely to be continually responding to stochastic variations in environmental parameters such as rainfall and temperature.

Finally, under a flux of nature paradigm, disturbance is seen as integral to most, if not all, ecosystems and disturbance events are now commonly perceived as the norm rather than the exception. The role of disturbance in creating and maintaining spatial and temporal heterogeneity is now recognized by most ecologists; as a result, many conservation biologists agree that the suppression of disturbance is no longer desirable, and the conservation of ecosystems should include the maintenance of disturbance regimes such as burning patterns. However, many patterns of disturbance remain poorly understood, and the application of these ideas is fraught with difficulty.

Interpreting ecological change under a non-equilibrium paradigm requires knowledge of the interactions between organisms, environmental stochasticity and disturbance, and the 'natural variability' which results from these processes (Landres *et al.* 1999). Equilibrium-based interpretations of ecological change tend to predict relatively simple patterns of change; following a disturbance, an equilibrial system will usually either absorb the disturbance without change (resistance) or return to its original state (resilience). However, equilibrial systems are essentially perceived as fragile, and if subjected to too great a disturbance, they are expected to embark on an apparently linear and irreversible trajectory of negative change, such as desertification, deforestation or degradation. In contrast, the patterns of change predicted under a non-equilibrium paradigm are more likely to be indeterminate and complicated: biotic interactions are likely to be non-linear due to feedbacks; stochasticity is by definition unpredictable; and patterns of disturbance are complex and may best be understood in terms of probabilities rather than as predictable regimes.

In Pare, Mkomazi and Tsavo, it may be that vegetation change cannot be explained by any one model because biotic interactions, stochasticity and disturbance act and interact at different spatial and temporal scales, constituting a spatial and temporal hierarchy. Hierarchical patch dynamics provides a conceptual framework for understanding the interactions between ecological processes which act at different scales. The concept of patch dynamics was originated by Watt (1947), who explored the relationship between pattern and process in the plant community. Watt perceived the plant community as a mosaic; patches of vegetation were at different stages of succession and the boundaries of patches were functionally defined by the process of vegetation change over time. He predicted that vegetation change within each patch would be cyclical and that a plant community in a constant environment would maintain a constant proportion of patches at each successional stage. A change in the environment might cause departures from this stable composition. Watt's ideas were applied and developed in forest gap dynamics, the cyclical mosaic concept and the shifting mosaic steady state (Richards 1952; Bormann and Likens 1979; Remmert 1991; Olff *et al.* 1999), theories which share Watt's idea of variability at the patch scale and stability at larger spatial scales.

This link between pattern, process and scale can be developed further to include many processes, operating at a range of spatial scales in a hierarchical system (O'Neill *et al.* 1986; Wu and Loucks 1995), from continental, through regional (10^3 km^2), landscape (10^2 km^2), local (10^1–10^{-3} km^2) to the micro-scale (100 m^2–0.1 m^2) (adapted from Whittaker *et al.* 2001; and Pickett *et al.* 1989). A similar hierarchy can be envisaged for the temporal scales, consisting of the evolutionary or geological timescale (thousands/millions of years), the ecological timescale (decades to hundreds of years), and the annual or seasonal timescale (months/years) (Willis and Whittaker 2002). Tiers in the hierarchy emerge from the effects of processes acting at different scales, rather than being imposed by the observer (Pickett *et al.* 1989; Kotliar and Wiens 1990). Lower levels in the hierarchy are nested within higher levels (Wu and Loucks 1995) and, consequently, it is not possible to understand environmental change at large spatial scales or, in the long term, by simply extrapolating from small-scale or short-term data-sets.

Power and knowledge

The shift to a non-equilibrium paradigm, and the development of hierarchical patch dynamics, has created new opportunities for understanding spatial and temporal variability in the environment. However, changing conceptual models do not capture all the dynamics of the changing ideas about these environments. Notions of degradation and environmental change are also part of socially organized discourses, which reflect relations of power and authority and people's particular values as well as their interpretations of nature.

For example, some non-equilibrium interpretations of nature retain elements of the balance of nature paradigm in that they continue to assume that humans are not part of nature, and that their influence on ecosystems is 'unnatural'. The post-Enlightenment distinction between natural and anthropogenic phenomena maps onto the symbolic opposition between order and disorder. Based on the balance of nature (equilibrium) paradigm, for example, conservation biologists aimed to preserve ecosystems without change; ecosystems were perceived as self-regulating, and it was assumed that preventing disturbance by humans would lead to a functioning and stable habitat. Based on a flux of nature (non-equilibrium) paradigm, spatial and temporal variability are perceived as the norm, and disturbance, for example by fire, herbivores and extreme climatic events, is accepted. However, some non-equilibrium explanations of vegetation change continue to assume that human influences are disruptive to natural regulatory mechanisms. For example, Caughley's woodland grassland hypothesis predicted stable limit cycles in tree and elephant populations, 'except where human density is high enough to enforce an artificial equilibrium' (Caughley 1976, 280). Thus, even in this non-equilibrium model, human influence is perceived as unnatural, disorderly and potentially destabilizing. Major challenges for interpretations based on the flux of nature paradigm are to incorporate knowledge of how humans have shaped landscapes over long time periods; to understand the interplay between social, climatic and ecological factors; and to integrate this understanding into interpretations of environmental change. In more general terms, it seems likely that assumptions about the objectivity of knowledge underlie hypotheses based on the flux of nature paradigm. These underlying beliefs need to be made explicit, in order that their effects on the interpretation of nature can be understood.

All three case studies reflect the powerful influence of discourses on the interpretation of ecological phenomena and the institutionalized implementation of policy. Ideological constructs and implicit assumptions can therefore have quite material effects. The case studies demonstrate the deep historical roots of narratives about the effects of humans, cattle and elephants on African forests, rangelands and conservation areas. These environmental narratives define a 'normal' ecological state, lay out a causal sequence describing the threats to systemic stability, and prescribe a course of action that can prevent a looming crisis of permanent degradation (Leach and Mearns 1996b). The most important aspect of these particular symbolic systems, however, is that all are embedded in powerful social institutions. These administrative and conservationist elites define which sources of knowledge are valid and how accepted facts fit into the larger narrative. The sophisticated ecological knowledge of farmers and herders (and, of course, elephants) remains untapped or disregarded because it lacks the imprimatur of scientific objectivity and elite expertise. Consideration of the social and political organization of knowledge in colonial and postcolonial Africa is therefore fundamental for the interpretation of ecological data.

Such an approach enlarges the scope of environmental analysis by including social, ideological and political dynamics and discourses as aspects of ecosystems. Discourse analysis is typically associated with the writings of Michel Foucault; in the domains of critical theory and postmodern social analysis, a discourse is a power-laden set of statements about a referential object. From this perspective, there are no coherent, taken-for-granted or innate facts or structures of meaning. Instead, all discourses are sets of knowledge that emerge to serve a power structure and so re-create it. According to Foucault and his followers, it follows, therefore, that there is no objective truth to be learned by scientific investigation, but only a continuum of dominant and oppressed representations. This turn from objective/materialist analysis toward a more subjective/idealist mode does not, however, require a wholesale rejection of the scientific method. Discourse analysis can serve as a robust means of hypothesis generation, testing and evaluation.

In order to build a viable synthesis that can show the multiple connections (and disjunctures) between muddy fields and social fields, we must shed notions of the balance of nature, the equilibrium of social structure and the hegemony of particular discourses. The dominant view in both the ecology and anthropology of the 1950s saw populations harmoniously interacting in self-regulating systems (respectively, Odum 1953 and Radcliffe-Brown 1952). In this light, a climax forest appeared to be an entity quite similar to a stable society. Even after many anthropologists had jettisoned the overtones of stasis and harmony from the culture concept, they continued to identify 'culture' as systems of relationships with symbolic, structural or adaptive features (Keesing 1974). Over the last quarter-century, however, anthropology and sociology have increasingly relied on a new vocabulary of indeterminacy and instability to explore the changing characteristics of culture/society through paradigms of process, practice and structuration (respectively, Moore 1986, Bourdieu 1990 and Giddens 1984). In a move quite parallel to the rise of the flux of nature paradigm in ecology, social science is now investigating the flux of culture.

Putting politics in ecological analysis is not particularly new. Structuralist political ecology emerged in the late 1980s as an interdisciplinary concern for how social inequality shapes environmental change (Blaikie and Brookfield 1987; Bryant 1992). Inspired in part by postmodern hermeneutics, recent work in political ecology has called for a poststructural approach emphasizing the determining influence of systems of ideas arranged as 'regional discursive formations' (Peet and Watts 1996, 13ff) – such as, for example, the notion of land degradation in Africa. Suggesting that political ecology did not have enough politics in it, these poststructuralists demanded that analysis incorporate both the pragmatic politics of resource struggles and the culturally specific symbols that constitute those struggles. For Africanists, a poststructural political ecology must analyse how colonial and postcolonial ideologies of gender, age and class intersect with material processes of production and reproduction (e.g. Carney 1996; Schroeder and Suryanata 1996) to interact with and influence environmental change. The bifurcation in political ecology is, at its root, an issue of how one conceptualizes power. Power is three-dimensional, and privileging just one aspect impoverishes political analysis (Lukes 1986). For structuralist political ecologists, power is an overt matter of force and coercion (power dimension #1) among classes over resource control and exchange. The poststructuralists are more interested in the way that agendas for resource use and ecological management are quietly shaped by social inequalities (power dimension #2) and the power of ideas to place limits on the consciousness of all social actors (power dimension #3). A political ecology that can contribute to ecological analysis must include all three dimensions of power as historical processes. As a method for political ecology, such an approach must be open-ended and non-deterministic. It is not necessary for the historical analysis of discourse to replace the scientific method by revealing an ecological discourse as yet another manifestation of elite domination.

Sources of knowledge

The terms 'deforestation' and 'degradation' are open to question because they suggest a previously stable environment. The indigenous species found throughout North Pare's sacred forests, and the testimony of the men who care for them, could support this remnant model of environmental change, just as the patchy nature of tree cover in Mkomazi and Tsavo could be perceived as the degradation of a once closed woodland canopy. Other scenarios are also possible, however. Before the agricultural ancestors of the Pare and Wagweno peoples arrived in North Pare, the area's original vegetation cover may not have been the kind of high canopy forest currently found on some of the mountain peaks. Forests may have been largely confined to river valleys. Some of the sacred forests could have been deliberately planted or unintentionally grown out of undisturbed areas with thick shrubs, perhaps from seeds spread by birds or primates. Similarly, the lowland savannas of Mkomazi and Tsavo may never have been in balance; the distribution and abundance of trees might be in a state of continuous flux, resulting from a mosaic of shifting disturbances, biotic interactions, climatic changes and human influences. Only archaeological investigation of the soil profiles of several sacred forests, radiocarbon dating of charcoal from precolonial iron-smelting sites and analysis of fossil pollen can conclusively document how and when the vegetation of North Pare, Mkomazi and Tsavo changed.

In ecology, the shift to a non-equilibrium paradigm raises questions concerning the rate, magnitude, spatial extent and causes of variability; testing non-equilibrium hypotheses requires data which elucidate the links between pattern, process and scale (Watt 1947; Wu and Loucks 1995) and requires much more comprehensive data sources than are necessary for equilibrium-based research. With their underlying assumptions of stasis, equilibrium-based hypotheses demand only snapshot data and are usually spatially and temporally scale free. In contrast, non-equilibrium hypotheses describe change, and require a series of observations over time within a spatially defined framework. Different processes may influence variability at different spatial and temporal scales, and extrapolation of observations is likely to be misleading; rather, data must be collected at scales appropriate to the process under investigation. The social organization of ecological knowledge can serve as a third sort of scalar variable. Adding a socio-political scale (based, perhaps, on the degree of institutionalized power in social groups) to the standard biophysical axes of space and time may lead to a more nuanced non-equilibrium ecology.

Similarly, the recognition of the manifold ways in which data and environmental narratives are socially constructed by all actors, whether government officials, scientists, local leaders or farmers and herders means that it is particularly important to test narratives against each other. Discourse analysis may have much to reveal about the relations of power and authority and their role in the production of knowledge, but it remains possible that they may also say something about nature. Nature is not always an inert empty presence, a blank sheet to be written on, but an active agent that makes its voice heard through and despite the activities of people (Demeritt 1994). Deciding precisely what is being said will require thorough triangulation and cross-referencing different representations of nature, using as many sources of data as are possible.

Testing hypotheses about environmental change therefore requires long-term data sets, and observations collected over a range of different spatial scales. There are several possible sources of such data, and a comprehensive understanding of natural variation is more likely if several data-sets are combined in order to effectively explore the interplay between different factors which influence vegetation change. Four possible relevant data sources are listed below:

1 Palaeoecological techniques can provide an insight into vegetation change on timescales of hundreds or thousands of years; pollen analysis can provide information on changes in the plant community over time, providing data relevant to the debates over deforestation and degradation in Pare, Mkomazi and Tsavo.
2 Remotely sensed data (aerial photography and satellite imagery) can provide detailed information on vegetation change over large spatial scales, for the past 30 years in the case of satellite data and 50 years in the case of aerial photographs.
3 Local ecological knowledge can provide descriptions of vegetation change within the spatial frames of dynamic human lives, and over the time frame of several generations. Such oral histories of landscape transformations must be seen as both objective reports of ecological conditions and subjective discursive representations. They are both socially constructed and empirically driven.
4 Elite discourses (found in archives, policy documents and scientific papers) can provide explanations for vegetation change that may be strikingly at odds with the descriptions emerging from other data sources. Tracing the historical trajectory of dominant representations of a given landscape provides the methodological advantage of critical relativism. Looking at ecological knowledge as a social process laden with power and shot through with various forms of inequality can help the analyst avoid the pitfalls of unquestioned assumptions.

Conclusion

The flux paradigms of nature and culture describe a human–ecological relationship that is non-equilibrial, historically contingent and constantly negotiated at both material and ideological levels by unequal actors. Discursive approaches can complement materialist approaches by expanding the domains of ecological inquiry and demanding that analysts cross-check their data for unquestioned assumptions.

This means, therefore, that researchers can and should explore multiple paradigms when analysing environmental affairs. Rather than accepting and testing a ruling theory, researchers can try to develop a range of hypotheses, thus avoiding 'the dangers of parental affection for a favourite theory' (Chamberlin 1890). According to the Method of Multiple Working Hypotheses, researchers are advised to 'bring into view every rational explanation of new phenomenon, and to develop every tenable hypothesis respecting their cause and history' (Chamberlin [1890] 1965, 756). However, it has been noted that in biological systems, where many possible variables can be monitored, the choice of variable will influence the development of hypotheses (Pahl-Wostl 1995); this problem will be further multiplied when hypotheses relating to both ecological and social systems are considered.

Explanations emerging from the flux paradigms of nature and culture will necessarily be complex, and using the method of multiple hypotheses across ecological and social paradigms would need to admit the possibility of tentative interpretations. Several of the variables might interact to produce an observed phenomenon, and thus the hypotheses need not be mutually exclusive. Instead of comparing the merits of different hypotheses and their associated methodologies, and asking 'what is the best method', we can ask what are the distinctive values of different methods, and how might various hypotheses be combined to capture the complexity of a situation/phenomenon. By ensuring that both materialist and ideological paradigms are used as bases for hypotheses, this approach could capture both perspectives, in order to describe phenomena which have both ecological and social dimensions.

Finally, we would caution that it may be necessary to make explicit the limits to our ability to know about ecological and cultural dynamics. A fair amount of the research we have criticized in the stories above were written with the underlying assumption that nature is knowable and that current methods generated sufficient understanding to make management and policy decisions possible. It was work that was often conceived as part of the march of progress and enlightenment, a Whig history written by its actors. But there are grounds to be less optimistic about such research.

We are not making a philosophical point here about the inherent unknowability of nature. Our arguments above are based on the idea that in principle nature can be known – we have advocated ideas that will give us better knowledge. But we would also advocate making explicit the bounds to that knowledge. These bounds can reside in nature. For example, hierarchical patch dynamics may involve a multitude of scales which we are unable adequately to sample, or which do not persist for sufficient time for our methods of observation to capture. Alternatively, these boundaries may simply reflect the complexity of nature combined with the inadequate investment in research and exploration thus far. Palaeoecological work, for example, could be increased vastly in the tropics; to date, most work has concentrated on major lakes and waterbodies, overlooking the volumes of data about smaller-scale change that may be obtainable from smaller deposits. Despite the attention and devotion that Africa commands from Africanists, and the excitement its environment induces, the fact remains that a great deal of basic knowledge is still to be learnt about Africa's environment.

The bounds also reside in the political battles surrounding environmental trends and resources. Environmental degradation generates a good deal of revenue and aid projects for central government. Protected areas and national parks not only defend nature from human encroachment, but also generate valuable foreign exchange. They, and the rare species they contain, can also be championed by conservation NGOs, who can raise millions of dollars, and gain much prestige, from publicity campaigns. The material consequences of ideological constructs can be extremely important symbolically and materially to those who hold them. These are not circumstances in which conclusions from data can be freely drawn, or indeed the hypotheses driving the research can be freely conceived. We believe that it is only by making such forces explicit and, where necessary, admitting that they obstruct progress, that it is possible for any progress to be made at all.

Notes

1 This section is based on ethnographic and historical research by Mike Sheridan in 1997–8.

2 The first population estimate for North Pare comes from a report by the Lutheran missionary Hans Fuchs (1905). Fuchs used the chiefs' tax registers to estimate that 9600 people lived in North Pare.

3 The Rules provided a list of 'reserved tree species' that could not be cut even if they were located outside of a Forest Reserve. A landowner could not cut such a tree on his own farm unless he could prove that he had planted and tended it himself. The Rules also gave the chiefs rights to prosecute *any* action they considered to have contributed to deforestation.

4 This section of the paper summarizes arguments presented in more detail elsewhere (Brockington and Homewood 2001; Brockington 2002). More data, discussed in greater depth, are dealt with there. They are based on anthropological research and surveys and archival work carried out between 1994 and 1996 by Dan Brockington.

5 Debates about cattle on rangelands have been more fractious here because the herders have tried to use lands intended for wildlife alone or which is only accessible via illegal border crossings.

6 They would not give all ecologists such anxiety. For a discussion of the appropriateness and derivation of Anderson's stocking rates, see Behnke *et al.* (1993).

7 Without these grazing reserves, these animals would not be able to cover the distances between the remaining water and the available pastures at the end of the dry season.

8 This section is based on a literature review by Lindsey Gillson, which was part of a palaeoecological thesis on the Tsavo area, carried out between 1998 and 2002.

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