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Towards a non-equilibrium ecology: perspectives from an arid land

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'. . . the whole surrounding area has been overgrazed so thoroughly that only the large trees remain in a level plain of bare sand. There are no young trees nor can any raise its head owing to the intensive browsing of the numerous cattle, goats and donkeys ... as the large trees die off one by one and no others take their place it seems that all vegetation must eventually disappear . .. (Van Warmelo, 1962, p. 39).

'Abuse of natural resources in the past has aggravated the problems of the livestock industry in the Homeland. Severe deterioration has occurred' (Loxton et al, 1974, p. 1).

'.... eventually the whole ecosystem will suffer severely and collapse . . .' (Infoscience, 1994, p. 22).

The statements above describe the existence of widespread and devastating environmental degradation in arid north-west Namibia, where I am currently conducting fieldwork. They could, however, have been taken from any number of academic papers and consultancy reports expressing the majority view that a situation of pending 'desertification' through overuse of natural resources threatens dryland environments throughout the world, and particularly in sub-Saharan Africa. One would expect some fairly conclusive evidence to provide the basis for such confident assertions. In fact, the above statements concerning the Namibian context are supported by no data whatsoever. Elsewhere, this negative perception of drylands exists even when various production indices for local economic systems demonstrate that productivity has been at least maintained, if not improved, over the time period in question (see, for example, Homewood, 1993, for an analysis of livestock productivity indices in Baringo, Kenya, an area repeatedly referred to as 'the agricultural slums of Kenya').

This year, and despite predicted drought, north-west Namibia experienced greatly above-average rainfall which completely transformed the bare ground of previous dry years into a largely uninterrupted ocean of waving grassland (Fig. 1). And this includes the same area that last year was described as being on the brink of collapse! Clearly some serious questions need to be raised concerning why the perception of progressive degradation in dryland systems is so widely held, despite the extreme variability of these environments and in the face of evidence to the contrary.

This is no trivial issue for two related reasons. First, development policy and intervention in drylands are usually lodged within a framework that sees over-stocking and over-grazing as an inevitable outcome of management strategies by local pastoralists, and has as its aim the establishment of (livestock) stocking and harvesting levels which are 'sustainable', i.e. constant, through time. The acknowledged failure of many such interventions, despite the technical expertise of the development professionals involved, has had dire consequences for the pastoralist societies affected.

Second, the problems encountered by development projects in drylands, together with the lack of convincing evidence for many assertions of long-term environmental degradation in these areas, are aspects of a single fundamental issue: the validity of deeply held assumptions conceived in the context of northern temperate zones regarding ecological dynamics, and their applicability in providing a framework for thinking about arid and semi-arid environments. To paraphrase Stuart Pimm (1991, p. 17), we need to worry about our 'model' of how arid systems work because it is causing us to make possibly wrong predictions concerning trends within these systems, and particularly those related to human use of arid land resources.

Many common assumptions regarding ecosystem dynamics in general can be traced to a single theoretical norm which dominates mainstream academic ecology and popular environmental literature alike. This is the constraining principle of equilibrium dynamics, and it is so accepted in ecological thinking that it is rarely even acknowledged let alone questioned. It has amounted to nothing less than an 'equilibrium paradigm' governing ecological thought, and guiding the focus of ecological research, management policy and expectations of environmental productivity throughout this century. As is currently being discussed in the literature concerning arid land ecology, (see, for example, Sandford, 1983; Wiens, 1984; Caughley, Shepherd & Short, 1987; Ellis & Swift, 1988; Westoby, Walker

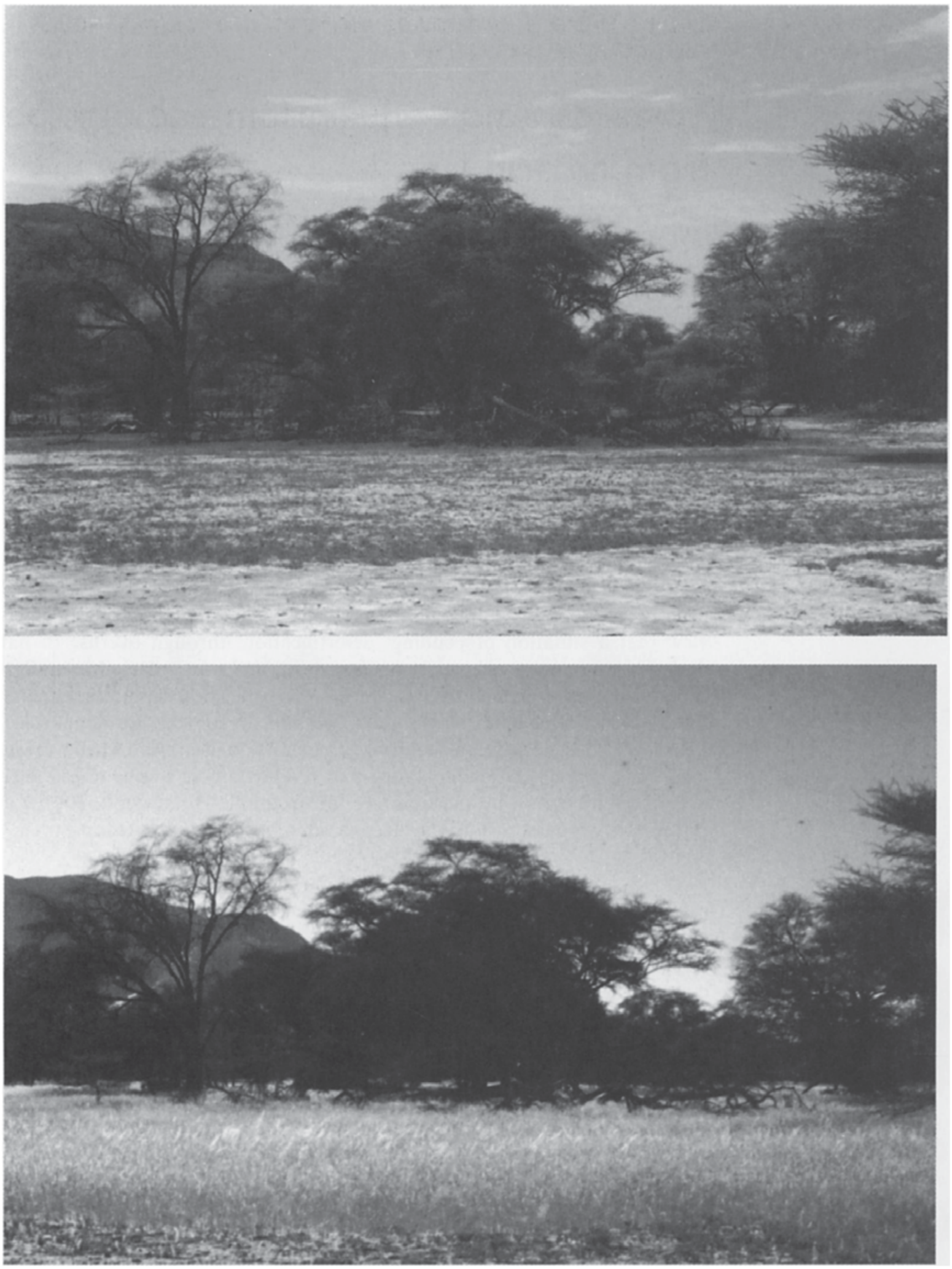

FIG. 1. The Sesfontein Basin, Namibia: on the brink of collapse? No: (a) the green flush at the start of the rains; (b) a grassland returns. (Photos: Sian Sullivan.)

& Noy-Meir, 1989; Behnke, Scoones & Kerven, 1993), the extension of assumptions derived within the framework of equilibrium dynamics is extremely problematic for arid systems. Given the fact that arid and semi-arid grassland, steppe and desert environments account for some 34% of the land area of the planet (Wiens, 1984: p. 450), it is pertinent to question why they are perceived as ‘extreme’, and why analyses of their dynamics are ‘shoehorned’ within a theoretical framework that developed in a totally different environmental context.

THE EQUILIBRIUM MODEL: BIOTIC-BIOTIC INTERACTIONS AND THE 'BALANCE OF NATURE'

Conventional ecology tends to make the implicit assumption that the fundamental state of communities of species is one of equilibrium; a stable balance of species densities is maintained through inter- and intra-specific interactions, which fine-tune the biotic component of the ecosystem within the opportunities and constraints presented by a constant abiotic environment. In other words, ecosystems are viewed as isolated and closed biotic systems, the components (i.e. species) of which gradually 'equilibrate' to stable, external conditions. The predetermined end-point, or 'climax', of this irreversible evolution towards equilibrium is a perfectly balanced biotic community which is stable through time unless disturbed. The sources of such disturbance are always perceived as external to the (closed) biotic system.

This conception of ecosystems as rather 'rigid' structures in a passive environment allows the discipline of ecology to focus on understanding them in terms of the properties of their component species and their configuration, rather than their dynamic behaviour (Jantsch, 1980, p. 24). More complicated equilibrium models, such as those which view ecosystem behaviour as characterized by stable limit cycles or multiple stable states, integrate elements of dynamic behaviour. The dominant interest, however, remains the ability of these systems either to return to equilibrium following disturbance (resilience), or to retain equilibrium in the face of disturbance (resistance).

This conception of ecosystem behaviour lies deep in the very foundations of western science. Its strongest influences are the theoretical constructs and observations of classical thermodynamics which, in turn, are rooted in the Cartesian-Newtonian conception of a Nature which obeys laws and is thus predictable and controllable. The crucial point about thermodynamic systems is that any deflection from normal behaviour or equilibrium is seen as random fluctuation or noise rather than as an integral part of the system. The mathematical language used to describe such systems and applied to questions in ecology is thus biased towards analytically tractable interactions which are presumed to have a fundamental equilibrium solution.

It is significant that these concepts in science evolved in a relatively predictable 'natural' environment, and were intimately linked with an economic system which seeked to control and maintain (in the short-term at least) environmental productivity for profit. A northern temperate zone 'equilibrium-centred view of constant nature' (Holling, 1986, p. 310, 313) thus provides a logical basis from which to calculate economic measures such as the maximum sustained yield of a particular resource, and for conservative management strategies designed to maintain this.

More recently, equilibrium dynamics have formed the basis for General Systems Theory and steady-state systems thinking which have been enormously influential in ecology. Questions relevant to a systems ecology shaped by the assumption of equilibrium relate predominantly to identifying negative feedback biotic relationships which preserve the stability of a defined 'healthy' state (Jantsch, 1980, p. 56). This focus on defining a community stable state considered to be the 'norm' legitimates the application of the label 'degradation' to any process thought to deflect the biotic system away from this state.

A NON EQUILIBRIUM ECOLOGY: INTEGRATING ABIOTIC-BIOTIC INTERACTIONS

As Wiens (1984, p. 455) states, 'belief in equilibrium theory amounts to verification of a paradigm due to faith in that paradigm', rather than on the weight of empirically tested evidence. Most importantly, the assumption of a passive abiotic context external to a closed biotic system fundamentally precludes the possibility that environmental variability may be integral to understanding ecological behaviour.

This is nothing short of disastrous for the understanding of arid and semi-arid systems. In these cases biological productivity is primarily moisture, as opposed to nutrient, limited and rainfall, usually the only source of water, is inherently extremely variable and unpredictable. Aperiodic and idiosyncratic rainfall events in time and space thus drive the biotic system, preventing the species community from reaching a stable state composed of average densities and regulated by density dependent feedback control. This is particularly true for smaller time and spatial scales.

Such a perspective can find firm theoretical foundations in the 'harder' physical sciences in the dynamics of what have become known as Prigogine dissipative structures[1]; physical systems characterized by openness and system-environment interactions, non-equilibrium, multiple levels or scales, and internal reinforcement of fluctuations. Thus, ecosystem properties arise as a process driven by dynamic and non-linear interactions both within the biotic system and between this system and its environment (Jantsch, 1980, p. 24).

An ecology which accepts variable abiotic parameters as integral to ecosystem behaviour needs to shift its interest from the mechanisms that maintain a stable equilibrium, and the potential sources of deflection from this desirable state. More appropriate questions would relate to the ways in which a condition of non-equilibrium, characterized by continual and unpredictable fluctuation at different scales, is essential for ecosystem health and resilience (Holling, 1986). This could include, for example, the means whereby systems with inherently low quantitative stability maintain the same qualitative relationships in the face of continual change, and the strategies through which human resource management systems cope with quantitative fluctuations in resource availability. Instead, dominant thinking about arid and semi-arid systems remains largely focussed on exactly the opposite: on the means of imposing stability by reducing, rather than 'tracking', variation in productivity; on proclaiming situations of irreversible vegetation degradation whenever successive dry years eliminate herbaceous cover and leave large tracts of bare ground; on declaring as irrational and destructive locally evolved resource management strategies designed to capitalize on good years in order to survive drought years; on introducing livestock stocking quotas and offtake levels based on concepts of a constant carrying capacity.

We have only to look at the quotations at the start of this editorial to see how pervasive equilibrium thinking is in opinions concerning the status of an arid land over the last 30 years. In the first quote, for example, we come across the term 'over-grazed', implicit in which is the existence of some (undefined) 'normal' and acceptable level of grazing which has been over-reached. This is directly related to the concept of carrying capacity, defined as the constant level of stocking at which herbivory balances primary productivity. How can this be an appropriate concept in a context where primary productivity is largely determined by extremely variable, stochastic rainfall events, and not by density dependent relationships in a resource limited environment? The second quote asserts the occurrence of 'severe deterioration'. This is interpreted as meaning a progressive (linear) decline in productivity; again, a notion relying on the perceived existence of a 'normal' and definable state. If productivity is seen as being inherently variable, then such a perception is logically untenable, i.e. its 'normal' state is variable! Finally, the area is described as being on the verge of 'system collapse'. What exactly does this mean? I can only imagine that the authors (without any quantitative or long-term data at all) perceive the system to have moved so far away from its desirable equilibrium state that it is on the brink of shifting to a qualitatively different state. This is the antithesis of a non-equilibrium perspective which sees a wide range of variation as integral to dryland ecosystems, and has a positive view of such systems as displaying a remarkable degree of persistence in the face of stochastic abiotic events.

DOES A NON-EQUILIBRIUM FRAMEWORK PRECLUDE THE EXISTENCE OF DEGRADATION IN DRYLANDS? BIOTIC-ABIOTIC INTERACTIONS

So far, I have been making a plea for a theoretical framework that questions the validity of many statements concerning vegetation degradation in drylands, by suggesting that much of what is

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[1] After the French chemist who made these structures his life-work.

described as degradation may be part of the normal range of variation displayed by these systems. This is not to say that patch degradation in arid and semi-arid environments does not exist. The cause of such degradation, however, is unlikely to be related to excessively strong biotic interactions resulting from 'over-stocking' by 'irrational' subsistence pastoralists. Rather, it is more likely to be due to the effects on the physical environment, namely soil structure and fertility, of concentrating livestock and settlement in particular locations. The policies which encourage this concentration of livestock and human populations include the drilling of boreholes in areas without permanent water (often those previously used only as wet season grazing), and the encouragement of permanent settlement to facilitate administration of previously mobile populations. These potentially damaging policies derive directly from attempts to increase productivity and predictability by reducing the variability or 'noise' that is essential for the resilience of arid systems. Or in other words, by imposing interventions aimed at restoring equilibrium onto a non-equilibrium system.

TOWARDS A NON-EQUILIBRIUM ECOLOGY

Such a shift in thinking concerning the driving parameters of arid and semi-arid systems can have significant implications for the discipline of ecology as a whole. In particular, it emphasizes the critical need to introduce conceptual values explicitly into ecological thinking. Through doing so we may arrive at an ecology that does not continually take as its reference point a theory of ecosystem behaviour that evolved within a temperate, 'green', context. Instead we can conceive of an ecology that celebrates variability as well as average values, process and pattern as well as structure, stasis and order, and creative as well as conservative behaviour by both ecosystems and humans as integral components of those systems. Above all, here's to an ecology that drops the duality between biotic and abiotic dynamic phenomena, and recognizes unpredictable abiotic events as part of healthy ecosystem behaviour.

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