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The Applicability of the Carrying Capacity Concept in Africa

Comment on PDN Paper 29b 'The Concept of Rangeland Carrying Capacity in Sub-Saharan Africa - Myth or Reality' by P N de Leeuw and J C Tothill (May 1990)

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In their recent paper, de Leeuw and Tothill (1990) discussed the shortcomings of estimating carrying capacity (CC) of pastoral systems in Africa. They noted the difficulty of determining available forage per animal due to high annual and spatial variability in plant production, seasonal changes in forage quantity and quality, livestock species mix, and the use of supplemental feeds. Nevertheless, they concluded that the concept 'is useful for planning purposes' and that 'the underlying principles on which it is based need full acceptance' if sustained resource management is to be accomplished. While agreeing with their review of problems associated with the concept, we take exception to their conclusions. We will present our arguments by addressing the following three questions: (i) Is the concept of CC sound? (ii) Can CC be adequately estimated?, and (iii) Can CC information, even if we could obtain it, be meaningfully applied in pastoral production systems? Finally, we offer an alternative approach for conserving rangeland resources in pastoral systems.

Is the Concept of Carrying Capacity Sound?

The notion that there could be some limit to the rate of increase in growth of populations was suggested by human demographers in the seventeenth and eighteenth centuries. Fifty years after Malthus's treatise on exponential growth in 1796, P F Verhulst proposed a logistic equation which contains probably the earliest reference to carrying capacity (Hutchinson 1978). In this model, rediscovered in the 1920s, carrying capacity (K) is defined as the maximum number of individuals that can persist under certain specified conditions, particularly limited space and food supply (Colinvaux 1986). This definition implies that carrying capacity is the total resources available divided by the minimum maintenance requirement of each individual (Ricklefs 1979). Another useful concept in the logistic growth model is the optimal yield or maximum sustainable yield, which is the maximum growth rate of a population under the conditions prevailing. It is found at a population size that equals K/2 (Wilson 1980).

Under strictly controlled conditions with a constant food supply the logistic growth model gives a reasonable fit in the cases of microbial organisms and relatively uncomplicated animals such as certain small invertebrates (Hutchinson 1978, Colinvaux 1986). Under these conditions carrying capacity (K) is a stable equilibrium point and the food supply is the major density-dependent factor.

An important reason why the logistic model works so well when tested in laboratory experiments is that the food is replenished; there is no negative feed-back of population size on the availability of food. This is a very different situation from that normally assumed in livestock grazing where animal numbers not only respond to the availability of resources but may impact them as well.

American pioneers in range management borrowed the term 'carrying capacity' from population ecology but significantly altered the concept. Sampson (1923) defined CC of rangeland as 'the number of stock... which the area will support ... without decreasing the forage production in subsequent seasons.[1]' Subsequent variations on this definition all emphasize or imply long term sustained productivity, either of the range resource or of the livestock utilizing it. (Sustained livestock production presumes the maintenance of productive range resources.) In range/livestock management, CC is determined by both livestock and vegetation responses to stocking rate (SR). In reference to livestock, the CC becomes the SR yielding maximum livestock production per area, a point corresponding more to optimal yield (K/2) than carrying capacity (K) in the logistic model. In the vegetation approach, CC is determined as the maximum

[1] The complete quotation is ... 'The grazing capacity of a pasture area may be defined as the number of stock of one or more classes which the area will support in good condition during the time that the forage is palatable and accessible, without decreasing the forage production in subsequent seasons.' (Sampson 1923, page 328). For the purpose of our commentary, we will not distinguish between grazing capacity and carrying capacity.

livestock population that can be sustained without degrading the forage resource.[2]

The validity of CC as a management concept, however, is based on the premise that range productivity is dependent upon SR; heavy grazing promotes degradation and reducing SR leads to improvement. In Sub-Saharan Africa this premise can be challenged on two counts. First, the great variability in rainfall, especially the incidence of drought, can overshadow the influence of herbivory on the range resource. Thus range productivity becomes more a function of climate (a density-independent factor) than of SR (Ellis and Swift 1988, Westoby *et al.* 1989), and the climatic and SR effects interact and exert episodic rather than continuous impacts. Livestock populations are more likely to be depressed by drought than by overgrazing, and when a series of wet years follows the drought, the regenerative capacity of the herds is often too low (Wilson 1986) to keep up with the recovery of forage production. It is not surprising that some evidence indicates that livestock populations in Africa are generally below CC (Coughenour *et al.* 1985).

The second challenge is that as forage resources decline under increasing grazing pressure pastoralists move their animals to more favourable areas. We do not deny that degradation due to overgrazing occurs in Sub-Saharan Africa, but suggest that it occurs only under special, rather than general, circumstances. Namely, when animals are concentrated so that the forage biomass on rangelands rather than other forage resources, forage quality, or drinking water is the limiting factor, and when mobility of the herds is constrained.

Many pasture production systems in Sub-Saharan Africa use crop residues, fallow farmland, miscellaneous patches (roadsides, interspaces between fields *etc*), and ‘special resources (Scoones 1989) such as seasonal wetlands, as well as rangelands. The rangelands are not necessarily the limiting resource for livestock production (*eg* Scoones 1989, van Raay and de Leeuw 1970), except perhaps during a severe drought. If the overall SR is restricted by resources other than rangeland, would not a value for CC based on estimated range forage biomass be irrelevant?

Can Carrying Capacity be Adequately Estimated?

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[2] The determination of degradation is goal dependent. If the goal is to maximize herd size rather than meat production, a higher level of degradation may be tolerated. Also, if range condition is related to climax vegetation rather than forage production irrespective of species composition, a different interpretation of degradation will be applied.

De Leeuw and Tothill (1990) mentioned several of the problems in estimating CC, as noted above. Their list of problems, however is by no means exhaustive. Stoddart (1960), in a generally ignored paper, presented a total of fourteen factors that need to be estimated to determine CC, including topography, distribution of water and livestock, effects of wild herbivores, season of use, grazing management practice, and non-animal demands on the range resource. We would like to emphasize a few additional points that are not often considered in attempts to determine the CC of a specific area.

Determinations of CC based on measures of annual or seasonal plant biomass production and daily dry matter intake, can lead to inaccurate estimates for three reasons.

i - It is often assumed that the animals in question are able to ingest the prescribed amount of dry matter per day. However, as several studies, even on improved pastures, have shown, this is not always the case because of sward density (Stobbs 1973) or time spent searching for sparse forage.

ii - Another complication is the fact that biomass available for consumption is virtually always based on estimates of peak plant biomass. However, when a range is used at high grazing pressures (yet within the long-term sustainable SR), forage production is usually less than estimated peak biomass.

iii - Probably even more important is the realization that the choice of proper use (as defined in de Leeuw and Tothill 1990), which in most cases is an educated guess at best, can have a profound effect on the estimate of CC. For instance, the decision to apply a proper use of 45% instead of 30% increases the calculated CC by half. The ‘proper use’ is not some constant value for a plant species or community reflecting its tolerance to defoliation but rather a parameter that will vary according to growing conditions, species composition, time of defoliation, and type of herbivore (Cook and Stoddart 1953).

As Sampson observed in the first textbook on range management (1923) ‘in view of the numerous variable and uncontrollable factors that present themselves nearly every season, it is not likely that the grazing capacity factor will ever be worked out to a high degree of scientific accuracy’.

We strongly concur with Stoddart (1960), another founder of range science, when he claimed that ‘there is no method whereby any technician can go into a new country and measure anything which will automatically give him the grazing capacity’. A similar conclusion was reached by Smith (1984) in an excellent review on the methods used by US land management agencies to determine CC of rangelands.

Regardless or unaware of these warnings, numerous specialists have made attempts in Sub-Saharan Africa to estimate carrying capacity on the assumption that, if stocked at CC, pastoral production systems could achieve the dual goals of range conservation and a relatively high and constant offtake. On the whole, these efforts have demonstrated that CC can not be estimated accurately enough for planning purposes.

Measurements of the same resources have yielded divergent estimates for CC, and no confidence intervals are ever reported. De Leeuw and Tothill (1990) report estimates of CC for similar environments in the Sahel of 14, 19 and 23 TLU km^2. In planning range development for a 100 km^2 area, that represents a difference of 900 TLUs which could be a controversial issue if development plans call upon pastoral households to adjust their herd size to a particular CC value.

Theoretically impossible claims of levels of overgrazing have been made, *eg* SR at 160% greater than CC (USAID 1980), and 200% greater than CC (Field 1980[3]). Several authors (Riewe 1961; Hart 1972; Jones and Sandland 1974) have proposed a quadratic relationship between stocking rate and livestock production per unit area. This implies that the optimum SR, expressed as the SR at which maximum gain per ha is achieved, is half the SR at which animals are starting to lose weight. Or, in other words, at a SR twice as high as CC (maximum yield per area) animals start to lose weight (Riewe 1961; Jones and Sandland 1974). The assumption of this model may be valid under conditions where the forage on offer does not vary significantly in quantity and quality. In situations where high SRs cause negative feedback (reducing forage productivity) the difference between the SR of maximum yield per unit area and the SR at which there is no weight gain may be even smaller (Roberts 1980). These models suggest that SR's greater than twice the CC are biologically unsustainable, and therefore such claims should be viewed with suspicion.

[3] Field made careful calculations of actual SR and CC (in terms of SSUs of 450 kg) for each Region in Somalia based on estimates of populations of camels, cattle, sheep and goats, their age-class distributions and estimated liveweights by age-class; the proportion of diet of each livestock type coming from herbaceous and browse resources; the DM feed requirements of each livestock type; estimated production of herbaceous and browse material; and a proper use factor of 50%. He concluded that actual SRs were more than twice the CC for 13 of the 16 Regions, averaging three times the CC overall. At the extreme, Bari Region SR was estimated at eight times its CC.

Can Carrying Capacity be Meaningfully Applied?

In one paragraph de Leeuw and Tothill (1990) addressed this question, pointing out that the CC concept ‘assumes that livestock are kept within fixed areas of land with recognized boundaries’ and noted that ‘mobility of stock together with communal land tenure and fluid rights of access to grazing and water’ complicate the application of this concept to African pastoral systems. We will examine these points in more detail.

The concepts of CC and SR assume that a unique population of livestock is directly associated with a defined grazing area. In systems where livestock are herded rather than fenced, and land tenure is communal or open access, the grazing sites used by the livestock of a specific household can vary greatly between years, as can the livestock demand placed on a given grazing site. Households can adjust the area of land used to achieve a balance between livestock nutritional needs and the energy demands of searching for forage. Households can also adjust the time spent grazing a seasonal forage resource. Even when a household holds its grazing management constant, variability in use by other households, both resident and transient, can greatly alter the livestock demand placed on a given grazing site.

Reciprocal agreements for resource use are a further complication to the application of the CC concept to pastoral systems. In many pastoral societies, one group will allow another group, in need, access to grazing or watering resources. It is understood that when the group offering this hospitality is itself in need, the other group will reciprocate by allowing access to their grazing and water resources. Reciprocal agreements allow pastoral groups to survive in environments of high annual variability in the amount and distribution of precipitation. These agreements along with communal use make it difficult to apply the concepts of CC to pastoral systems, for regardless of the calculated CC, an occasional and unpredictable high livestock demand can be placed on a group’s grazing resources.

The CC concept assumes that the decision-maker has sole control of the grazing resource. In systems where land tenure is communal or open access, numerous households, each making more-or-less independent management decisions, are using the same grazing resource. When there is one manager of the grazing area, this manager views land as the limiting resource and the balance between livestock and land becomes a critical factor. When there are numerous decision-makers sharing a grazing resource, each decision-maker has available an area of land greater than his/her livestock can use. From the viewpoint of the household, land is in surplus and thus has a low value. Livestock and labor become the main constraints on household welfare and the balance between livestock and labor become the critical management issue. In such situations households strongly resist adjusting livestock to the land base, an irrational practice viewed from the household level, and therefore it is very difficult to get compliance with efforts to adjust livestock to a calculated CC.

Another issue which brings into question the appropriateness of the CC concept in pastoral systems is the investment role of livestock. In western ranching systems, livestock generally offer a low return on capital (Workman 1986) and any excess capital created through livestock production flows into more lucrative investments. In rural Africa, livestock generally are the investment offering the greatest return. For this reason, capital flows into livestock, rather than out of it. It is irrational to expect a pastoral household to convert its capital from livestock to local currencies, unless this cash can flow into investments more lucrative than livestock. Lacking more lucrative investments, each household attempts to increase its herd size (wealth), making the successful application of the CC concept in pastoral societies impractical.

Though there have been numerous attempts, we know of no case in which a government has successfully persuaded pastoral households, or a pastoral group, in Africa to voluntarily limit livestock numbers to an estimated CC.

Conclusion

We have concluded that the CC concept is of questionable validity in livestock production systems in Africa, that it is virtually impossible to accurately estimate CC, and that the concept can not be meaningfully applied in pastoral systems. The enormous expense devoted to estimating CC in Sub-Saharan Africa has contributed little to livestock development and has diverted resources from other priorities. Let us admit the problems with the CC concept, and stop trying to apply it.

We still need to determine how to ensure that permanent degradation to forage resources does not occur because of occasional excessive SR. We recommend taking an opportunistic approach basing the annual grazing strategy on that year's forage production. This allows households to adjust to spatial variability in forage production, provides the most balanced distribution of livestock to forage, and supports more people than a conservative approach based on the estimated or drought-year CC for rangeland.

To avoid resource degradation, we recommend Stoddart's suggestion (1960) of starting with an initial SR (the existing livestock population) and monitoring changes in livestock production and the forage resource. Livestock could be monitored for long-term trends in weight gain, mortality of young animals and milk production. The forage resource could be monitored for long-term trends in species composition and *per cent* cover of ungrazed vegetation. Long-term trends for the soil properties of infiltration capacity and erosion should also be monitored. Permanent monitoring programs are needed to develop databases adequate to distinguish long-term trends from annual variability.

When monitoring detects SR-induced declines in long-term livestock or forage productivity, or in infiltration capacity, or increases in soil erosion, then measures must be taken to conserve the forage resource upon which households depend. Such system degradation occurs where livestock are concentrated to the point that plant biomass becomes the factor limiting livestock production. Such concentrations of livestock in African pastoral systems tend to be very localized and frequently the result of government programs, *ie* water development, grazing reserves *etc*. All government programs in pastoral areas should be scrutinized for their effects on livestock densities, and concentrations that make plant biomass on rangelands limiting should be avoided. When such concentrations do occur, it might be easier to assist some households to leave a degrading area than to persuade all households to reduce their herd size. Efforts to avoid degrading concentrations of livestock might focus on managing household density, rather than controlling livestock density.

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Rangeland Management in Africa

Further comments on PDN 28b 'Patch Use by Cattle in Dryland Zimbabwe: Farmer Knowledge and Ecological Theory' by Ian Scoones (August 1989)

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Ian Scoones's research on livestock grazing and browse patterns in Zimbabwe is of great importance. Nevertheless, unless it is exceedingly well promoted and supported by further studies of a similar nature, it may well not be accorded the attention it should receive. This is because Scoones's findings in essence debunk the whole basis upon which countless official reports have laid claim to impending environmental doom in the communal areas over the past 50 years, and the whole basis upon which all remedial policy strategies, including those still being implemented, have been designed. Thus, his research fundamentally challenges the conventional livestock management wisdom in Zimbabwe, a wisdom so entrenched that, as I encountered myself, comments about 'overgrazing', 'overstocking', and the need to encourage grazing schemes to prevent farmers from destroying their grazing areas, are casually tossed off by the bulk of Zimbabwe's agricultural extension staff.

The research carried out by Scoones is unique in Zimbabwe in that it is the first time a detailed research study of livestock in the communal areas has been carried out in which social science methods have been accorded as important a role as natural science methods.[4] In the former area, Scoones was aided by Ken Wilson, a biological anthropologist, who initiated the highly participatory research style in Mazvihwa that Scoones adopted in his own work. Consequently Scoones's work has been very much farmer led, and even his natural science research begins from farmers' classifications of soils, vegetation and ecological zones.

The strength of Scoones's work then is that he presents and corroborates from

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[4] Social science methods have yet to receive any credibility within the government's Department of Research and Specialist Services. Despite a Farming Systems Research Unit being established in 1984, by the end of 1989 no social scientist had yet been employed in the Department (see Avila, M *et al.* 1989 *Zimbabwe: Organisation and Management of On-Farm Research in the Department of Research and Specialist Services* ISNAR, OFCOR Case Study No 5).

his formal sampling work, much more than just where and when cattle graze in a dry communal area. What he does is to show quite clearly that farmers' livestock management strategies in such research constrained areas make a great deal more sense than the government's promotion of stock regulation and grazing schemes has ever done. Government schemes since the 1940s have aimed at the establishment of defined paddocks, the restriction of animals to these, and the enforcement of fixed carrying capacities. These schemes still predominantly include only the topland areas, which in all land use plans for the communal areas, going back to the centralisation schemes of the 1930s, are defined as 'the grazing areas'. Thus by showing that it is nonsense to speak of any form of fixed carrying capacity, and that it is totally misguided to think of restricting cattle to topland areas (even if it is accepted, as post-independence grazing schemes do, that arable fields will be used as winter grazing), Scoones's work makes a case for the abandonment of current government policies towards livestock in the communal areas.

As suggested at the outset, what this implies is the dumping of 50 years of conventional wisdom. For a start this means that livestock researchers must be persuaded to take Scoones's work - and methods - seriously, and to look more closely at the quite differentiated use by livestock of different habitat types. From my own research conducted in communal areas in natural region III, I can confirm that this heavy reliance on key resources by communal area livestock owners to keep their animals alive is widespread in the country. Second, new ideas about grazing management need to be developed - ideas which must start from acknowledging the sense of what farmers do rather than the stupidity. Of course, because of land constraints, farmers are forced into abuse of their key resources as they themselves, usually very worriedly, are the first to admit. What to do about it when, despite land resettlement, the communal area population has increased considerably in the decade since independence, is a very tricky question. Any realistic answers will not be forthcoming until both researchers and politicians in Zimbabwe are prepared to talk more readily to farmers.

Talking to farmers by itself will not achieve very much unless an accompanying significant change of attitude also takes place. Since the government first imposed land use policies on the peasantry in the 1930s, the government's attitude has persistently been that peasant farmers abuse the land and must be stopped from doing so for their own good. Even the means of doing so have had remarkable continuity, as I show in my own research on agrarian policy in Zimbabwe,[5] since this period. At the heart of this is the issue of control of land: admitting the peasantry are not so dumb means also admitting that they may

[5] *The State and Agrarian Change in Zimbabwe's Communal Areas* MacMillan *forthcoming*.

have the *nous* to manage their own environments, with enabling rather than constraining by the state. However, the present government, which fears what it terms a return to ‘traditional’ rule, has not shown any sign yet, for instance, of allowing farmers in either communal or resettlement areas to control the management of their own land use.

It is a large apple cart that Scoones has overturned. Will those who will otherwise have to pick the apples up (and rebuild the cart), try and ignore the fact that their cart is upside down or not? It will be interesting to see.

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