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The concept of carrying capacity and land-use

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Abstract

Land-use is in large parts of the third world far from sustained. Ecosystems and sociological systems are degrading as a result of resource depletion. Restoring the equilibrium between exploitation and the availability of resources is a matter of economical and ecological survival for both man and nature in these systems. The concept of carrying capacity lends itself for an analysis of actual and potential land-use which in turn permits to identify the development potential and the limiting factors on which may be alleviated by inputs in order to stop degradation and raise productivity.

Introduction

In large parts of the world renewable natural resources such as soil, water, flora and fauna constitute the sole base of subsistence for a majority of the population. These natural resources are exploited in different ways, for example through agriculture and husbandry, but always with domestic animals and labour as almost the only inputs. Due to mainly external political and economical factors the pressure on these resources has increased and the whole system, man and resources, is sliding into a vicious circle of pauperization and degradation. The sustainability of land-use, meaning a long-term equilibrium between the exploitation of natural resources and their potential, is in jeopardy and has to be restored as an absolute condition for survival.

It is the purpose of this paper to present and elaborate this line of thought, based upon research experience in the (semi-)arid regions of West Africa.

Study area

The region concerned is the Sudan zone in West Africa; this bio-climatical zone is situated south of the Sahara desert and north of the equatorial rain forest (Fig. 1).

The climate is seasonal, with an annual rainfall of 700 mm in the north to 1200 mm in the south. The length of the rainy season (4-7 months) determines the grow-

ing season. Soils are in general old and well weathered with a low cation exchange capacity.

The vegetation is a typical woodland savanna: a closed grass layer with annuals in the northern part and cespitose perennials in the south, and an open layer of shrubs and trees (20-60 % canopy cover). The fauna counts about 25 species of large mammals, mostly antelopes (Bovidae).

In the dry season the savanna is frequently set on fire to stimulate regrowth of perennial grasses, to improve visibility and to prevent bush encroachment.

The natural resources as soil, water, vegetation and fauna are exploited by two major forms of utilization:

- rain-fed agriculture, in which a long fallow period is necessary to restore soil fertility after several years of cultivation. Towards the north, the length of the rainy season becomes the limiting factor;
- livestock husbandry, in which seasonal migrations are a major adaptation to the temporal and spatial distribution of the sparse range resources. The cattle move north in the rainy season and, because of lack of water and forage, south in the dry season.

Two other forms of land-use can be considered to be secondary in terms of importance:

- wood-cutting for fuel, construction, etc. A country such as Burkina Faso is dependent on wood for 95 % of its energy.
- hunting. Game is a highly appreciated and consequently grossly overexploited source of meat and other products.

These different types of land-use were traditionally clearly divided along ethnical lines in agriculturalists and pastoralists (Geerling & Diakité, 1986). This tends to get obscured under the increasing pressure on the land: pastoralists start to farm and farmers are keeping more and more cattle in order to diversify.

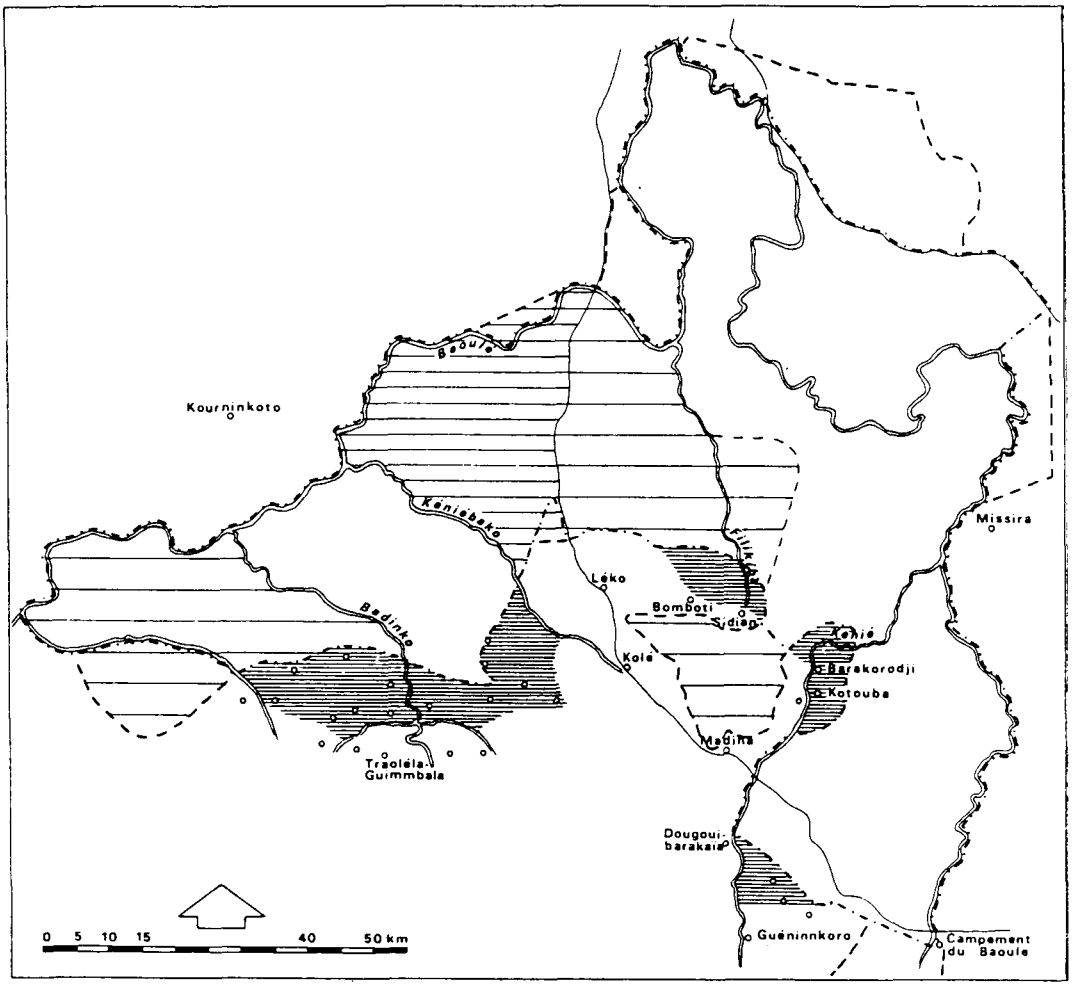
Analysis of present-day land-use

The production is totally determined by the natural renewability of these resources. Inputs such as fertilizers are hardly available. Man's existence depends totally on the natural ecosystem.

The natural resources were traditionally considered as common goods, exploited according to more or less informal rights and rules. These traditional systems did however not resist the external social, economical and political changes and, if modernized, they are often not accepted or respected.

Man's activities are not necessarily leading to an equilibrium between himself and the land he utilizes. On the contrary, phenomena such as the nutrient depletion in extensive exploitation systems are symptoms of disturbed equilibria.

The northern part of the Mossi plateau in Burkina Faso, for example around Barsalogho (Fig. 1), may be an extreme example, but it appears only ahead of other regions in terms of development – in the wrong direction, that is: in one of the research areas in this region 80 % of the natural vegetation has disappeared under the combined impact of agriculture, livestock, wood-cutting and drought. Only



LEGEND

RESERVE BOUNDARIES

BOUNDARIES OF INCLUDED AREAS

BOUNDARIES OF MANAGEMENT UNITS

RIVERS

ROADS

VILLAGE

MANAGEMENT UNITS

NATIONAL PARK

WILDLIFE UTILIZATION

GAME AND LIVESTOCK RESERVE

EXCLUDED FARMING AREAS

Fig. 1. Ecological zones in West Africa.

15 % of the area is still suitable for agriculture, and the grazing capacity for livestock there is only 10 % of the potential. The level of resource depletion is such that in a severe dry season such as in 1985 a mortality of 60 % of the cattle occurred. Both the farming system and the whole social structure are desintegrating as a consequence. Investments (e.g. in labour) are adjusted to the expected outputs, which leads to a decrease of not directly productive activities (such as soil protection) and thus to further degradation. Up to 50 % of the population has left at least temporarily the region.

Restoring sustainability in the use of the resources is a strict condition for man's economical and even physical survival in these systems.

Sustainability of land-use means a long-term equilibrium between the exploitation of natural resources and their potential. Two situations of equilibrium can be distinguished in this respect:

- exploitation, with off-take compensated by inputs such as fertilizers from outside the system;
- exploitation, but with the off-take not exceeding the quantities which the environment can generate.

The subject of the research programme of the Nature Conservation Department is the second situation of equilibrium, the first being the concern of other departments within the University.

The concept of carrying capacity

In the context of sustainable land-use, as defined above, the concept of carrying capacity is important and widely used. In range ecology, carrying capacity is defined as the maximum number of animals which can live in a certain area without causing degradation. Although this definition is correct, it is too limited and too static to be used in the analysis of an exploitated system – too limited, because this definition has no validity for forest exploitation, for example, and too static because it does not take the variability of ecological factors determining the carrying capacity into account.

More useful is: carrying capacity is the level of equilibrium between the availability of a certain element limiting a given type of exploitation in an ecosystem and the level of exploitation of that element. This equilibrium is dynamic as it is determined by the interaction of various elements in the ecosystem and by variable operational factors such as rainfall.

In a natural ecosystem, without exploitation by man, the level of equilibrium is characterized by a zero net production.

In a system exploited by man, the objective is harvesting, which means that a surplus to be cropped has to be produced. This requires a new equilibrium (which is an absolute condition for sustainability) at a level below the level of carrying capacity without exploitation by man (ecological carrying capacity).

If production-raising inputs such as fertilizers are used, the principle is the same, but an equilibrium will not establish itself easily, as the interventions in these cases are more profound, and side-effects often occur.

Table 1. Carrying capacity for game species (in animal numbers) in a part of the Baoulé region, area c. 2000 km^2, Mali (de Bie et al., 1986).

	Years with average rainfall	Dry years
warthog	10 550	2 500
bushbuck	2 000	1 300
red-flanked duiker	850	600
grey duiker	4 600	3 500
reedbuck	6 500	1 000
waterbuck	1 600	240
roan antelope	2 850	600
oribi	12 000	2 400

Some of the limiting factors are:
- climate: temperature, rainfall, seasonality
- water: surface water, drainage
- soils: fertility, texture, erosion risks
- vegetation: structure, species composition, forage quality
- fauna: habitat and food requirements

These factors are specific for the area concerned (e.g. woodland savanna), for the plant (trees, grasses) or animal species (cattle, game) to be exploited and for the objectives of the exploitation (wood, meat, milk or a 'function' such as 'nature'). Therefore the area, the objective of exploitation and the level of technology have to be defined before being able to calculate the carrying capacity. Table 1 presents the influence of one of these factors, rainfall, on the ecological carrying capacity for game species in the northern Sudan savanna of Mali.

On the base of the conceptual model, the relevant elements for a given management system can be determined and then quantified. In terms of methodology of quantification usually standard methods on aspects such as soil fertility, biomass of plant species, food preference, digestibility etc., can be used or adapted.

Compatibility

Given a certain carrying capacity – which sets the sustainable level of exploitation – the question is how different types of land-use can be integrated on the field level (territorial compatibility) and on the farming system level.

In terms of sustainability a diversified farming system is preferable already for the purpose of risk spreading. Compatibility on the farming system level is possible, and in the actual farming and husbandry systems already exists. This trend is increasing, albeit for negative reasons: the increasing lack of land in agriculture and in husbandry forces the population to make a living from anything available.

In terms of territorial compatibility the potential is determined by the limiting elements. For example, with cattle grazing in forests, two different land-use types are exploiting the vegetation. The combined effects of these exploitation types may lead to nutrient depletion. This means that neither the foresters nor the livestock

can exploit the available vegetation (wood or grass) to the full extent without curtailing the possibilities for the other.

In the combination livestock-game, the competition is more direct; cattle may fil the niche of, for example, buffalo or hartebeest. A combination is only possible if one accepts that comparable (wildlife) species disappear.

Agriculture is incompatible with livestock and game in terms of space. The usefulness of crop residues for cattle is usually grossly overestimated. On the other hand, intensification of agriculture will produce by-products of a higher quality and thus can be instrumental in the intensification of animal husbandry with the annotation that in that case husbandry will be secondary to agriculture.

We can conclude that the advantage of integrating two or more land-use types lies mainly on the farming system, on the level of the field the potential is strictly limited.

Recent 'inventions' such as agro-forestry and silvo-pastoralism are subject to this reasoning: they may well contribute to diversification but less so to an increase in total production.

Management of natural resources

In the 'Recherche sur l'Utilisation Rationnelle du Gibier au Sahel' (RURGS) project (Geerling & Diakité, 1986) the consequences of this approach have been worked out for the organization of wildlife utilization as a type of land-use and for the 'Boucle du Baoule' Biosphere Reserve in Mali (Fig. 1).

Organization of wildlife land-use

The organization of wildlife utilization as a type of land-use is based on an analysis according to the scheme presented in Fig. 2. The major aspects of this analysis are:

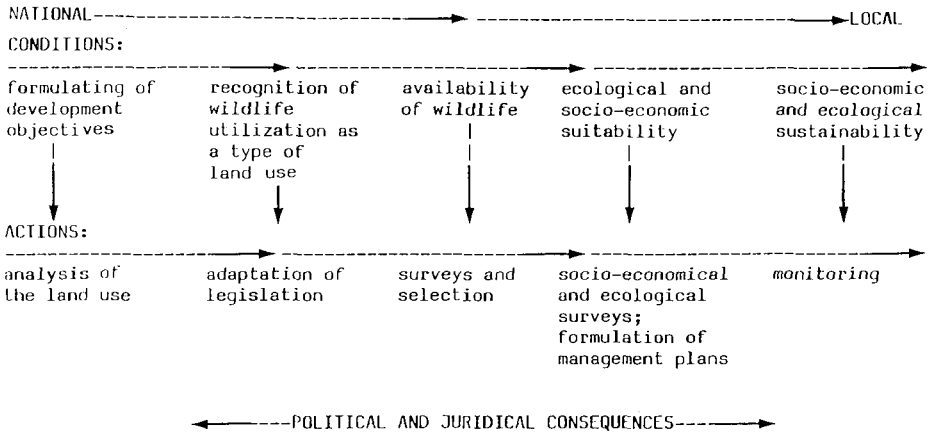


Fig. 2. Organization of wildlife utilization.

– the *recognition* of wildlife utilization as a land-use type in the national development programmes. Legislation etc. has to be adapted accordingly;
– the *evaluation* of areas suitable for wildlife utilization on their potential of sustaining viable animal populations;
– an *inventory* of the species suitable for cropping in relation to both animal numbers and the presence of markets;
– a *survey* of the potential harvesters. These harvesters can be characterized by their expertise, level of internal organization, the possibilities of controlling quota and their potential to handle the harvesting, treating and marketing of larger quantities of meat.
– the *decision* of who is going to harvest and what is a matter of matching the harvestable quantities with the available types of harvesters (and of harvesting). This choice has to incorporate as much as possible the expertise available and has to take into account the maximum of interest for the concerning region, in order to improve and strengthen the total land-use of the region. The ties between the land and the users should be as strong as possible in order to assure sustainability of exploitation.
– the *planning and execution* of the practical consequences for management. These range from management measures such as protection, extension programmes, fixing of quota and their control and monitoring to eventual technical assistance in various stages of the execution of the programme.

Land-use planning

In the Biosphere Reserve 'Boucle du Baoulé', (c. 8000 km^2) the pastoralists moving south with their livestock in the dry season reach the northern edge of the Reserve. The Reserve itself is only marginally suitable for livestock as there is a low availability of forage of good quality and the whole region is infested by tse-tse flies, the vectors of sleeping sickness. Agriculture is found only in the valleys.

In the past two decades the pressure on the area has increased considerably which has resulted in overgrazing of the Sahel north of the reserve, an increase of livestock numbers moving into and through the Reserve, and farmers moving into the Reserve from the south.

In order to tackle this problem, a social, economical and ecological analysis of this Reserve and its utilization was made. This resulted in a number of options for the management of the area. In the formulation of these options the following objectives were used as a starting point:
– to improve the stability of land utilization;
– to guarantee the conservation of the natural ecosystem.

The following criteria were taken into consideration:
– the integrity of the Reserve from a management point of view;
– the territorial demands of wildlife, habitat diversity and distribution of species, especially those whose existence is threatened;
– the spatial incompatibility of agriculture with other land-use types;
– the function of the Reserve as transit route (for pastoral livestock).

The configuration chosen by the Mali Government and actually implemented (Fig. 3) is based on the following considerations:

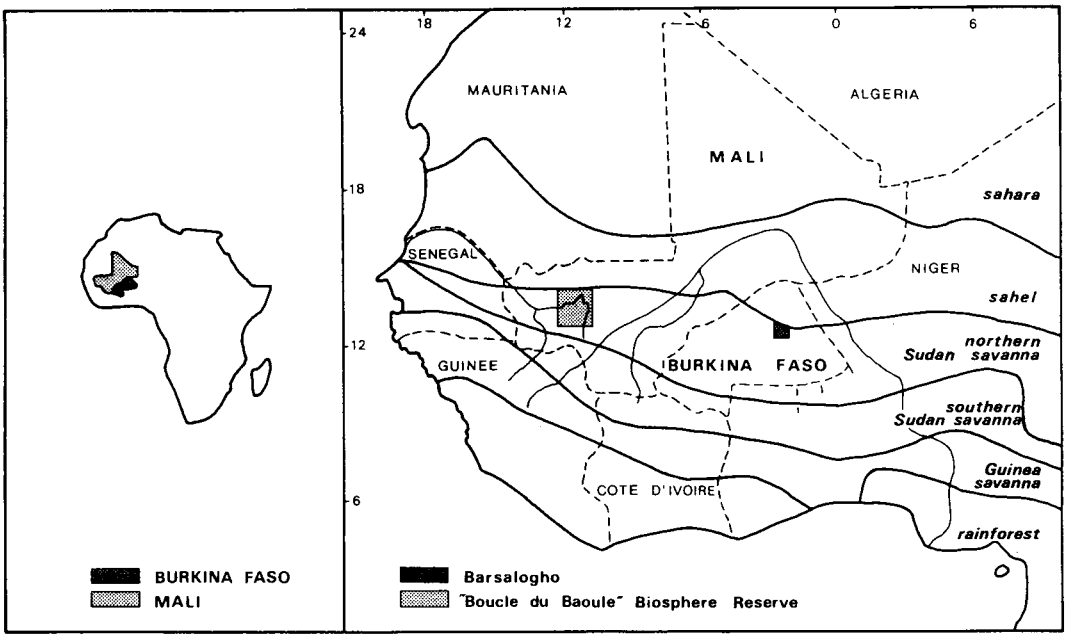


Fig. 3. Land-use planning in the 'Boucle du Baoulé' Biosphere reserve.

– agricultural areas are outside the limits of the Reserve; this loss of area is compensated by the incorporation of non-occupied zones, originally outside the Reserve
– national parks have key positions in the ecological zones
– the areas for wildlife utilization are relatively small but given the fact that they are part of a larger protected area, animal populations would not be in danger
– the transit route for livestock is chosen where already an important cattle trail exists.

Conclusion

The sustainability of land-use in general and of the exploitation of natural resources in particular is not to be taken for granted, neither in the third world nor in the 'north'. This is particulary evident in the Sahel and Sudan zones of West Africa where overexploitation leads to the degradation of the ecosystem and of the social system.

The equilibrium between the rate of exploitation and the availability of the resources has been upset and needs to be restored. In research supporting projects and programmes in these zones the concept of carrying capacity has to be used as a method of analysis in order to provide the basic data for the organization and planning of land-use.

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