Carrying Capacity

Sustainable Use and Demographic Determinants of Natural Habitats and Ecosystems Management

Robin Grimble

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Abstract

This paper was prepared for the forthcoming World Bank Handbook on Natural Habitats and Ecosystems Management. It provides an overview of the carrying capacity concept and assesses its value and use in practical management. It starts by reviewing the concept of carrying capacity and the natural limits to resource exploitation set by the environment. Making use of boxed examples, it introduces the concepts of thresholds, susceptibility and resilience before discussing the question of land use change in the face of population growth and increased consumptive demands on resources. It shows that these changes may or may not improve land productivity depending largely on socio-economic circumstances. However, these changes are likely to affect environmental services and functions.

The paper highlights the need to recognize basic dichotomies between ecocentric and anthropocentric perspectives in viewing environmental issues: ecocentric approaches focus on the ecosystem itself, and are fundamentally concerned with conservation of ecological functions and services, while anthropocentric approaches are primarily concerned with the productivity of the ecosystem and the people it can support.

A further division exists between Malthusian and Boserupian perspectives. The Malthusian school focuses on the limits to food supply and population growth imposed by carrying capacity, while the Boserupian tradition plays down these limits and demonstrates how human activity can successfully adapt to increasing population densities.

The paper examines the issues with a discussion of an environment-population model from the livestock sector and concludes that the optimal position on the trade-off curve between economic activity and the environmental state depends on management objectives and thus must ultimately be determined by subjective judgement rather than objective calculation. The paper concludes by reviewing the lessons of the analysis for practical policy and management. The key messages are the need for planning with clear objectives, for prioritizing between objectives, and for proper study of any situation prior to intervention.

Keywords: carrying capacity, ecosystems, sustainability, degradation, management, policy, population growth, land use, Malthus, and Boserup.
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Endnotes

1 Background Papers:

1 - Cheke, B. 1995. “Carrying Capacity, Sustainable Use and Demographic Determinants of Ecosystem Management.”

2 - Dijkman, J. 1995. “Carrying Capacity and Sustainable Use in Ecosystem Management: Livestock.”


4 - Quan, J. 1995. “Carrying Capacity and Sustainable Use in Ecosystem Management: Forestry.”

5 - Quan, J. 1995. “Carrying Capacity and Sustainable Use in Ecosystem Management: Agriculture.”


7 - Zanre, R. 1995 “Carrying Capacity and Sustainable Use in Ecosystem Management: Tourism/Wildlands (Protected Areas).”
1 Introduction

The ability of land resources to support growing populations on a sustainable basis has been of concern ever since the publications of Thomas Malthus almost two hundred years ago. He argued that population growth would outstrip food supplies because of their inherently different growth patterns. Since the time of Malthus, the issue has periodically re-emerged and is again at the fore with the realization that the Earth will be faced with having to support at least twice its present human population in the next century. These fears are particularly acute in developing countries, where fast growing populations have for the first time met with limits to land area, and the potential for spontaneous expansion of agricultural areas is disappearing. At the same time, there are growing threats to the Earth’s life support systems from agents as varied as industrial pollution, deforestation, unsustainable exploitation of potentially renewable resources such as forests and fisheries, and soil erosion. As well as causing local impacts, the impacts of these agents are beginning to be felt at the global level through biodiversity loss, global warming, and the reduced capacity of the earth to assimilate human waste.

Humans exploit the environment in two basic ways: through the use of natural resources for direct consumption or inputs into production processes, and through the use of the environment as a receptacle for waste products. The notion of carrying capacity (CC) centers on the ecological principle that land, water and other natural resources in a given area can support only a limited number or density of people, cattle or other animal species. CC may be larger than first thought, or increased by investment or management, but still ultimately sets a limit to population level of economic activity. The concept is closely related to the notion of sustainable use (SU) and the two cannot be discussed independently. CC sets the limit or threshold to which natural resources can be used on a sustainable basis with a given level of management inputs. Where this limit is exceeded through “over-population” or other forms of human “over-exploitation,” degradation occurs and the carrying capacity may be further reduced.

The nature of the relationship between human activity and the natural environment is both exceedingly complex and imperfectly understood. It is clear that some sort of trade-offs exist between human use and the environment, and that ‘over-population’ or ‘over-use’ of resources can lead to degradation. However the information is disparate, incomplete and sometimes contradictory. Views range from CC protagonists, who argue that population growth and economic activity imperil the future of the earth, to sceptics and technocrats (including many economists) who see natural resources as interchangeable with built resources and emphasize human ingenuity and the ability of people to adapt to new resource situations.

This report seeks to assemble knowledge of CC and related concepts from different
perspectives, relate them to the goal of sustainable development, and consider their utility for environmental management and project design. The issues are considered in the context of demographic change, and include examples of over-population and over-exploitation, as well as successful adaptations to population pressure by local people.

The study draws on material from a wide variety of sources, including different disciplines (notably ecology and economics), different sectors (agriculture, forestry, fisheries, livestock, tourism and wildlife), and different scales of analysis (local and global), though with an emphasis on micro issues. It is not specific to region or location and, except where specifically discussed, uses the terms “natural habitats” and “ecosystems” interchangeably with “natural resources” and “land resources”.

Although reference is made to other animal species and areas, the primary focus is on human populations and developing countries.
Carrying Capacity

The Concept

Carrying capacity is the population-supporting capacity of an ecosystem that is determined by the natural factors of environmental resilience associated with constraints imposed by soil, water and climatic conditions, and the efficacy of human resource management practices. Although strictly appropriate to natural ecosystems (e.g., a catchment area), the term is conventionally applied to areas of variable size and description, including artificial areas which may cut across ecosystems (e.g., a district). There is no doubt that, at least at an early stage of development, different areas have different population-supporting capacities determined largely by their natural endowment. The concept suggests that beyond the natural limits set by these factors, no major increases in the dependent population can be sustained (refer to Box 1).

Non-human examples are often used by way of illustration. For example, a particular area may be capable of supporting 100 deer. When 100 deer live in the area there is a balance between animal numbers, available food, shelter and water. If that balance is upset by a substantial growth in numbers of deer, the productive capacities of the range may disappear. Food resources become depleted and perhaps destroyed as animals search for nutrition. In such a situation, herd numbers

Box 1
Natural Endowments and Population Densities

Although the distinctions may not be absolute, different parts of the world vary widely in their natural productivity and population absorptive capacities (e.g. the tundra, temperate latitudes and the tropics). At an early stage of development, countries are largely natural resource based and these resources largely determine the nature of livelihood systems and economic activities. Environmental parameters such as topography, soil type, transpiration and rainfall patterns vary greatly between counties, regions and zones. The ecosystems that result from different combinations of these parameters can accommodate vastly different population densities, and by implication, have different carrying capacities. For example, the average world population density of 40 per square km includes a range of densities as different as 4,464 in Singapore, 293 in Rwanda, 29 in Canada and 14 in Mongolia.

Even within a single country, natural resources and population densities can differ enormously. For example, Kenya's population density (according to 1986 figures) averages 42 persons per km² but varies by a factor of up to 140 between agro-ecological zones; 2 persons per km² in arid areas, 10-25 persons in semi-arid, 210 persons in the humid west and 280 persons in the central highlands (in terms of land area, the vast majority of the country falls into the two dryer categories). The principal factor determining these differences is rainfall, both absolute amount and length of rainy season, though soil type is also important. Although differences in population density reflect infrastructural development and proximity to urban centers, to a large extent they reflect different regional natural carrying capacities (LRDC, 1986).
We should mention some expressions and concepts closely related to those of CC. The term critical population density (CPD) has been defined as "the maximum density of population that can be supported on a given area of land, using a given technology, on a sustainable basis" (Baker, 1993), a definition equivalent to CC. Another variation on the theme is the notion of pressure of population on resources used by Blaikie and Brookfield (1987), which attempts to establish a similar link between population and land resources without the need to specify critical thresholds embodied in the term CC; this concept has the advantage of positing a relationship without suggesting that this is necessarily the overriding factor governing land degradation.

The idea of CC leads to the concept of sustainable use (SU), which dominates ecological thinking on how people may exploit resources in a sustainable way. It differs from the CC concept in that it concerns the population or harvest (yield or offtake) of an area rather than the system itself. Maximum sustainable yield (MSY) or maximum sustainable use (MSU) indicates the maximum population that can be supported, or the maximum offtake that can be extracted, on a sustainable basis, i.e., without exceeding the system's CC. The equivalent terms maximum sustainable catch and maximum sustainable cut are used respectively in fisheries and forestry, and critical load with relation to polluting effects such as the incidence of acid rain on a forest. The terms may be no easier to calculate than CC, as sustainable populations or harvest rates can be determined only in relation to the CC itself, but may be crudely assessed through empirical observation.

In recent years efforts have been made to incorporate the CC concept into a practical framework for use by managers and planners. Rather than estimating a particular CC and managing resources to remain below it, some suggest the value of assessing limits to acceptable change (LAC). This accepts the fact that use of an absolute or fixed standard is not practical and that some compromise (or trade-off) between the environment and human consumption often has to be made. The notion has been operationalized by establishing environmental standards, which have long been used by planners in developed countries (particularly that of safe minimum standards). Although standards or guidelines can be readily established, they are subjectively determined and their implementation suffers from the major problem of finding a basis for determining which environmental impacts are not acceptable. A more comprehensive application of the LAC concept moves beyond minimum standards to incorporate participatory planning mechanisms, define performance indicators, and design adaptive management frameworks for sustainable development under conditions of uncertainty.

The concept of CC, however, is more complicated than this. If rather than deer the species had been sheep, or indeed homo sapiens, the number of 'animals' capable of being supported would have been quite different. Also, these limits were imposed by natural forces not influenced by human management. It is clear that capacity limits vary according to the type of population under consideration, and the activities conducted by that population. Had management intervened, for example by supplementary feeding or irrigation of foliage, the range would have been capable of supporting a greater number of animals. Thus, the CC of land is not an absolute or fixed property, but can be diminished by over or unsuitable use or enhanced by good management (USDA, op cit.).

The Malthusian Model

The concept of CC developed from the ideas of the early political economists and ecolo-
gists, particularly Thomas Malthus. Malthus observed in his *Essay on Population* (1798) that while populations grow geometrically, the means of subsistence increases only linearly, resulting in inevitable and increasing imbalance. He reasoned that the lack of elasticity in food supply ultimately governs the rate of population growth; further expansion is limited by positive checks of famine, disease or warfare, self-equilibrating forces which in the long term contain the population within limits permitted by the wealth of resources. These arguments were later refined to take account of the notion of relative scarcity; as populations grow, the best land is cultivated first, forcing people onto poorer and more marginal land. Marginal land requires more land for households to support themselves and leads to a weakened and more vulnerable population.

This argument forms the basis of the contemporary neo-Malthusian model. The model asserts that when population growth exceeds that of agricultural production, living standards fall or the environment is degraded, effects which combine in the long term to constrain populations. Malthus thought that the increase of population to a level beyond the carrying capacity of the land must lead to the elimination of surplus population through starvation or other checks that can be traced back to the insufficiency of food supplies. Neo-Malthusians have extended the theory to suggest that the increase in population leads to the adoption of land-degrading practices; these practices are progressively extended to new areas, thus further reducing the abundance of resources and exacerbating the ultimate food-supply problem. The neo-Malthusian school is thus rooted in the deeply pessimistic belief that sustainable land use is an unachievable goal in a world of steadily increasing populations.

Malthus' ideas concerning the relationship between finite natural resources and ultimate limits to the expansion of human populations were further developed by Verhulst, who in 1838 produced the logistic equation to describe the sigmoid growth pattern exhibited by a population with limited resources (Fig. 1). At low density the population grows in uninhibited exponential fashion, with growth

**Figure 1**

**A Hypothetical Population Growth Curve and its Natural Limits**

![Population Growth Curve](image-url)
rates tapering off at high densities as resources become more limiting. As higher densities are reached, the population asymptotically approaches a maximum (and stable) equilibrium limit known as K, the saturation point or carrying capacity. Verhulst intended his logistic equation to be used for human populations, and believed that it represented an underlying natural 'law' of population growth.

**Thresholds**

Thresholds are used in ecology to denote the limits in population density of a species, and thus define the natural carrying capacity. When an animal population exceeds this limit, the population will decline through increased mortality, reduced fecundity, or emigration.

Thresholds have been likened to balancing a ball on the rim of a basin; the ball will either slide down and settle back in the basin or fall off the side into the unknown (Holling, 1973). In certain instances there may be sudden and irreversible ecological collapse, bringing an end to human activity. More commonly, however, the outcome is less immediate or catastrophic, with small changes acting on individual species without obvious effects on the whole ecosystem. In this case a threshold can be thought of as a zone of change; as human or other populations increase there is a gradual or step-wise deterioration in the biological or productive properties of the system.

The picture is complicated by the synergistic nature of ecological systems and the fact that the whole is greater than the sum of its parts. Most studies have been of single species although, in reality, species do not live in isolation but share a habitat with other organisms. The number of organisms present in a single field, forest or lake are not easily determined, nor are the complex interactions between them. Repeated failure to appreciate this interdependence and complexity has led to unexpected human impacts on the environment.

**Susceptibility And Resilience**

All natural resource systems are subject to human-induced pressures or stress, and hence liable to change. The susceptibility of an ecosystem or habitat to change, however, depends on the nature and properties of the system in question. The resilience of a system is a measure of its sensitivity or vulnerability to change: the ability to withstand or absorb disturbance, be it human or naturally induced, that results in a change in the essential nature of the system. Economic activities are sustainable in their present form only if life-support ecosystems on which they depend are resilient.

One way of thinking about resilience is to focus on ecosystem dynamics where there are multiple, locally stable equilibria (Arrow et al, 1995). Resilience in this sense is “a mea-

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**Box 3**

**The Resilience of African Rangelands**

In the harsh and erratic climates of pastoral Africa, there are marked seasonal and inter-annual fluctuations between wet and dry periods. During the wet season when the vegetation is growing, it is vulnerable to damage by herbivores but also tends to be in considerable surplus to requirements. Conversely, in the dry season, when grazing pressure is high and demand far outstrips supply, plants tend to be relatively impervious to abuse; the living parts retreat behind thorns, woody structures, below ground or are stored in seeds. Thus, plants are well adapted to high grazing pressure during dry periods when forage is scarce. These dry periods are frequent and severe enough to limit domestic herbivore populations and thus define the CC of the region. However, the ecological systems have a considerable capacity to absorb perturbation and minimize disturbance (Benkhe, 1994).
Carrying Capacity

Sure of the magnitude of disturbance that can be absorbed before a system centered on one locally stable equilibrium flips to another. A resilient system, then, is one which can survive new pressures, and in doing so remain centered on the same equilibrium, i.e., remain essentially the same. For instance, low-intensity shifting agriculture in a forest will change plant composition and age structures in parts of the forest but, when fallow periods are sufficient and other parts are untouched, the forest is resilient enough to remain essentially a forest. The same may also be true of the forest with low-intensity, careful logging. Other ecosystems such as coral reefs are less resilient and more readily disturbed by limited human activity (refer to Box 3).

Natural resource systems thus vary in their resilience and are likely to be less resilient (i.e., more fragile) where rainfall is low or erratic, soils are erodable, and slopes are considerable. Such systems cannot absorb extended or rapid population growth, or more intensive economic activity, without considerable modification to their character and, more arguably, a loss of productivity. They are commonly thought of as being at a critical threshold and marginal for exploitation.

The loss of ecosystem resilience may be important for three reasons (Arrow, op cit.). Firstly, the discontinuous change in ecosystem functions as the system “flips between equilibria” could be associated with a sudden...

Box 4

Land Degradation in Ethiopia

It is widely accepted that land degradation presents a serious problem in Ethiopia. Official statistics in the 1980s suggested that 4% of the highlands were already degraded beyond recovery for agricultural purposes, and 25% moderately eroded. Due to population increase, stagnation in technology, civil war and uncertainty, the pace of degradation has not since diminished, and continues to threaten the natural resource base of the northern highlands.

Land which was once fallowed and rotated is now cultivated continuously, and cultivation has spread into areas formerly reserved for grazing. The expansion of cultivation has diminished the area available for grazing, and the diminished cattle/grazing ratio has reduced cattle productivity. It is reported that “sometime after the 1940s, population and livestock growth reached a point at which the resilience of the local ecology started to break down. When the rains failed in 1973 and 1984 the stage was set for disaster” (Stahl, 1990).

The causes are described by Stahl (after Blakie, op cit.) as hierarchical. Insecurity has bred a short-term outlook, and centralized paternalistic intervention by government has produced a dependency syndrome. State supported activities have focused on ideology and organization, and no economic incentives or attempt to encourage local or individual initiatives have been introduced. With the exception of soil bunding, there have been few immediate economic benefits from conservation work.

In these circumstances the only available response to population pressure has been to extend existing agriculture systems to marginal land on surrounding hillsides and to use traditional lands more intensively (though with little improved technology). This suggests that inappropriate policy measures and interventions by government can negate the inclinations of local people to adapt sustainably to population pressure. The problem of land degradation in Ethiopia is not tied solely, and perhaps not principally, to population growth and the natural limits of CC, but rather to inappropriate political and institutional structures. A study by Morton in the Sudan similarly shows that ‘bad government’ can frustrate people’s natural tendencies towards sustainable intensification and commercialization as population density increases (Morton, 1994). The evidence suggests, then, that while it is possible to raise the CC of an area, we cannot count on this when institutional and policy measures are unfavorable.
loss of biological productivity and to a reduced capacity to support human life. Secondly, it may imply an irreversible change in the set of economic or livelihood options available to present and future generations, or greatly increase the cost of exploitation. Soil erosion or degradation of a groundwater aquifer, for example, may seriously increase costs and reduce future living standards in an area. Thirdly, discontinuous and irreversible changes from familiar to unfamiliar states increase the uncertainties associated with environmental changes (refer to Box 4). We are remarkably ignorant about the dynamic effects of changes in ecosystem variables (e.g., thresholds, buffering capacity, resilience, and time-lags) and even more so of the implications for exploitation, management and socio-economic well-being.

Degradation and Change

Degradation can be defined as any depreciation in the properties, productivity and functions of an ecosystem or habitat. It may involve a loss of soil fertility, ecological function (e.g., hydrological and climatic regulation), or the extent and diversity of biological species. Such changes are increasingly seen to have adverse economic as well as ecological consequences, and there has been much recent attempt to put economic values on them. However, we are still often unable to distinguish between fluctuations

Box 5

Contrasting Perceptions of Land Degradation and Improvement in Cameroon

A form of shifting agriculture incorporating forest fallows has long been practised in the tropical forest of Cameroon and local authorities are concerned about its effect on deforestation. In the late 1980s a project was instigated with overseas aid to establish timber plantations on land that had been cut and burnt, briefly cultivated, and left to return to forest.

Project authorities held that shifting agricultural practices were degrading and depleting the forest, and that it was highly desirable to establish plantations on what was described as depleted and abandoned land. This was especially so if the plantations were composed solely of introduced tree species of international value for timber. Local people, however, held that their agricultural system was perfectly sustainable and did not cause degradation. Degradation, they said, was caused by the project: the project was replacing forest fallows left to regenerate naturally by a few introduced species of no use to them, and harvested by others. The new habitat was much less biologically diverse than the secondary forest it replaced and did not provide the multiple products and game habitats long used by them. Local people also said that recently-fallowed secondary forest was more valuable than the dense forest it replaced because less labor was required to convert it for agriculture. Indeed, they deliberately selected shorter fallows for growing certain crops, trading off the fertility losses against the higher economic returns to labor (labor was the major limiting factor).

The local shifting agricultural system worked on the basis that the forests were resilient and disturbance would correct itself over time, and return to something approaching its original state. In this case the CC of the forest ecosystem had not been reached, the shifting farming system was an integral part of the ecological system, and ecological break down had not occurred. More generally, it demonstrates that the question of degradation should be considered only in relation to objectives. Local people were interested in maintaining and improving their livelihoods while the goal of foresters was to maximize the area under commercial timber forest.

A rider should be added. In this locality forests were not under great pressure and, at least for the time being, the shifting agricultural system was sustainable. In other circumstances, however, increasing populations may impose severe pressure on resources, and forests will degrade and diminish. Whether or not it is acceptable to convert forests to agricultural land can only be judged by local circumstances.
and trends, or tell whether or not the process is reversible. Similarly, the basis for assessing and comparing the costs and benefits of change have received minimal attention.

An increase in human population or economic activity in an ecosystem may lead to a change in nature of that ecosystem, or a 'flip' to another ecosystem, which is not necessarily better or worse, just different. Whether it is better or worse can only be assessed on the specifics of the case, and the importance and rarity of the system in its own right. For example, the introduction of livestock into a natural parkland may substantially alter the vegetation and reduce the game population. Whether, or how much, this matters will depend on the particular attributes and rarity of the ecosystem and the perspectives of those directly or indirectly affected—now and in the future. An ecologist or wildlands manager might be concerned with changes that reduce biodiversity, the safari operator with the effect on game viewing, and the livestock manager with commercial offtake. This suggests the critical importance of recognizing different perspectives in understanding natural resource degradation, and generalized or blanket statements about what is good management should be treated with care (Refer to Box 5).

Measurement

While the CC concept is necessary for understanding environmental issues, its utility in practical resource management is open to question. The concept is equilibrium based, yet most systems, and particularly those under human influence, are continually evolving. Furthermore, the CC of a system depends on what is being assessed, the period and boundaries selected, the technologies available, and the aims of the exercise. These pose perhaps insurmountable problems for measurement and practical management.

The attempt to utilize the concept for management purposes has been taken furthest in relation to livestock and rangeland development. These attempts, however, have been beset by problems. It has been found that

<table>
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<td><strong>Problems of Measurement and Management in African Rangelands</strong></td>
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Multi-year drought may be the ultimate restriction on many livestock populations. Because of the enormous climatic variation over a prolonged period, the use of an average, or indeed the lowest stock size, is meaningless for many management purposes, though conservative stocking policies allow for a buffer of surplus storage that can be used in poor years. Moreover, where lands are held communally, local pastoral herds are seldom settled but move around searching for areas where water and grazing conditions are favorable.

These conditions do not allow the use of range management techniques or calculations of carrying capacity developed for systems in equilibrium. Management systems rather require a capacity to respond quickly to unforeseen challenges and opportunities. This is management by adaptive coping and opportunism, rather than optimization and control. Grazing systems in these areas are characterized by complexity, variability and uncertainty, and perturbations difficult to predict and impossible to control. Nomadic pastoralists have adapted to these circumstances by flexible and opportunistic management.

The objectives of managers may also differ widely: pastoralists may keep livestock as a 'bank account' and are interested in increasing stock numbers, while range managers wish to maximize commercial offtake. Clearly the CC for livestock or appropriate stocking density depends greatly on the purpose and assumptions of the analysis.
inter-season, inter-year and inter-location variations are extreme, and no specific CC can be calculated independent of these variations. Moreover, different managers require different services from the system and it is clear that there is no single CC of a system; actual numbers depend on the assumptions employed (refer to Box 6). These questions are considered more thoroughly in the following section.

The concept of CC is best associated with a single and well defined ecosystem or habitat, particularly one in or near an equilibrium state (refer to Box 7). Except for areas designated and managed as conservation areas, such situations are increasingly rare. The world is replete with examples of how ecosystems change over time with increasing settlement and human exploitation, and in these circumstances we are perhaps attempting to measure the unmeasurable (refer to Box 8). Moreover, we have no objective measure of degradation or progress; a town bypass that cuts across a national park is applauded by some and deprecated by others. In the following chapter we move from the CC concept itself to approaches that are more concerned with environmental change as viewed from the human perspective.

Endnotes

1 More recent concerns about use-impacts are not restricted to changes in the bio-physical environment, and relate to social or cultural impact; e.g., on the lifestyle and cultures of local people, or in the case of tourism, on the quality of visitors' experience.

2 As the upper bound for the logistic growth equation, K indicates the population's ability to survive and reproduce at a given level of resource consumption. However the equation is based on assumptions that are strained even for simple organisms and especially so for human populations. For example, the model does not consider that the population at K might modify its resource base over time and endogenously change the CC (Fearnside, 1990).

3 The stability or restorative ability of an ecosystem is a closely related concept representing the ability of system to return to an equilibrium state after a disturbance; the more rapidly it returns and the less it fluctuates, the more stable it is. When a perturbation does not cause the system to change its state it is in 'equilibrium'.

4 Excess waste over the environment's assimilative capacity adversely affects humans and ecosystems directly through pollution, and indirectly through the diminished environmental ability to perform ecological functions that sustain the earth's life support system and regenerate renewable resources. A vicious circle of degradation can thus be envisioned.
The laws of thermodynamics show that decreasing energy value is obtainable from natural resources as they are consumed because of inefficiency in the conversion processes, in which energy is dispersed into utilizable and non-utilizable forms. This is relevant to global CC because (a) human resources are dependent on finite natural resources (material and energy) for their survival, (b) natural resources are depleting due to the consumptive patterns of humans and population growth, and (c) resource utilization generates increasing amounts of wastes which the environment has only a limited capacity to assimilate and (eventually) convert back into harmless or useful products.4 Huge solar input and centuries of time are required for fossil fuel and many other natural resources to regenerate, rendering them “non-renewable” within the time-scale of human concern. The earth’s resources can thus be expected to decline under current resource use patterns which will ultimately force a decline in population numbers or economic activity until an equilibrium or balance is reached. (Note that it is unclear that a “balance” or “steady-state” will ever occur. Moreover, this theoretical balance point is associated with a degraded environmental state and reduced carrying capacity, and thus does not reflect sustainability).

The extent to which this theory manifests itself in practice and the timing of its occurrence will depend upon changes in economic incentives and technological developments. These factors are constrained because, while technological developments can be expected to improve efficiency (reduce wastage) in the resource–product conversion process, they cannot increase the quantity of resources (as yet the sun’s power cannot be harnessed to substantially speed up the regeneration or recycling process). Furthermore, economic incentives by definition, require that the benefits associated with more efficient resource use exceed the costs of related efficiency investments. Not all efficiency investments are inherently economically sound. Additionally, widespread failure to price natural resources at their full value distorts investment decisions, reducing incentives for efficient resource use.
Box 8
Environmental Dependency and Adaptation Processes

It is known that animal populations in the wild have elaborate adaptation processes that respond to changes in the availability of food. As the CC determined by natural food supply fluctuates, species adjust their numbers to meet these situations. Seasonal migration, cycles in mortality and fertility, hibernation, or drastic reductions in numbers during extended periods of drought are commonly observed. These responses reflect the direct dependence of animal populations on the volume of food and water they are able to derive from their natural habitats (Muscat; in Mahar, 1985).

At the point where a local animal population is forced to reduce its consumption or numbers in the face of natural calamity or reduced food supply, its population has exceeded the short-run CC of its environment. Seasonal and cyclical fluctuations in animal numbers are part of recurrent biological adaptation to a fluctuating environment, each population coping with the conditions of its ecological niche on a temporary or longer-term basis. Mortality increases do not necessarily indicate that the long-run environmental CC has been exceeded, as populations may recover as conditions return to normal.

Anthropologists studying human pre-history have shown that early human groups went through periods of varying populations in response to changes in food supply, and there is evidence that these populations at times employed artificial controls such as infanticide to sustain population stability (Thomas, reported in Mahar, op cit.). Primitive societies, such as hunter-gatherer bushmen of the Kalihari, have a particularly close dependency on the CC of the environment. These bushmen traditionally existed in ‘comfortable’ equilibrium, living by hunting game and collecting plants, and making frequent treks for food and water. Using birth control measures, the community achieved a long-term equilibrium between population numbers, caloric intake, and leisure preferences. Despite the severity of their environment, it is estimated that only one-third of their time was devoted to food collection.

In circumstances such as these, CC imposes a constraint on human populations and the income or life-style enjoyed. Bushmen live to a large measure in isolation, without conflict with others, and there is no defence or territorial motive for promoting population increase which would upset their equilibrium. Nor is there pressure from government, commercial incentives, access to new technologies, or in or out migration that would change their society from a closed to an open society. In these circumstances, the community could vary only its numbers and leisure/work allocation, and the CC of the land would completely determine its size.

Such closed economies, however, are increasingly unusual in the world today. Most contemporary farming systems are influenced by trade, government, migration, technology and accumulation of capital. The declining importance of agriculture in the structure of production and employment may also greatly reduce the dependence of human populations on their natural environment, or spread this dependency more globally. Development almost by definition brings openness and declining environmental dependency (at least directly). Although globally the concept may still be crucial, for some high trading populations such as the Netherlands, Switzerland and Singapore, the inherent qualities of their immediate area (tourism aside) would appear to have become almost irrelevant to economic activity and constitute little barrier to population and economic growth.
3 Alternative Paradigms

The CC literature is remarkably disparate and embedded in different schools of thought and disciplinary origins. Natural and social science based conceptions are commonly incomparable, adding to the problems of natural resource managers and other potential users of this information. Despite its importance, there has been little neutral or cross-disciplinary analysis or synthesis for intervention and management outside the area of ecological economics. The most radical difference is between ecocentric and anthropocentric approaches (Refer to Box 9).

Contrasting Perspectives

Ecocentric perspectives focus on the inherent qualities of the ecosystem or habitat itself, normally emphasizing the ability of the system to sustain itself over time. Human activities may be part of that system but can be destructive where population numbers or use-intensity exceeds a certain level, and the system 'degrades'. This may take the form of a reduction in genus, species or habitat diversity, or damage to the ecological functions and services contributed by that ecosystem. Conservation and protection of the ecosystem in more or less its present form is seen as paramount for the sake of the system itself, albeit it may be argued, for the long-term benefit of mankind.

Anthropocentric perspectives, on the other hand, focus on the productivity of the system and the numbers of people the system can support. In this case the system is regarded not in its own right but as a collection of resources available for exploitation by man, and biophysical changes are seen as relevant only in so far as they affect human welfare. Thus substantial system changes brought about by increasing human populations and the

| Box 9 |
| Environmental, Social and Economic Compatibility and Conflict in the Himalayas |
| An overseas-aided environmental forestry project in the Indian Himalayas was established on the premise that the ecocentric and anthropocentric interests were entirely compatible. Closer examination demonstrated that this was not necessarily the case under increasing population pressures. A low-intensive use of forests by local people for the collection of natural products and livestock grazing does not threaten the forest ecosystem; indeed, low-intensive exploitation has taken place for many decades. However, in recent years, growing population and commercial incentives have increased use-intensity (e.g., for logging and collection of medicinal plants for sale) to levels that may exceed the system’s CC. One consequence has been a clamp-down on certain forms of forest use, such as the use of timber for house construction. Rising populations and demand for land have also increased pressures for conversion of forests to agriculture. These pressures have come from local farmers who require land for subsistence agriculture, from government departments looking for areas to settle landless people, and from commercial operators who wish to expand their apple and soft fruit orchards. |
form of exploitation are seen as inevitable and sometimes encouraged. People-centered and environment-centered approaches adopt a completely different basis for assessing what is good or bad about environmental change.

To an extent, differences between ecocentric and anthropocentric perspectives can be explained by differences in time scales. Ecocentric approaches do not generally address the time issue, but by implication give more-or-less equal weight to present and future generations. Mainstream economists, on the other hand, adopt a ‘discounting’ approach which gives greater weight to the present than to the future. This rests on the assumptions that economic growth will continue if good investments are made, and economically rational decisionmaking represents the way that most individuals and societies actually behave.5

The two approaches also differ in their treatment of management systems and technology. Ecocentric approaches take a tighter definition of CC and relate it to the inherent and absolute properties of the ecosystem itself, unrelated to technology and management. Anthropocentric approaches, on the other hand, suggest it is impossible to distinguish between the ecosystem itself and the technology and management system employed in its exploitation, and give equal weight to the latter (refer to Figure 3).

### The Boserup Model

The anthropocentric paradigm is most closely represented by the Boserup model. Esther Boserup (1965) pointed out that the pessimistic scenarios Malthus had depicted failed to take account of humankind’s seemingly insatiable capacity to adapt to its environ-

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<table>
<thead>
<tr>
<th>Ecocentric</th>
<th>Anthropocentric</th>
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<tr>
<td>Environment-prioritization</td>
<td>Human-prioritization</td>
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<tr>
<td>Conservation focus</td>
<td>Resource productivity focus</td>
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<tr>
<td>Malthusian</td>
<td>Boserupian</td>
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<tr>
<td>Physical and population determinants</td>
<td>Technology and Management determinants</td>
</tr>
<tr>
<td>CC concept highly relevant</td>
<td>CC less relevant</td>
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**Relevance of the Carrying Capacity Concept**

Instead of gloomy predictions of famine or environmental degradation in developing countries, Boserup saw in population growth an incentive for agricultural intensification through the economic rationality of human behavior. Population growth - or rather growth in the labor force available for agricultural work - was seen as a triggering mechanism for higher levels of land productivity through autonomous intensification, in the way of increased labor input per unit of land, and technological development.
Boserup thus reversed the causal link between food supply and population. Food supply no longer was seen to constrain population size but instead could be an inducement to development. Boserup demonstrated that, rather than the environment setting ceilings to population size according to Malthusian principles, people in fact adapt to the opportunities provided by the increased labor supply and develop farming systems and technologies that equal or improve on those replaced (refer to Box 10).

Most current literature on population and the environment demonstrates its Malthusian or Boserupian inheritance. At a local level, the former focuses on evidence of soil, water and forest degradation while the latter focuses on examples of spontaneous intensification by rural people. Similar arguments have been developed at a global level, particularly the weak sustainability and strong sustainability notions developed in environmental economics (Pearce, 1994).6

The Malthusian or strong sustainability argument emphasizes the primary value of ecosystems, the finiteness of resources, and the limited scope for substitution between natural and built assets; indeed, certain natural capital (biodiversity or the ozone layer, for example) is seen as critical to the continued function of global ecosystems, and cannot be replaced by investment. Strong sustainability also suggests that we do not sufficiently understand the dynamics of ecological systems and this uncertainty requires caution—hence the precautionary principle. The Boserupian or weak sustainability perspective, on the other hand, suggests that natural and built capital are interchangeable, and only the total (not the form) of capital stock passed on is relevant to future welfare. For example, the destructive exploitation of natural resources is acceptable if there is at least a commensurate level of capital investment in the economy, even something that is not directly substitutable.

The mainstream view in the rural development literature is still Malthusian, emphasizing the “strong synergy and causality chain linking population growth with land degradation and poor agricultural performance” (Cleaver and Shreiber, 1994). Hence rapid population growth is seen as the principal factor “triggering and continuing to stimulate” the downward spiral in environmental resource degradation as is occurring in countries such as Ethiopia (see Box 4). However it is increasingly clear that the evidence is not all one-way. Much recent research has reinforced the Boserupian arguments, including two compelling examples from Machakos in Kenya (Box 11) and Kissidougou in Guinea-Conakry (Box 12). It is not clear that population growth will be a force for degradation or development, depending as it does on a host of political and institutional circumstances.

Box 10

Demographic Factors

Three alternative points can be made about demographic conditions. Firstly, population growth inevitably affects the age structure and the labor force increases commensurably only after a substantial time lag. Problems of dependency may increase, and further weight may be placed on women, particularly in female-headed households. Out-migration of young male labor may take place alongside population increase and actually reduce labor availability for certain activities, particularly for heavy jobs such as forest-clearing. Secondly, problems of assimilation and adjustment may be greater when the rate of growth is high, as technical and managerial processes take time to develop. Thirdly, the principle of diminishing returns suggests that, other things being equal, labor productivity will fall over time, though it may continue to be a seasonal constraint. Thus innovation and technological development may be required just to keep pace with population increase.
Land Use Intensification in Machakos, Kenya

The most comprehensive and deliberate attempt to study the relationship between population growth, land use and economic change has been carried out in Machakos, a semi-arid district in Kenya, southeast of Nairobi. The study adopted a historical approach and compared land use, population change and other measures between the 1930s and 1990. It was predicted in the 1930s that a combination of rapid population growth and mismanagement of land resources would lead to serious environmental degradation and loss of productivity on a Malthusian scale. How the district avoided such economic distress has been recorded in a widely cited study (Tiffen et al, 1994; English et al, 1994).

Since 1930, population has grown from just over a quarter of a million to almost 1.4 million in 1990. The areas under cultivation have expanded enormously at the expense of forest, bush and range lands. A continuous process of agricultural innovation has taken place, including the introduction of new crops, mixed farming, animal traction and terracing systems. Cash cropping has raised the value of land and encouraged the adoption of conservation measures, while staple food crops have stabilized around the levels required for basic subsistence. Despite deforestation, fuelwood and timber supplies have been sustained through increased tree production by farmers. Although grazing areas have been reduced, increased cattle numbers have been supported through stall feeding and increased fodder production.

The extent of change in land resource management in Machakos is illustrated by the comparison of 1930 and 1990 photographs taken of the same scene. The 1930 photographs show bare, gully-eroded and practically treeless hills. The livestock herding practices of the Akamba people were seen as a primary cause of degradation, and constituted a real worry to the colonial administration (perhaps one of the earliest expressions of governmental environmental awareness). Over the subsequent 60 years the problems of erosion have been met with increasing success. Over 200,000 ha. have now been terraced or partially terraced, and little cultivated land remains untouched.

This evidence suggests that population growth led to an increase in relative scarcity of land, which has stimulated intensification of agricultural management and production. Much of this success must be attributed to favorable institutional and economic circumstances, including governmental support for research, education, extension, and perhaps more importantly, road construction. Land tenure presented no problem; land registration has not been a prior condition for investment since customary Akamba law has always taken an individualistic view of land and provided sufficient security. The proximity to Nairobi has also greatly facilitated the process, providing both a market for agricultural surpluses and a source of employment (income-earning) opportunities for local people.

There is no doubt that Machakos provides exemplary evidence of how severe population pressure in a poor area can, when conditions are right, lead to the development of intensive and sustainable land management practices and thus push back critical thresholds. Present production levels far exceed anything that might have been contemplated in the 1930s, and attempts to have held populations to such predetermined levels would have been disastrous. It should be added, however, that ecological values were not assessed in the study and it must be assumed that ecosystem and species biodiversity, and their economic products and functions, suffered considerable modifications and loss in the process of change.

A rider should be added to this generally optimistic account. The population of Machakos is still growing rapidly, and the extent to which intensification of land use can proceed further is uncertain; almost 100% of the land is now terraced and close to 90% of farmers use improved seeds. It is not proven that living standards can rise with a further decline in land/labor ratios. As in northeast Thailand (Box 14), the future may rest outside the area, and particularly on further employment and income-earning opportunities in Nairobi and elsewhere. Machakos is unusual in that it is a success story in a country which faces many of the problems associated with population pressure, including erosion, deforestation and salinization. The case cannot be regarded as proof that good management will outweigh the natural restrictions set by the CC, or whether it represents a reprieve or exception in the long-run stripping of resources by population growth. On balance, however, there is reason for optimism: the Machakos case demonstrates that the CC, in an anthropocentric if not eccentronic sense, is a moveable boundary. At least in favorable circumstances, natural resource limits can be raised considerably by the spontaneous actions of local people. Clearly the doomsday predictions inherent in a strict interpretation of the CC concept do not apply.
The Socio-Political Environment

The extent to which a given ecosystem can assimilate a growing population on a sustainable basis depends not only on bio-physical conditions, but also on a variety of institutional and socio-economic circumstances which define the 'rules of the game'. These include demographic variables and institutional and cultural factors governing decision-making in the community. To dwell on these extensively is outside the scope of this paper, but a few words can be made in passing.\(^7\)

Whatever the physical environment or level of development, local societies can be expected to adjust to increasing populations, and make environmentally sustainable changes to their farming systems. Not infrequently, however, socio-political factors outside the control of local people negate these natural tendencies for sustainable management. Dominant amongst these are conditions of civil war, insecurity or uncertainty, which breed 'short-termism', and tenurial conditions which minimize personal or communal responsibility. This commonly occurs in 'open access' situations where ownership of property is not well defined or enforced, and where in consequence the rational self-interest of individuals is detrimental to the interest of the community as a whole. It is clear that in these circumstances the CC of an area is determined as much by tenure, politics and economics as it is by biophysical factors and population levels.

Furthermore, there are other equally important considerations about whether the process of adaptation and intensification is environmentally harmful. As populations rise, for example, there may be an extension of agriculture into forested areas at the expense of natural forest, implying massive ecosystem disruption. Whatever the form this may take, from an ecocentric perspective this is viewed as environmental degradation, and as such is decried by those with strong environmental interests. However, the conversion of forests to agriculture may considerably increase the productivity and population absorbing capacity of the area, and the new farming system may be as sustainable as the system it replaced (from a productivity perspective). Conversion of forest to agriculture may therefore be an inevitable step in the evolutionary process: from forest to agriculture, and from scattered settlement to villages which later merge into towns. From an economic and social perspective, then, the process of change might be perceived as beneficial, and perhaps inevitable if development is to occur.

Certain factors unforeseen at the time have acted against fulfillment of Malthusian predictions and allowed both a vast increase in human populations and also an increase in prosperity in many parts of the world. At a macro level, these relate to an expansion of occupied territory, particularly the colonization of vast tracts of land in the New World and extensification of agriculture into underpopulated and often more fragile parts of developing countries. There are also numerous examples of how increasing populations have successfully intensified their farming systems even in fragile environments, and now support populations many times their original numbers. However there are also many examples of natural resource degradation that has occurred where socio-economic conditions have not provided incentives for sustainable management.

Whether or not intensification of natural resource use can continue indefinitely, however, is open to question. Even where intensification increases land productivity, many natural products, functions and life-support services are lost. The aggregate and cumulative effect of these losses is unknown and we cannot blindly assume that there will be no long-term consequences.
Box 12
Adaptive Management in Guinea-Conakry

Recent field research in Kissidougou Prefecture in Guinea-Conakry has traced the history of vegetation and land-use patterns and examined the relationship with local demographic and organizational change (Fairhead and Leach, 1994).

Prior to this research, observers considered upland farmers in the Prefecture as exploiting cultivated land to its maximum, using a sequence of progressively less demanding crops before moving to a new site, then leaving the old depleted site fallow. Such practices were regarded as progressively degrading of vegetation and hence of future productivity. Population increase was believed to accelerate this process by forcing a shortening of fallow periods.

The study revealed, however, that local people do not consider they are degrading the land or the vegetation when they farm; on the contrary, they believe that the agronomic and rotational practices they use actually improve soil structure and raise productivity. When land is cultivated for several years it becomes more easily worked and develops better water infiltration and retention capacities. The improvements in soil structure are not lost in the subsequent fallow so that when the time comes for farmers to clear new land they turn in preference to previously cultivated sites. Thus, over time, soils which once supported only poor savanna grasses came to produce relatively woody savanna and eventually good yields of rice and other crops. Farmers also suggest that the thicker vegetation of the fallow is more resistant than uncultivated land to damage by bush fires, which strike from time to time.

An increasing distinction between land-extensive and land-intensive farming systems appears to be developing in the region. The gallery forests which are cultivated with upland rice every 8-10 years are already used to a maximum, and fallows cannot be shortened or they become ineffective. On the other hand, other densely settled parts of the district are being farmed increasing intensively. Population growth has been accompanied by out migration of young males, who usually clear new land. Their absence has added to the tendency for more intensive cultivation of presently opened land.

The relationship between population growth and forest cover was also researched. The usual belief of outsiders is that the islands of dense humid forest found around the villages were relics of once more extensive forest cover which has progressively been converted to savanna. The reality is quite different. Far from being relics of ancient forest, these forest islands have been created as populations built up, for reasons including fortification, fire protection, forest product sources and shade. In Kissidougou more people have generally led to more management, and often to an increase in tree cover in the vicinity of settlement.

A final lesson from the study is that the desirable features of natural resource management in the region have depended less on formal or organized action than on the sum of management actions of individual households or small groups of households set up for specific purposes. People have adjusted practices to the new pressures created by demographic and socio-economic change, bearing out the Boserup principles.

A Livestock Model

Study of the practical use of the CC concept has been taken furthest in livestock production. However, findings indicate that strict focus on CC may result in inappropriate interventions (refer to Box 13). To complete our analysis we turn to a model of the environment-livestock population relationship in the African rangelands developed by Roy Benke and Ian Scoones (Benkhe and Scoones, 1993).

The starting point is the assumption that the quality of rangeland grazing is affected by
As in most of the development literature, the focus of attention in livestock management has not been on the issue of land degradation per se but on the capacity of the system to meet immediate production goals or stocking densities. Attempts to assess the CC have been taken furthest with reference to African rangelands where the stocking density would appear to be closely related to the biophysical qualities of an area, as few if any inputs (such as feed and fertilizer) are brought in from outside.

Livestock CC is based on the idea of 'ecological carrying capacity' under which livestock numbers grow until restricted feed supplies reduce birth rates and increase death rates, known as 'K'. K represents a limit to the population of livestock that can be held in an area and, whatever the management system, population must be managed at density below K. Calculations involve estimating the total edible vegetative biomass produced annually from a specific area and comparing this with the forage consumption requirements of the livestock herd, adding an arbitrary 'proper use factor', as a safety margin. These calculations take no account of the objectives of management, stock movements or use of vegetative niches, and suggest that rangelands are vastly overstocked. Estimates for Somalia and Lesotho, for example, show certain rangelands to exceed the CC by a factor of eight. These increases are undoubtedly associated with changes in pasture composition which are degrading from an ecocentric position; however, they have not been severe enough to limit the number of stock and perhaps have even positively encouraged it.

Experience with utilizing the concept has thus met with repeated failure, and recent thinking in range ecology has moved into three areas (Ellis, 1993). Firstly, African pastoral production systems are influenced by a range of different livelihood objectives. The objectives of commercial managers who wish to maximize production of quality beef, for example, are likely to have little in common with pastoralists who keep livestock for a variety of purposes and are concerned more with stock size than offtake levels. Secondly, the productivity of African rangelands is heterogeneous in space and variable over time, which makes flexible movement and stocking crucial. Thirdly, vegetation status and livestock numbers are determined by natural events such as droughts. In these circumstances it is thought that grazing has only a limited effect on the long-term productivity of the rangelands, and opportunistic or tracking strategies are most efficient in the use of valuable feed. Interventions that fail to address these three considerations are unlikely to succeed.

Recent evidence from livestock systems in West Africa (Bourn and Wint, 1994; and ODI comments, 1994) also provides evidence of sustainable intensification with population growth where conditions are favorable. This research provides further evidence of livestock-crop linkages and makes clear that labor as well as fodder resources are needed for livestock production. Limited fodder resources available around farming communities can be stretched through careful management and by feed supplementation, and present less of an impediment than first thought. Development can also increase the availability of usable land by pushing back the tsetse fly boundary without the use of chemicals.
costs, is maximized. Here there are somewhat fewer animals and the pasture is in better condition. This level may roughly accord with a level of resource utilization that appears to outsiders to be optimal and thus frequently forms the basis for officially recommended resource utilization rates.\(^9\)

The most botanically rich position, with the greatest species diversity and vegetative biomass, lies at the top left of the trade-off curve (point B). At this point livestock have no adverse impact on the environment and form part of the natural ecosystem.

While accepting the numerous simplifications of this model, some important conclusions can be drawn. The optimum position on the curve will always depend on the exercise or production system in question and the objectives and priorities of the managers. By definition the optimum position lies along the curve, but in different circumstances the optimum position can be point E, P or B. E falls close to the maximum stocking rate, a point which nomadic pastoralists endeavour to approach using opportunistic, niche seeking and migratory production systems. P represents the commercial optimum, the point where rent is maximized under commercial ranching schemes. B represents the most biologically desirable point, one that conservationists may wish to promote. Other points on this curve could be indicated to suggest the optimum position for touristic activities and wildlife viewing, a situation where botanical and productive sub-optimal positions may be desirable.

This being true, it makes little sense to talk loosely of over-population or over-exploitation (over-stocking, over-grazing, over-fishing, over-cutting) of any resource. These are pejorative or at least subjective terms. Their use indicates a particular posture or viewpoint that may not be shared with others. While we do not suggest that this difficulty precludes use of these terms, we do suggest that in all cases they are not used independently of consideration of the goals and purpose of the exercise, and the perspective of the observer should be clearly stated.

The model can also be used to depict a
change in management system which may raise the CC of an area. The provision of watering points in a rangeland, for example, may remove a limiting factor and so push back the boundary to the numbers of livestock that can be kept. A similar situation could be observed with the application of fertilizer to a grass sward, or the use of more productive grass species. In Figure 5 we hold point B, the botanical optimum, as constant but illustrate how technology can raise the commercial optimum from P1 to P2 and the ecological CC from E1 to E2.

In marginal areas, opportunities to increase production are less available and the concern is often with avoiding the problems of soil and water degradation. Technical solutions to these problems are well known: they include physical processes such as the construction of stone bunds, check dams and terraces, the planting of bushes and trees in threatened areas, and avoiding potentially destructive farm practices associated with over-cultivation or over-stocking of hillsides. Where these practices are successfully adopted, a great many more people can be accommodated on the same area of land.10

Endnotes

5 An alternative view is proposed by economists such as Daly and Georgescu-Roegen who suggest that there is a limit to the time-span of humankind and the basic goal should be to ensure the survival of the human species for as long as possible. This latter view emphasizes the importance of containing population and economic growth within limits and gives overwhelming importance to the global importance of CC.

6 Economists commonly reason that the minimum requirement for sustainable development is passing on to the next generation an aggregate capital stock no less than the one that exists today. This capital stock constitutes man-made capital (machines and infrastructure), human capital (knowledge and skills), and natural resources.
On a global basis the standard of living may be a more important determinant of resource usage than population growth. Communities in developed countries may consume natural resources at a rate far in excess of the majority in developing countries, though their contact with resources is much more remote.

This can be likened to a production possibility boundary in standard economics.

In Zimbabwe, official recommended stocking rates are a half to a third of estimated ecological carrying capacity (Scoones, 1990).

It is noted, however, that many of the most widely adopted advances in agricultural technology, such as mechanization, have been successful because they have increased the productivity of labor more than of land.
This examination of the concept and utility of CC leads to a number of conclusions and implications for policy, planning and management.

The concept of CC is useful at a conceptual level for understanding the challenges of natural resource management. The concept generates awareness about the finiteness of biological and physical resources, the vulnerability of different environments, and the potential danger of 'over-exploitation'. Failure to appreciate the complexity and interdependency of human impact on the environment has led to many unexpected and unwanted consequences. However, the study has also shown that human population density is only one of many factors governing sustainable land use and there are many examples of growing populations being successfully absorbed in rural areas with appropriate technologies and management systems.

Having said that, we cannot assume that further intensification will always be possible; certain environmental functions and services are almost inevitably lost and we cannot be sure about the continued ingenuity of man to cope with these losses.

There are major practical difficulties in utilizing the CC concept for environmental planning and natural resource management. CC is a theoretical construct and in most situations there are insurmountable problems in applying the concept. Practical difficulties mostly relate to the notion's imprecision, which makes it difficult to measure or calculate. The concept relates to equilibrium situations and closed economies where threshold levels are relatively clear and static. Most environments, however, are transient and changing, circumstances which act against calculation of a single CC or even a range. No examples have been found in the literature where the calculation of a particular population CC has been a practical aid to natural resource management.

Practical difficulties also relate to imperfect understanding of CC thresholds and the consequences of exceeding them. Our knowledge of natural resource thresholds is also theoretical rather than practical. We do not know where or when the effects of exceeding a particular population are immediate and catastrophic, or in what circumstances the CC is like an elastic band which, with good management, can be almost infinitely stretched. Neither do we know the extent to which local CC limits are naturally overcome as economic systems become larger and more open, or whether this just transfers local problems to a more global level of concern (refer to Box 14). All we can say for sure is that thresholds are complex, variable in nature, and continually changing. Research is required to examine the principles governing the resilience of habitats and ecosystems, and so facilitate generalization.

Problems of utilizing the CC concept are conceptual as well as practical. In the absence of much greater knowledge of change and its consequences, the concept of degradation will
often be subjectively determined. Whether or not an ecosystem has reached or exceeded its CC depends on the criteria used to judge. From an ecocentric perspective, any disturbance or ecological change may be regarded as harmful whereas from an anthropocentric perspective the change may be regarded as desirable. Almost inevitably more people mean more interference with natural systems, but whether or not this is deemed good or bad depends on the criteria applied and the purpose of the analysis.

Planning demands clear objectives and prioritization between objectives. Many programs and projects have suffered from the assumption, conscious or unconscious, that ecological and economic interests necessarily coincide. Potential problems are often played down with the (well-intentioned) premise that 'what's good for the environment is good for local people'. That this may not be the case flies in the face of conventional thinking. It is, however, particularly important that natural resource planners and decisionmakers are aware of such problems, and be able to recognize and address trade-offs and conflicts at an early stage of planning.

Clear distinction is required between projects that emphasize natural resource conservation and those which serve the livelihoods of people. In regional or project planning it is important to distinguish between natural resource projects designed to conserve an ecosystem or habitat in (more or less) its existing form and those where economic or social development are given priority. As indicated above, the objectives are not necessarily compatible. Decisions require careful analysis of ecological, economic and social considerations, and in the end a degree of political judgement is probably unavoidable.

The CC concept best relates to wildlands and protected areas where priority is given to conservation and protection. The CC concept is most useful in circumstances where biodiversity and aesthetic considerations are paramount and maintenance of ecosystem and habitat characteristics in their present form is required. Where ecosystems are particularly rare and valuable there may be no conflicts or trade-offs with socio-economic aims and objectives, because to degrade the environment would also destroy the economic value of the resource. Such win-win situations, however, are easily over-estimated. Seldom if ever does conservation have zero opportunity cost, and almost invariably conservation projects have major implications for local people.

The CC of an area is normally set by natural or bio-physical limits, but socio-political factors may be equally important. If human population or exploitation exceeds a certain level, some form of ecological change (which may be destructive) necessarily results. However, the CC of an area may be determined not just by the physical and biological environment but also by political and institutional conditions. It has been widely demonstrated that local people act in a sustainable fashion where the right incentives are present. Where these incentives are misplaced or lacking, however, the CC is likely to be exceeded. There is perhaps as much variation in institutional circumstances as is in bio-physical constraints.

Generalizations about the environmental consequences of population growth should be avoided. From an ecocentric perspective, more people generate more economic activity and more environmental disturbance. Untouched or little modified natural resources are increasingly rare, and hence more highly valued, especially in areas where population densities are high. Most ecosystems and habitats, however, are considerably modified by human activity. Where conditions are right, people adjust to increasing populations and introduce new management and technological systems. Where this is the case, the
productivity of natural resource systems appears to be almost endless. We should remember, however, that individual consumption of resources is much greater in the developed than developing world. Indeed, increasing consumption, per se, has greater potential environmental consequence than population growth.

*Emphasis must be given to proper study of any situation prior to intervention.* Projects and programs should never be set up based on general assumptions about what is happening to people and the environment. There is no substitute for detailed and integrated study and analysis of the bio-physical, socio-economic and institutional circumstances, all of which takes time. The causes and effects of natural resource and development problems are invariably complex and locally specific, and affect different people in different ways. To neglect this phase of the project cycle in the desire for speedy results is to invite trouble later.

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### Box 14

**Land Extensification in Thailand**

Thailand is an interesting example because population pressure relative to CC was identified as a problem in the 1960s by a World Bank country study. The team noted that unless productivity was raised, the county’s exportable surplus of rice would be absorbed by domestic consumption. However, this projected outcome has not come to pass. Irrigation and changes in technology have enabled the Chao Phraya delta to sustain both exports and domestic demand nearly twice as large as it was in 1960. Thus the Central Plain is a region that has successfully avoided the economic pressure imposed by the CC that appeared to be a likely outcome thirty years ago.

The northeast region is poorer and less advanced. With one third of the population, it is the poorest part of the country in terms of its soil and water endowment and regional income. Population has risen rapidly for most of this period, linked to a remarkable spread of rainfed agriculture to newly opened areas. There has also been a shift into new crops as improved physical access and relative price movements changed economic incentives. The region has also benefited from links with the rest of the thriving economy and the vigorous export-oriented marketing system. These benefits include remittances from family members employed in Bangkok and net government transfers to the region.

However, for much of this period the driving force behind rural development has been forest clearing and an extensification of cultivation into more marginal areas, a process which is no longer possible on a substantial scale. Prospects for technological improvement of rainfed agriculture are limited and the region is said to be approaching a limit to growth in the agricultural sector set by its CC. Although the northeast is more constrained by CC, there will be both an intensification of certain agricultural enterprises and a general decline in the relative importance of the sector. If this is the case, natural limitations will continue to be mitigated by movement towards an increasingly open economy.


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