THE MULTIPLE PRODUCTS, FUNCTIONS AND USERS OF NATURAL RESOURCE SYSTEMS

Brent M. Swallow

ABSTRACT

This paper[1] presents an analytical framework for guiding studies of the use and management of natural resource systems in which: (i) several goods and services of value are produced; (ii) resource users have multiple objectives vis-a-vis collective management of the natural resource system; and (iii) sub-groups of resource users are distinguished by their property rights, endowments and preferences. The framework is motivated and validated by reference to rangeland systems in Africa. Several implications for research and policy emerge.

INTRODUCTION

Economic models of resource management regimes tend to focus on the advantages and disadvantages of different property institutions for allocating a single resource among a group of homogeneous users, e.g. water among irrigation farms, a species of fish among commercial fishers, timber among foresters, grass among grazers. But most resource management regimes actually govern the use and management of landscapes or ecosystems that provide a number of products valued by people. A woodland, for example, might provide several goods — food from plants and animals, medicinal plants, fuelwood, building materials ~ and services — erosion control, nutrient cycling, carbon sequestration, habitat for

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wildlife, reservoir of biological diversity, groundwater recharge, recreation and aesthetic enjoyment (Bingham et al. 1995; Gottfried et al. 1996). Some products emanate from the ecosystem or landscape as a whole, others from particular components or niches within the ecosystem or landscape. Similarly, some of the institutions that govern multiple-product landscapes or ecosystems apply to the whole, others to particular products or components, still others to inter-related sets of products or components. Developing policies and institutional arrangements for good management of such multiple-product ecosystems or landscapes is a major challenge to analysts, policy makers and communities.

A second challenge is that the resource management institutions often perform several related functions vis-a-vis property rights and collective action for management of the ecosystem or landscape. Different individuals or sub-groups may value different functions or the same functions differently. A third related challenge is that the individuals and sub-groups who use and value the products of a landscape or ecosystem often have different rights to those products and different endowments with which to capitalize on those rights. Individuals and sub-groups may differ, inter alia, by their endowments of productive capital, production efficiency, physical location vis-a-vis the resource, operational power and bargaining power.

This paper responds to those challenges by presenting and applying a framework for analysing multiple-product, multiple-function and multiple-user natural resource systems. Section 2 presents some background information on the problem situation that is used throughout the paper to motivate and validate the analytical framework. Section 3 presents an analytical framework for guiding the study of landscapes and ecosystems that generate multiple products, are used and valued by heterogenous groups of people, and whose institutions perform multiple functions. The framework is used in Section 4 to explore the issue of the optimal sizes of natural resource systems and resource management regimes. The results imply that some well-known resource management principles may not have the general applicability often proposed. Section 5 is a concluding discussion.

AN OVERVIEW OF AFRICAN RANGELAND SYSTEMS

Many of the points made herein are motivated with examples from African rangelands. There are four reasons for choosing this example. First, rangeland utilization is one of the most important and ubiquitous types of land use in Africa and elsewhere in the developing world. Eighty-two percent of the agricultural land in Africa is classified as permanent *pasture* (World Bank 1996, 367). Second, large numbers of very poor people are directly affected. In sub-Saharan Africa there are about 25 million pastoralists (people belonging to households that obtain more than half of their gross household revenue from livestock) and 240 million agro-pastoralists (people belonging to households that obtain 10-50 percent of their gross household revenue from livestock), most of whom obtain significant quantities of livestock feed from natural pastures (Swallow 1994). Nearly half of those people live in absolute poverty.[2]

Third, most of the rangelands in sub-Saharan Africa are governed by resource management regimes that proscribe private rights to some components or products, common rights to other components or products, and no specific rights to other components or products. A relatively small share of the total area of rangeland in sub-Saharan Africa is governed by purely private, purely common or purely state property regimes. Fourth, most African rangelands generate multiple products (Le Houerou 1980) and are used by heterogeneous groups of users (Scoones et al. 1993).

In this paper the term 'rangeland' is used to refer to the grasslands, scrublands, bushlands and woodlands that are used as natural pastures for domesticated livestock. Rangelands contain grasses, but also a variety of tree species. Le Houérou (1987) estimates that only about 20 percent of rangelands in Africa are grasslands; the remaining 80 percent are scrublands, bushlands or woodlands. Trees on rangelands are important sources of animal feed; Le Houérou (1980) estimates that woody species contribute 10-20 percent of livestock feed in the Sahel. Trees are also important sources of goods and services in addition to animal

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[2] About 92% of the permanent pasture in sub-Saharan Africa is contained in 19 countries. The rural population of these 19 countries is about 287 million, 134 million of whom live in absolute poverty (calculations based on statistics given in World Bank (1996).

feed. Human food, energy, building materials, raw materials for industry, boundary demarcation, fencing, shade, soil management, water management and wind shelter are tree products valued by local populations (Raintree 1991).

Many rangelands in the driest areas of Africa are not suitable for crop cultivation and thus are appropriately referred to as permanent pastures. But large areas of Africa's rangelands are located in somewhat more humid areas and thus can be cultivated or are contiguous to areas that are cultivated. In southern Burkina Faso, for example, almost all land (much of which is now considered to be scrubland, bushland or woodland) has been cultivated at some time during the twentieth century (personal communication with Ann Fournier, ORSTOM, Burkina Faso). An important function of such long-term fallows, therefore, is the buildup and conservation of nutrients for future crop cultivation. Livestock are often managed to facilitate the transfer of nutrients from rangelands to nearby croplands (Powell and Williams 1995).

ANALYTICAL FRAMEWORK OF NATURAL RESOURCE SYSTEMS

Terminology

Before presenting the analytical framework it is important to clarify some terminology. The term *natural resource system* is used throughout the remainder of the paper to refer to landscapes or ecosystems, the goods and services those landscapes or ecosystems generate, the inter-relationships between and among components, products, and resource users, and the institutions and organizations that govern those inter-relationships. Natural resource systems may include, therefore, *property rights regimes* — sets of institutions that define the conditions of access to, and control over, goods and services arising from a natural resource system (adapted from Edwards and Steins 1996, 2). The property rights regime of a natural resource system may proscribe private, common or state property rights to the whole landscape or ecosystem, but in most cases proscribes private, common and state property rights to different components or products of the landscape or ecosystem. Natural resource systems may also include *organizations and institutions for collective action* in natural resource management.

Overall Analytical Framework

This section provides a formal description of the overall analytical framework. The next three sub-sections describe the components of the analytical framework in much greater detail.

A natural resource system produces r products according to r inter-related production functions. Of the r production functions, c ($c \leq r$) include variables under direct human control; the remainder [r - c] are determined recursively through intermediate outputs. e of the production functions ($e \leq r$) include stochastic environmental variables. A group [G] of n economic agents derive benefits from the r products. Besides belonging to G, the n economic agents also belong to one of k sub-groups. Each sub-group [gj, j=1, ..., k] is comprised of between 1 and n members

Each sub-group is comprised of one or interest groups or clubs; the likelihood that interest groups or clubs exist depends, *ceteris paribus*, on the demand for the possible functions by the group or sub-groups, the number of individuals comprising the group, and the personal characteristics of the individuals that comprise the group. Each individual can be characterized according to their property rights [PRi], endowments [Ei] and preferences [Pi].

k=1 implies that all individuals in G have the same interests in the natural resource system and there is no collective action within the overall group. k=n implies that all individuals in G have different interests in the natural resource system and there is no collective action within the overall group. $1 < k < n$ implies that there are two or more sub-groups; sub-groups are likely to be defined by their interests in the products of the natural resource system or the functions of the resource management regime.

The Multiple Products of Natural Resource Systems

Gottfried (1992) suggests that natural resource systems that provide several inter-related goods and services are appropriately modeled as "multiple product productive assets that may be long-lived." The productive asset in the case of African rangelands is a geographical area of bushland, some of which is used to produce food crops. The three primary products of the bushland are crops, trees and grass. Those primary products are

often combined with other inputs (e.g. labour, capital, livestock) to provide goods and services of value to people, including: (i) human food ~ meat and milk from domesticated livestock, bush meat, gathered foods and cereals; (ii) energy — trees, tree products, manure; (iii) building materials — tree products, material for thatching, material for handicrafts; (iv) conservation of biological diversity — including the special cases in which local residents benefit from tourism and safari operations; and (v) sequestration of atmospheric carbon ~ especially in the roots of deep-rooted trees and grasses. The inter-related production functions are given by equations (1) to (5). Other products such as livestock per se and soil nutrient management are intermediate between the primary products and the products of value to people.

Equation (1) models food as a function of the three primary products of the rangeland — crops, trees and grass, two inputs under human control — labour and livestock, and climate (a stochastic variable). Equation (2) models energy as a function of trees and labour and equation (3) models building materials as a function of trees, grass, labour and livestock. Equations (4) and (5) indicate that biodiversity preservation and carbon sequestration are not under direct human control but are indirectly affected through the production of trees, grass and crops.

(1) Human food = fl (Crops, Trees, Grass, Labour, Livestock, Climate)

(2) Energy = f2 (Trees, Labour)

(3) Building materials = f3 (Trees, Grass, Labor, Livestock)

(4) Biodiversity preservation = f4 (Trees, Grass, Crops)

(5) Carbon sequestration = f5 (Trees)

The Multiple Functions of Resource Management Institutions and Regimes

A maintained hypothesis in this paper is that the property rights and collective action institutions that often mediate the relationships between people and natural resources depend in part upon the motivations of those who value the products of the natural resource system. To some extent, therefore, institutions are functional and institutional change is endogenous. Economic models of property rights institutions typically assume that the primary motivations

for property rights institutions are, first, to internalize the benefits of new investments or resource-conserving behaviour and, second, to minimize the related transaction costs.

Another maintained hypothesis in this paper is that people, especially those living in less developed countries, often have other motivations for wanting changes in the property rights and collective action institutions. The various motivations are described in this sub-section.

Internalization of environmental externalities. Gottfried et al. (1996) discuss the advantages of small-scale cooperatives or common property regimes for managing heterogeneous landscapes. The need for some form of public regulation or cooperation among the users of such natural resource systems arises from at least two sources: (i) the spatial pattern of resource use within a natural resource system affects the mix of goods and services supplied by the ecosystem or landscape; and (ii) ecosystems are inter-related so that the way in which one ecosystem is used has spillover effects on contiguous ecosystems. Wear (1992) (cited in Gottfried et al. 1996) refers to the effect of spatial pattern on landscape output mix as 'economies of configuration.'

The use of common property regimes as mechanisms for capturing 'economies of configuration' is now being tested by the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) in Zimbabwe. CAMPFIRE is a "holistic rural development program that aims to improve people's livelihoods by developing their capacity to manage their indigenous resources (grazing, forestry, water, wildlife) better" (Child and Peterson 1991, 7). In the decade or so that CAMPFIRE has been in existence, it has focused almost exclusively on the management and commercial exploitation of wildlife. The configuration of land use is very important for maintaining the habitat of the wildlife that generate the greatest revenues. An optimal landscape configuration will protect patches of landscape that are large enough to support herds of elephant and buffalo (with appropriate forage supplies and water sources) and corridors between patches of habitat (personal communication with David Cummings, WWF, Harare, Zimbabwe).

Management of environmental risks. Analysts of property institutions for grazing and fishery resources often note the importance of property institutions for managing the

environmental risks related to the use of resources that are variable across space and time. In economic terms, there are two distinct components of the risk management function: risk pooling and sequential adaptation. *Riskpooling* refers to the fact that, everything else equal, the greater the number of resource patches available, and the lower the co-variation between patches, the lower the total variability in resource supply available to an individual resource user (Wilson and Thompson 1993). The potential benefits of risk pooling depend upon the level of environmental risk, people's attitudes toward risk, and the availability of alternatives sources of income. Livestock owners in Africa tend to be exposed to high levels of environmental risks, particularly where average annual rainfall is low and evapotranspiration is high (Ellis 1995). I propose that most African livestock owners are averse to forage supply risk since the survival of their animals depends upon access to minimum levels of forage. They often have no access to markets for insurance or forage.

While the importance of the risk-pooling function of property rights institutions depends upon people's attitudes toward mean-preserving risk, *sequential adaptation* or 'tracking' is desirable regardless of people's attitudes toward risk. The essence of sequential adaptation is that variable environmental conditions result in landscapes comprised of patches generating different qualities and quantities of resource benefits over time. As long as there is not perfect correlation between the patches, the best quality resources will be available in one patch one period, a second patch the next period, and so on. The ability to move animals between patches as those patches generate forage of different quantity and quality is crucial to the efficiency and sustainability of extensive livestock production systems in the drier areas of sub-Saharan Africa (Scoones 1995; Dyson-Hudson 1991; van den Brink et al. 1995).

The presence of environmental risk and people's attitudes toward that risk have implications for the structure and operation of property institutions. First, the greater the environmental variability and lower the correlation between resource patches, the greater the benefits from property rights institutions that allow individual resource users access to a large number of resource patches. Second, the higher the costs of moving between patches, the lower the value of sequential adaptation (van den Brink et al. 1995). Third, the smaller the size of the patches, the smaller should be the herds and more frequent the movements between patches (Dyson-Hudson 1991). Fourth, an effective market for insurance would

reduce the risk pooling incentive for common property but not the sequential adaptation incentive.

Ways to ensure access to a variety of resource patches within a natural resource system include: (i) common property institutions that define and enforce group rights to an area (or areas) that contain complementary patches; (ii) private property institutions that define and enforce individual rights to particular patches and efficient markets for the exchange of those rights; and (iii) private property institutions with non-market exchange relations between the owners of particular plots. Examples of each type of institutional structure, and variants thereof, can be identified in sub-Saharan Africa, although common property appears to be most prevalent.

Security and equity in resource access. Related to the risk management function of common property are the livelihood security and equity functions. There is evidence from India that common property resources are important sources of subsistence, particularly during stress times and particularly for the rural poor. Jodha (1992) analyzed the contribution of common property resources to the welfare of rich and poor households in 82 villages in dry areas of 7 of India's states. He found that the poor derived much larger proportions of their fuel supplies, animal *grazing,* employment and total income from common property resources than did the wealthy. For example, the poor and wealthy derived an average of 80% and 20% of their grazing needs, respectively, from common property resources. Common property resources contributed 14-23% of the income of the poor but only 1-3% to the income of the wealthy. The contribution to the income of the poor increased to between 42% and 57% during times of drought.

The evidence is less clear for Africa. Wilson (1990) found that the rural poor in Zimbabwe relied on foods gathered from common property resources more than the wealthy and that those foods were particularly important in drought years. Hopkins et al. (1994) found that the poorest households in rural Niger (the bottom tercile) generated a high proportion of their money income from common property resources (8-9 percent) than did the more wealthy households (6 percent), even though the more wealthy households generated more in absolute terms. Hopkins et al. (1994) also found that common property

resources were particularly important to women, generating 15-18 percent of their cash income. A series of studies undertaken by the Centre for Applied Social Studies in the Bulilima Mangwe District of Zimbabwe show that the reliance on resources governed by a common property institutions varies by product. Relatively wealthy cattle owners rely more on common lands for grazing than the poor, while relatively poor households rely more on common lands for collection of thatching grass and gathered foods (personal communication with Elias Madzudzo, Centre for Applied Social Studies, January 1997).

Again, common property is one of the possible alternatives for securing livelihoods and for enhancing equity in resource access. Possible alternatives to common property for those functions include private property with reciprocity or efficient markets for wage labour, credit and insurance. Imperfections in the markets for labour, credit or insurance consequently increase the incentive to use common property in this manner. In such circumstances, common property can thus become "the employer of last resort" or "communal bank upon which the community or its members individually may draw under certain predetermined circumstances" (Baland and Platteau 1996, 211-218).

Increasing returns to scale in production and transaction. Quiggin (1993) argues that a primary *raison être* for common property and collective action in natural resource management is the capture of increasing returns to scale in agricultural production. Increasing returns to scale exist when the average cost of producing a unit of output declines with the number of outputs produced. For example, when most land is open for extensive grazing and browsing of livestock, average herding costs per animal tend to be lower in herds with greatest numbers of animals (see examples in Itty 1992). As the percentage of cultivated area increases, grazing animals need to be monitored more closely to prevent them from damaging crops, and the economies of scale disappear.

There are at least three ways that property rights and collective action institutions can facilitate the exploitation of these economies of scale in rangeland systems. First, large livestock production units could operate on large areas of private rangeland. Second, the landscape could be zoned into areas for exclusive grazing, cropping and other uses and the collective herds of individual owners herded on lands held under private or common property.

Third, particular patches of the landscape could be designated as common lands with prohibitions on certain types of land use to preclude uses that interfere with the exploitation of economies of scale. Toye (1995) notes that the optimal mechanism for capturing the benefits of increasing returns to scale will depend upon whether there are increasing or decreasing returns to scale in transacting.

The Multiple Users of Natural Resources

The individuals who use or otherwise benefit from the products of a natural resource system are likely to differ in a number of important respects. Those differences will affect their individual strategies toward resource use and the benefits and costs they expect to obtain from property rights and collective action institutions. Three types of criteria are used here to distinguish resource users — property rights, endowments and preferences. The following sub-sections describe those criteria in more detail.

Property rights. Following Swallow and Bromley (1995, 107), a right is a guarantee given by a collective authority system to those who comprise the entity and a property right is a right to a potential future benefit. Property rights to the products of a natural resource system may be the same for all those who benefit from those products. Often, however, the rights held by an individual are conditional upon his or her ethnicity, location of settlement, length of time settled in a particular area (Saul 1993), gender (Agarwal 1994) or caste (Thomas-Slayter and Bhatt 1994). Property rights can differ by the types of rights held or by the products to which they apply. For example, Moorehead (1989) describes a case in the Niger Delta in Mali where different ethnic groups had primary rights to different resources available in the delta: animal forage, fish, swamplands for producing rice, and uplands for producing millet, and more general secondary rights for gathering products such as fonio, forest fruits, water-lily seeds, tubers, young wild birds, and wood for smoking fish or domestic use.

Swallow and Bromley (1995, 111) note that rights are more difficult to implement than other types of institutions. To implement the rights of groups or sub-groups, there must be a central authority system that is able to interpret the aims of the larger society, judge between

the rights and duties of competing groups, and enforce sanctions on individuals, groups and collectives of groups. To implement the rights of individuals, the central authority system must interpret the aims of the group, judge between competing rights, and enforce sanctions on individuals and collectives of individuals. Many natural resource systems, especially those in less developed countries, do not have central authority systems with such power and authority and thus do not have property rights institutions. In those situations, resource use may be coordinated by rules, conventions or contracts. Resource users are distinguished on the basis of their endowments and preferences.

Endowments. The endowments of people who benefit from natural resource systems can be defined in several ways:

(1) Endowments of productive physical assets, labour and management resources. Chopra et al. (1990) found that endowments of cultivable land, cattle and particular machines determined households' use of common forest and grazing lands in India. Harris-White (1995) points out that the importance of asset endowments depends upon the specificity of the assets and the structure of markets for assets and capital.

(2) Production efficiency — McCarthy (1996) characterizes cattle-owning households by the marginal cost of input they incur to raise livestock on a common rangeland. Differences in marginal costs may be directly dependent upon endowments of productive assets, labour and management resources.

(3) Location vis-a-vis the natural resource system — Location can affect the quality of the resource products available (e.g. top-enders versus tail-enders in irrigation systems), the intensity which with one's actions are monitored, and the transaction costs that must be incurred to access the resource.

(4) Operational power. Individuals with operational power influence the "operational rules" that shape the day-to-day decisions of individual resource users (Edwards and Steins 1996, 14). The operation of customary property regimes in many parts of Africa have depended upon the combinations of coercion, exchange and conditioned power held by different resource users and customary authorities (Swallow and Bromley 1995; Peters 1995).

(5) Bargaining power. Individuals with bargaining power are able to change the "collective-choice rules" that comprise the institutional framework in which resource users operate and operational rules are established (Edwards and Steins 1996, 14).

Preferences. Resource users may also be defined by their preferences. Perhaps most obvious are differences between people who are concerned about different products of a multiple-product natural resource system. An increasing problem in the developed countries is that different individuals and groups have preferences for different products of grazing lands, woodlands and wetlands. For example, in the SIWAA area of southern Mali, resource users include urban-based cattle owners, sellers of fuelwood and charcoal, transhumant pastoralists, and local agrosilvopastoralists (Joldersma et al. 1994).

Resource users can also be defined on the basis of their preferences toward the different functions of the resource management institutions. For example, preferences toward the risk management function will depend upon people's attitudes toward variation in the supply of products from the natural resource system, which in turn depends upon their capacity to generate income from alternative sources and access to markets. Preferences toward the environmental externality function will depend upon whether people are the generators or recipients of external benefits or costs.

Implications of heterogeneity. There is some agreement in the literature that heterogeneous preferences and endowments are detrimental to cooperative use of a natural resource system. Murty (1994); Quiggin (1993) and McCarthy (1997) developed separate models that illustrate that groups with homogeneous endowments of productive assets are more likely to sustain effective resource management. On the other hand, Baland and Platteau (1995) argue that heterogenous rights can have positive effects on cooperative resource use.

Interest Groups And Clubs

Heterogeneity in property rights, endowments or preferences creates fertile ground for the sprouting of interest groups and clubs. Here I consider an interest group to be a subset

of individuals with shared interests in a particular product of a resource management regime or a particular function of a resource management regime. Interest groups may be informal groupings of individuals, nascent clubs, or formalized clubs.

"A club is a voluntary group deriving mutual benefit from sharing one or more of the following: production costs, the members' characteristics, or a good characterized by excludable benefits" (Cornes and Sandier 1986, 159). Clubs are voluntary, there are both costs and benefits associated with additional members, and there is some mechanism for excluding non-members. A club may provide a single product or multiple products. *Ceteris paribus,* clubs are most likely to form within a group when: (i) a minimum number of individuals perceive benefits from joining a club or clubs apart from their membership in the overall group (e.g. economies of scale, provision of an impure public good); (ii) the costs of club membership are low relative to the benefits; (iii) the costs associated with the establishment and operation of the club are low; (iv) the costs associated with the exclusion of non-members from the benefits of club membership are relatively low; (v) the optimal size of the club (or clubs) is smaller than the size of the overall group; (vi) there are relatively homogeneous subsets of individuals within the overall group; and (vii) individuals derive different levels of enjoyment from the attributes of the other group members (e.g. culture, language, endowments, preferences) (drawn from Comes and Sandier, pp. 159-210).

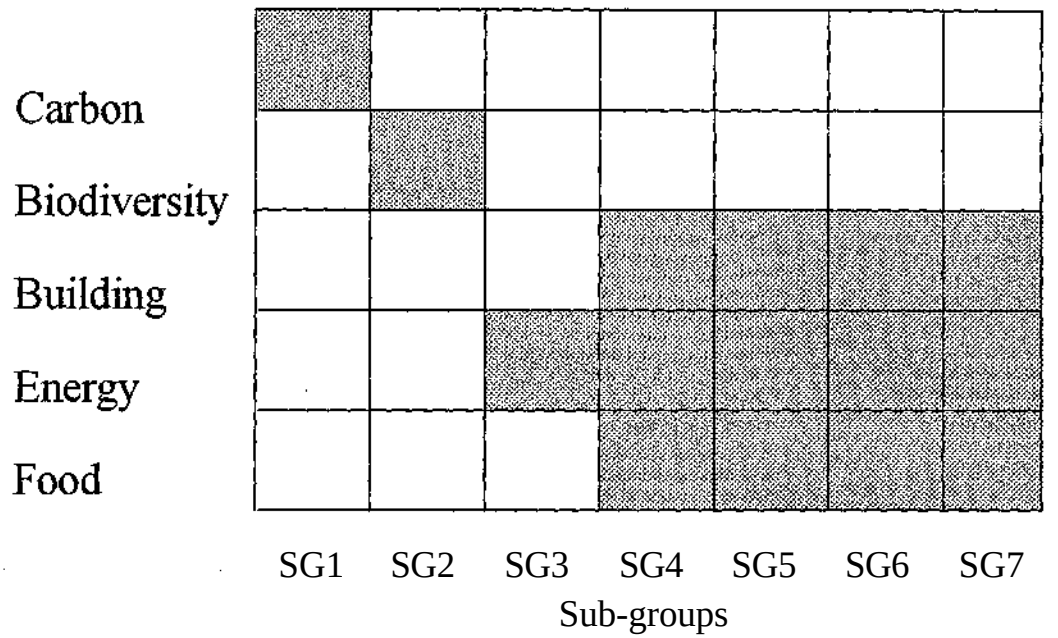
IMPLICATIONS FOR RESOURCE MANAGEMENT

This section illustrates the potential application of the analytical framework. First, the framework is specified for the case of a stylized African rangeland system. Second, implications are drawn for the optimal sizes and boundaries of natural resource systems and management are drawn.

A Stylized African Rangeland System

The rangeland system described in section 3.3 produces human food, energy, building materials, biodiversity preservation and carbon sequestration. The number of products, r, thus equals 5. The number of production functions affected by variables under direct human control, c, equals 2. The five products are arrayed along the vertical axis of Figure 1, with

Figure 1. Natural resource products and user sub-groups



interactions between products explicitly described by equations (1) to (5) above. Assume that there are 7 sub-groups of resource users (g1 ... g5), each of which contains 2 or more members. All n resource users belong to one sub-group and the sub-groups are mutually exclusive. The members of each sub-group are identical to one another in terms of endowments and preferences. Sub-groups are defined by differences in the endowments and preferences of their members. In terms of their preferences, the sub-groups are defined as follows: SG1 is an industrial producer of atmospheric carbon interested in the potential for co-implementation of carbon emission standards; SG2 is an environmental organization (club) whose members reside outside of the rangeland system per se; SG3 is a sub-group of fuelwood and charcoal sellers who enter the rangeland system to harvest wood products produced by the system; SG4, SG5, SG6 and SG7 are sub-groups concerned about the food, energy and building materials provided by the rangeland system.

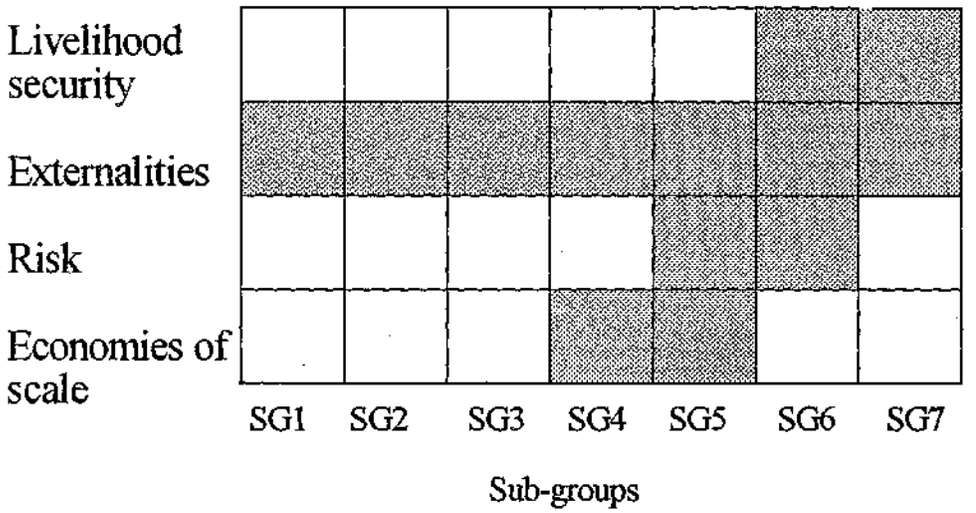
The sub-groups are arrayed along the horizontal axis of Figure 1 with the shaded cells illustrating the products of interest to each sub-group. Obviously the products of interest to SG1 and SG2 are completely different than those of interest to the other sub-groups. Equation (5) shows that the amount of carbon sequestered by the rangeland (of interest to

SG1) depends upon the biomass of trees and the intensity of burning. Tree biomass is an intermediate outcome from the production of food, energy and building materials. Equation (4) shows that the preservation of biodiversity (of interest to SG2) depends upon the intermediate outputs of trees, grass and crops. The interests of sub-groups SG1 and SG2 depend upon the labour and livestock that sub-groups SG3 to SG7 apply to the production of food, energy and building materials. The overlap of interests between SG1, SG2 and the other groups is an empirical matter that depends upon the parameters of the inter-related production functions.

Figure 2 illustrates the interactions between the seven sub-groups, again arrayed along the horizontal axis, and the functions of the resource management institutions, arrayed along the vertical axis. As described above, the four functions are: internalisation of environmental externalities, management of environmental risk, capture of economies of scale, and livelihood security. Sub-groups SG1, SG2 and SG3 are as defined above. Sub-groups SG4, SG5, SG6 and SG7 have identical preferences, but different endowments. SG4 is a sub-group of commercially-oriented producers who have diversified endowments of productive assets and good access to markets; SG5 is a group of pastoralists and agro-pastoralists whose primary assets are large herds of livestock; SG6 is a group of relatively poor pastoralists and agro-pastoralists whose primary assets are small herds of livestock; and SG7 is a sub-group of households that own no livestock nor cultivated land.

All of the sub-groups are concerned about different types of environmental externalities. Sub-groups SG1 and SG2 are concerned about environmental externalities that link tree biomass and biological preservation to the production of food, energy and building materials. There is no rivalry among the members of SG1 or SG2, but there may be rivalry between SG1 and SG2. Sub-group SG3 is only concerned about the environmental externalities among its members and between its members and the members of sub-groups SG4, SG5, SG6 and SG7. Sub-groups SG4, SG5, SG6 and SG7 are concerned with the externalities associated with the allocation of land between cultivation and grazing, the crowding of livestock on fixed areas of land, and the inter-temporal externalities that arise when current stocking rates and management practices (e.g. burning) affect future rangeland

Figure 2. Functions of property rights and collective action institutions and user sub-groups



conditions. In addition, SG4 is concerned with the possibility of undertaking collective action to establish and maintain new sources of water (a club or clubs). Sub-group SG5 has the same concerns as SG4, but is also concerned about the management of environmental risks. The members of SG6 are concerned about environmental risks and the same externalities as SG4 and SG5, but lack the necessary resources to invest in new water sources even if a suitable organization or club was established. Sub-groups SG6 and SG7 are concerned about access and availability of 'fall-back' resources, especially during periods of stress.

The efficiency, equity and environmental sustainability of resource use and management in this rangeland system will depend upon the characteristics of the inter-linked production functions, the interactions between resource users within each sub-group, and the interactions between sub-groups. For example, the production of biodiversity preservation and carbon sequestration do not depend upon the actions of the members of SG1 or SG2; sub-groups SG1 and SG2 may seek to provide incentives to sub-groups SG3, SG4, SG5, SG6 and SG7 to enhance the positive interactions between biodiversity preservation, carbon sequestration and food, energy and building materials. The members of SG4 and SG5 are concerned about the creation and function of a club for provision of a new water supply point; the members of SG6 are concerned about the negative impacts that the well may have on their access to fall-back resources during times of stress.

Optimal Sizes of a Resource Management Regime

It is argued that one of the most important features of a resource management regime is its size. Olson (1965) argues that the members of a group will only act in their common interest if the number of members is 'quite small' or if there is a source of coercion that enforces compliance. Baland and Platteau (1996) discuss several reasons why cooperation is more likely in small groups. First, because each member of a small group bears more of the costs associated with his or her own actions, he or she has more incentive to act in the common interest. Second, members of small groups tend to engage in repeated interactions in a variety of domains, including resource use. These interactions give rise to trust and support for moral norms about good behaviour. Third, people in small groups are likely to be well-informed about each others' actions and preferences. But if small groups have so many advantages, why have groups at all? Why choose common property if private property is an option?

The analytical framework suggests that a variety of benefits are associated with groups of different sizes and that there are different ways that group sizes may be accommodated within a natural resource system. Each component of the framework has implications for the 'optimal' sizes of natural resource systems and resource management regimes. First, the inter-related production functions may indicate convexities, economies of scale, or economies or scope in generation of the multiple products of the natural resource system. Indeed convexities (e.g. minimal necessary size of production unit) and economies of scale are likely to differ across the products generated by a natural resource system. For example, the preservation of large mammals typically requires patches of much larger size than the production of food crops. Economies of scope (cost advantages from co-production of two or more products) are also likely to vary for different combinations of products.

Second, the functions provided by the resource management institutions may have different implications for optimal size. For example, some of the environmental externalities associated with water and soil management in the Nile river system can be accommodated at the level of the micro-watershed; others can only be accommodated through the coordinated efforts of nation-states. The evidence from the arid areas of Africa suggests that the optimal

size for capturing economies of scale in livestock herding is smaller than the optimal size for optimal sequencing of resource use.

Third, the resource management regime may be defined on the basis of the characteristics of the resource users. This may be particularly evident when there are large differences between sub-groups of resource but relatively small differences within sub-groups.

An integrated assessment of multiple products, functions and users suggests at least four ways that the size implications of these three dimensions can be resolved:

(A) No resolution — The sizes of the natural resource system, the resource management regime and the sub-groups that comprise the resource management regime may be defined separately and their boundaries overlaid.

(B) Compromise — The size of the natural resource system may be a comprise between the size implications of the multiple products, multiple functions and multiple users.

(C) Separation — The natural resource system may be partitioned into niches or patches producing particular products; the individuals comprising the group of resource users may be divided into homogenous sub-groups with each sub-group assigned full property rights to a particular niche or patch; and the institutions comprising the resource management regime may be restricted to a single function (e.g. environmental externalities) and market alternatives put in place to accommodate the other functions.

(D) Accommodation — The overall size of the natural resource system could a compromise between the benefits associated with one of the functions, e.g. sequential adaptation, and the associated transaction costs. Within the overall system, clubs of different size and function form depending upon the motivations of different sub-groups of resource users and the production characteristics of the goods.

Which of these situations pertains will depend in part upon: (i) characteristics of the natural resource system — productivity, spatial heterogeneity, degree of temporal variability; (ii) characteristics of the local economy — existence and efficiency of markets for insurance, credit, labour and productive assets; and (iii) characteristics of the local society — heterogeneity of endowments, preferences and property rights, availability of alternative risk pooling mechanisms and costs of different types of transactions. I hypothesize that, ceteris paribus:

(H1) Results A and B will tend to be inefficient, in terms of achieving the goals of those who value the products of the natural resource system, and ineffective in terms of maintenance of the long-term productivity of the system.

(H2) The greater the coincidence in boundaries under Result A, the greater the likelihood of effective collective action and natural resource management.

(H3) Results A and B are more likely to pertain when the natural resource system is unproductive and heterogeneous across space and time; when the markets for insurance, credit, labour and productive assets are missing or highly inefficient; when the transaction costs associated with exchange and organization are high; and when state agencies attempt to replace customary management systems without a good understanding of the natural resource system and its use.

(H4) Result C is more likely to pertain when the natural resource system is highly productive and reliable across time; when the markets for insurance, credit, labour and productive assets are present and efficient; and when the transaction costs associated with exchange are low and the transaction costs associated with organization are high.

(H5) Result D is more likely to pertain when the natural resource system is highly productive but variable across space and time; when the markets for insurance, credit, labour and productive assets are missing or inefficient; and when the transaction costs associated with exchange are high and the transaction costs associated with organization are low.

DISCUSSION

Natural resource systems provide an array of goods and services of value to people. Good management of those systems requires improved understanding of the value of those services to different groups, inter-relationships between services, and how different goods or services are affected by policies, technologies and climatic changes. Good management also requires improved understanding of the multiple functions of different types of resource management regimes and sub-groups of resource users. This paper has presented an analytical framework for facilitating such understanding and has demonstrated the usefulness of the framework for analysing multiple-product rangelands in Africa.

The framework should also be useful for analysis of other systems and for identifying problems and themes cutting across different types of resource systems. The framework draws particular attention to: (i) the products of the system and linkages between those products; (ii) the motivations that people have for establishing and maintaining resource management institutions; (iii) the possibility of different types of property rights for different products, components or niches within the natural resource system; (iv) the effects of markets and other exchange mechanisms on those motivations; (v) the potential positive and negative effects of interest groups and clubs within an overall resource management regime; (vi) the vested interests of different sub-groups within a regime; and (vii) the implications of any changes in existing institutions for the welfare of different sub-groups.

This approach has potential implications for the size, structure and boundaries of natural resource systems and resource management institutions that may be inconsistent with the conclusions drawn from some previous studies. For example, Wilson and Thompson (1993) proposed that the existence of sub-groups, 'compensating coalitions' with pastoral *ejidatarios* in Mexico was evidence that the common property regimes had broken down, in part because they were too large. The multiple production, multiple function and multiple user approach suggest that the coalitions could be an appropriate response to the needs of different sub-groups and thus a sign of an adaptive and flexible regime. This is very similar to the argument used by Dyson-Hudson (1985) in his depiction of 'organizational flexibility' among East African pastoralists.

Ostrom (1994, 4-5) argues that clearly-defined boundaries and membership criteria are necessary pre-conditions for collective action for common property management.

> So long as the boundaries of the resource and the definition of the individuals who can use the resource remain uncertain, no one knows what they are managing or for whom. Without defining the boundaries of the CPR and closing it to 'outsiders,' local appropriators face the risk that any benefits they produce by their efforts will be reaped by outsiders who do not contribute to those efforts.

The approach adopted in this paper suggests that such statements need to be considered with caution. First, if the resource management institutions are designed to facilitate sequential adaptation and access to fall-back resources, it may not be practical to have boundaries that are fixed and well-defined for every possible contingency. In an uncertain world with

transaction costs, it may be preferable to have boundaries that are flexible or fuzzy (Behnke and Scoones 1993). Here I consider a flexible boundary to be one that is subject to change as a result of negotiation and agreement among resource users and a fuzzy boundary to be one that does not separate territories into discrete mutually-exclusive land units. Second, a natural resource system comprised of a number of heterogeneous resource patches and sub-groups of resource users is likely to characterized by a large number of internal boundaries. It would be possible, but misleading, to interpret multiple boundaries as being ill-defined.

The relationships depicted in the framework are too numerous and complex to be translated into a tight mathematical model. Simplifying assumptions will need to be made; this paper implies that particular care should be given to the appropriateness of different assumptions in different circumstances. An alternative approach would be to use the framework as the guide for the development of a simulation model.

A multiple-product, multiple-function and multiple user approach to the analysis of natural resource systems has several implications for policy. First, the governments of some African countries have recognized the failure of many of their past efforts to govern resource use through centralization of ownership and strict rules on use. One solution to those past failures is to devolve responsibility and authority for natural resource management to local-level administrative units and users' groups. Governments should consider devolving authority for different products and niches of the natural resource system to different levels of administration and different groups of resource users. Second, most African governments are implementing programmes of structural adjustment and market liberalization. Those changes are likely to result in greater heterogeneity among resource users and the formation of clubs to further the interests of particular sub-groups. Such clubs may improve or deter the efficiency of the overall system. They are likely to operate to the advantage of the individuals and sub-groups with the most operational and bargaining power and the disadvantage of the individuals and sub-groups with the least power. Governments should consider how they can facilitate the formation of clubs that are more inclusive, especially for key resources like water. Governments should also consider ways to safeguard the interests of disadvantaged groups.

REFERENCES

Agarwal, B. 1994. Gender and command over property: A critical gap in economic analysis and policy in South Asia. *World Development* 22 (10): 1455-1478.

Baland, J. M. and J. P. Platteau. 1995. *Does heterogeneity hinder collective action?* Cahiers De La Faculte Des Sciences Economiques Et Sociales No. 146. Namur, Belgium: Centre De Recherche En Economie Du Developpment, Facultes Universitaires Notre-Dame De La Paix.

_____. 1996. *Halting degradation of natural resources: Is there a role for rural communities.* Oxford: Clarendon Press.

Behnke, R. H. and I. Scoones. 1993. Rethinking range ecology: Implications for rangeland management in Africa, in *Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African savannas,* eds. R. H. Behnke, I. Scoones and C. Kerven, 1-30. London: ODI.

Bingham, G, R. Bishop, M. Brody, D. Bromley, E. Clark, W. Cooper, R. Costanza, T. Hale, G. Hayden, S. Kellert, R. Norgaard, B. Norton, J. Payne, C. Russell and G. Suter. 1995. Issues in ecosystem valuation: Improving information for decision making. *Ecological Economics* 14: 73-90.

van den Brink, R., D. W. Bromley and J.-P. Chavas. 1995. The economics of Cain and Abel: Agro-pastoral property rights in the Sahel. *Journal of Development Studies* 31(3): 373-399.

Child, B. and J. H. Peterson, Jr. 1991. *Campfire in rural development: The Bietbridge experience.* CASS Paper 1/91, Harare, Zimbabwe: Centre for Applied Social Studies, University of Zimbabwe.

Chopra, K. G., K. Kadedodi and M. N. Murty. 1990. *Participatory development: People and common property resources.* Studies in Economic Development and Planning, No. 52. Delhi, India: Institute of Economic Growth and Sage Publications.

Cornes, R. and T. Sandier. 1986. *The theory of externalities, public goods, and club goods.* Cambridge: Cambridge University Press.

Dyson-Hudson, N. 1991. Pastoral production systems and livestock development projects: An East African perspective. In *Putting people first: Sociological variables in rural development,* ed. M.M. Cernea, 219-256. Washington, D.C.: World Bank.

Edwards, V. and N. Steins. 1996. Developing an analytical framework for multiple-use commons. Paper presented at the Sixth Annual Conference of the International

Association for the Study of Common Property, June 5-8, University of California, Berkeley.

Ellis, J. 1995. Climate variability and complex ecosystem dynamics: Implications for pastoral development, In *Living with uncertainty: New directions in pastoral development in Africa,* ed. I. Scoones, 37-46. London: Intermediate Technology Publications.

Galbraith, J. K. 1983. *The anatomy of power.* Boston: Houghton Mifflin.

Gottfried, R. 1992. The value of a watershed as a series of linked multi product assets. *Ecological Economics* 5:145-161.

Gottfried, R., D. Wear and R. Lee. 1996. Institutional solutions to market failure on the landscape level. *Ecological Economics* 18: 133-140.

Harriss-White, B. 1995. Maps and landscapes of grain markets in South Asia. In *The new institutional economics and third world development,* eds. J. Hariss, J. Hunter and C. M. Lewis, 87-108. London and New York: Routledge.

Hopkins, J., S. Scherr and P. Gruhn. 1994. Food security and the commons: Evidence from Niger. Washington, D.C.: International Food Policy Research Institute. Mimeo.

Le Houérou, H, ed. 1980. *Browse in Africa: The current state of knowledge.* Addis Ababa, Ethiopia: International Livestock Centre for Africa.

_____. 1987. Indigenous shrubs and trees in the silvopastoral systems of Africa, In *Agroforestry: A Decade of Development,* eds. H. Steppler and P. K. Nair. Nairobi: International Council for Research on Agroforestry.

Itty, P. 1992. *Economics of village cattle production in tsetse affected areas of Africa: A study of trypanosomiasis control using trypanotolerant cattle and chemotherapy in Ethiopia, Kenya, Cote d'lvoire, The Gambia, Zaire and Togo.* Konstanz, Germany: Hartung-Gore Verlag.

Jodha, N. S. 1992. *Common property resources: A missing dimension of development strategies.* World Bank Discussion Paper No. 169. Washington, D.C.: World Bank.

Joldersma, R, L. Coulibaly, D. Souleymane, T. Hilhorst and J. Vlaar. 1994. *SIWAA, La Brousse Seche: Experience de Gestion Villageoise d'un Terrior Intervillageois au Mali.* ESPGRN Document No. 94/35. Mali: Institut d'Economie Rurale, Sikasso.

McCarthy, N. 1996. Common property and cooperation in rural Mexico. Ph.D. diss., University of California at Berkeley, Berkeley, CA.

Moorehead, R. 1989. Changes taking place in common property resource management in the inland Niger delta of Mali, In *Common property resources: Ecology and community-based sustainable development,* ed. F. Berkes. London: Belhaven Press.

Murty, M. N. 1994. Management of common property resources: Limits to voluntary collective action. *Environmental and Resource Economics* 4: 581-594.

Olson, M. 1965. The *logic of collective action.* Cambridge, MA: Harvard University Press.

Ostrom, E. 1994. *Neither market nor state: Governance of common-pool resources in the twenty-first century.* Washington, D.C.: International Food Policy Research Institute.

Powell, M. and T. O. Williams. 1995. An overview of mixed farming systems in Sub-Saharan Africa. In *Livestock and sustainable nutrient cycling in mixed farming systems of Sub-Saharan Africa,* eds. J. M. Powell, S. Fernandez-Rivera, T. O. Williams and C. Renard, 21-36. Volume II: Technical Papers. Addis Ababa: International Livestock Centre for Africa.

Quiggin, J. 1993. Common property, equality, and development. *World Development* 21 (7): 1123-1138.

Saul, M. 1993. Land custom in Bare: Agnatic corporation and rural capitalism in western Burkina, In *Land in African Agrarian Systems,* eds. T. J. Bassett and D. E. Crummey, 75-100. Madison, WI: University of Wisconsin Press.

Scoones, I. 1995. New directions in pastoral development in Africa. In *Living with uncertainty: New directions in pastoral development in Africa,* ed. I. Scoones, 1-36. London: Intermediate Technology Publications.

Scoones, I., M. Melnyk and J. N. Pretty. 1992. The hidden harvest: Wild foods and agricultural systems. A literature review and annotated bibliography. London: International Institute for Environment and Development.

Scoones, I., C. Toulmin and C. Lane. 1993. Land tenure for pastoral communities. In *The world's savannas: Economic driving forces, ecological constraints and policy options for sustainable land use,* eds. M. D. Young and O. T. Solbrig, 93-120. Paris: UNESCO and Parthenon Publishing Group.

Swallow, B. M. and D. W. Bromley. 1995. Institutions, governance and incentives in common property regimes for African rangelands. *Environmental and Resource Economics* 5: 1-20.

Swift, J. 1995. Dynamic ecological systems and the administration of pastoral development. In *Living with uncertainty,* ed. I. Scoones. London: IT Publications.

Thomas-Slayter, B. and N. Bhatt. 1994. Land, livestock and livelihoods: Changing dynamics of gender, caste and ethnicity in a Nepalese Village. *Human Ecology* 22 (4): 467-494.

Toye, J. 1995. The new institutional economics and its implications for development theory. In *The new institutional economics and third world development,* eds. J. Harriss, J. Hunter and C. M. Lewis, 49-68. Routledge: London and New York.

Wear, D. N. 1992. Forest management, institutions and ecological sustainability. Paper presented at the Appalachian Society of American Foresters Meeting, Asheville, North Carolina.

Wilson, K. B. 1990. Ecological dynamics and human welfare: A case study of population, health and nutrition in southern Zimbabwe. Ph.D. diss., Department of Anthropology, University College, London.

Wilson, P. N. and G. D. Thompson. 1993. Common property and uncertainty: Compensating coalitions by Mexico's pastoral *ejidatorios. Economic Development and Cultural Change* 41(2): 299-318.

World Bank. 1996. *African development indicators 1996.* Washington, D.C.