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SPECIAL SECTION: LAND USE OPTIONS IN DRY TROPICAL WOODLAND ECOSYSTEMS IN ZIMBABWE:

Introduction, overview and synthesis

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Abstract

The articles included in this special section focus on the ecological and economic interactions of woodland use in Western Zimbabwe. One of the aims was to investigate the use of modelling to achieve integration among disciplines. The integrated model draws on the models in the different papers comprising the special section. The model has five ecological sectors, five sectors covering woodland use by local people and the state forestry organisation, two sectors to cover agriculture, one sector for population growth and land use, a sector to cover carbon sequestration, and a sector to calculate net present values of the various uses. The state has usually attempted to keep people and their livestock out of the state forest. We show that the private benefits of cropland may be greater than those related to state or local use of the woodland, but further work is required to incorporate the public costs of subsidies to cropland, and the public benefits of woodland services. Livestock production in the woodlands is compatible with woodland management, both from economic and ecological perspectives. Expulsion of forest [1] dwellers from the state forest makes little ecological impact on the woodland, and does not improve the economic value of the woodland to the state. However, if the Forestry Commission relaxes the current control on in-migration, it is likely that the woodland will be rapidly depleted in the face of massive in-migration. Modelling is seen as a framework for integration of ecological and economic issues, but further work is required to incorporate institutional perspectives from the sociological and anthropological disciplines.

1. Introduction

Woodlands are central to the lives of over 50 million people in Africa, providing a host of goods and services, ranging from everyday items needed to sustain life, to cultural and spiritual values and to ecological services (Campbell et al., 1995; Clarke et al., 1996). Given the widespread nutrient poverty and fluctuating rainfall in many

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[1] The vegetation formation in these areas is, strictly speaking, woodland, but the areas gazetted under the Forest Act are officially termed state forests. We use the term 'forest dwellers' for illegal inhabitants within the state forests.

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of the woodland ecosystems, agricultural productivity is often limited, and people rely on woodlands as part of their livelihood portfolio. If the woodlands disappear or are degraded, local communities will bear much of the cost. As many of the woodlands form the basis for ecotourism, deforestation will also negatively influence tourism, which has become the most rapidly growing sector of the economy in Zimbabwe and neighbouring countries. In addition, woodland loss could reduce the value of public goods and services derived from woodlands, such as carbon sequestration.

Land use options in these tropical woodlands are many, including livestock ranching on a commercial scale, smallholder agriculture based on mixed crop and livestock production, safari hunting, non-consumptive tourism and timber production. The key question is what is the optimal mix of land use systems and practices? The papers in this special section all contribute to components of this question. In answering the question, we need to be aware of the many stakeholders involved, including smallholder farmers, large-scale commercial ranchers, safari operators, timber companies, the central treasury, international tourists and even the global community. The conflicts among stakeholders are many: we have investigated some of these using analyses that focus on ecological and economic processes (Costanza, 1991; Costanza et al., 1997).

For the last decade, a group of scientists from varying disciplines have been investigating the relationships between livelihood strategies and woodland systems in Zimbabwe. The diverse studies have provided detailed insights into the social, economic, political and ecological processes involved in these temporally and spatially heterogeneous systems (Campbell et al., 1991; Grundy et al., 1993; Matose, 1994; Mukamuri, 1995; Clarke et al., 1996; Frost, 1996; Mandondo, 1997). One challenge is to bring the diverse results together into a powerful analytical framework. One of the aims of the activities reported in this special section was to investigate the use of modeling to achieve integration among disciplines (Costanza et al., 1993).

We have largely focussed on a case study area, Mzola State Forest and the adjacent communal areas. While we have used the Mzola area because of previous research activities (Gwaai Working Group, 1997), the intention was to produce generalised models for southern Africa, applicable to woodland ecosystems on nutrient-poor soils in semi-arid regions (c. 650 mm mean annual rainfall). The models could be generalised to any boundary situation between communal areas with smallholder production systems and relatively intact woodland systems where large-scale commercial activities are a possibility. To understand such a system we need to understand the dynamics within the communal areas, the dynamics within the commercial areas and the interface dynamics.

Mzola State Forest is one of the demarcated woodlands administered and managed by the state authority, the Forestry Commission. As in some other state forests, there is serious conflict between the residents of the neighbouring communal areas and the Forestry Commission, with local people wanting to use a wide variety of products from the woodland (Matose 1994; Vermeulen 1996; Gwaai Working Group 1997). In addition, some 4000 persons have settled illegally in the state forest, and the Forestry Commission plans to have them removed through a court order. A full description of Mzola State Forest, and the activities of people in this kind of environment, can be found in Luckert et al. (2000).

In the study area, there are a number of key issues of interest. Taking an extreme view, one can ask whether the state forest should be degazetted, converted into a communal area. At the other extreme, one asks whether the status quo regarding land classification should be maintained, but with greater enforcement of the legislation, thereby keeping the forest firmly in the control of the state, a view expressed by many participants at a previous workshop (Gwaai Working Group, 1997). Alternatively, are there some resources that can be co-managed by the state and the local people, and what level of extraction can be permitted? Inherent in such questions are the more fundamental questions, namely: (i) What are the goods and services provided by these woodlands, and what are the tradeoffs amongst them? (ii) What are the key ecological and economic interactions? (iii) What are the dynamics of these interactions? (iv) How sustainable are the various land use options?

To address the above issues, a workshop was held from the 18th to 29th May, 1997, at Gwaai River, in the heart of tens of thousands of square kilometres of dry tropical woodland in Western Zimbabwe. Robert Costanza and Marjan van den Belt facilitated the workshop, introducing participants to the STELLA modeling software package and laying the foundations for the use of dynamic modelling in conflict resolution and consensus building (van den Belt et al., 1998). There are various graphical programming languages available that are specifically designed to facilitate modelling of non-linear, dynamic systems. Among the most versatile of these languages is STELLA II (High Performance Systems, 1993). The workshop was co-hosted by the Universities of Alberta, Maryland and Zimbabwe, and was attended by more than 30 delegates from a wide array of backgrounds, including seven universities, three research organisations, and one government department.

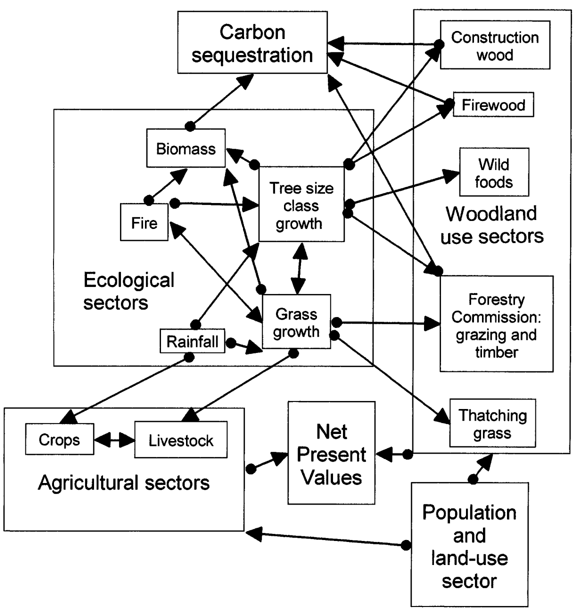

Fig. 1. The sectors of the integrated ecological–economic model.

2. Overview of the integrated model and study area

In the development of each of the papers in this special section a model was prepared. Components of these models were then used to prepare an integrated model of woodland and land use in Western Zimbabwe. The model has two ecological units (woodlands and dambos, the latter being lowland seasonally inundated grasslands) in each of the state forest and communal land. Thus, all the variables described below, and the ecological–economic processes they represent, can be simulated for one of four land units. The model contains five ecological sectors, five sectors covering woodland use by local people and the Forestry Commission, two sectors to cover agriculture, one sector for population growth and land use, a sector to cover carbon sequestration and a sector to calculate net present values (NPVs) of the various uses (Fig. 1).

The ecological sectors cover the major drivers of savanna systems: rainfall and fire (Frost, 1996), the growth of the major components of the systems (trees and grasses), and a biomass sector where all living and dead material generated by the growth sectors is calculated. Decomposition of dead material is included. These sectors are described in detail by Gambiza et al. (2000). Tree growth was simulated by using four size classes and defining the transitions amongst the size classes. The different size classes were, from biggest to smallest: gullivers (multi-stemmed shrubs), poles, small trees and harvestable trees.

The sectors covering woodland use, described in detail in Grundy et al. (2000), cover the use of the woodlands for firewood, construction poles, thatching grass and wild foods by local people, and the use of the state forest by the Forestry Commission. Each of the sectors covering local use has a component for calculating the availability of the product (using inputs from the ecological sectors), the level of use (dependent on availability) and prices of the products (dependent on availability). Use levels can be reduced in the state forest through simulating higher levels of enforcement of the regulations restricting use. Use levels in all land units feed back as consumption of plants and biomass in the ecological sectors. One of the sectors within the use section of the model covers the costs and benefits of the Zimbabwe Forestry Commission, these being determined by the grazing leases to commercial farmers and timber concessions to timber companies. The costs of their inputs are also included (management, enforcement, administration).

The agricultural sectors cover crop production and livestock production. The basic crop production model is described by Chivaura-Mususa et al. (2000). The production levels vary according to fertiliser inputs and rainfall. Grain in excess of subsistence needs is sold and contributes to disposable income, which is used for fertiliser inputs and purchase of livestock. Crop residues provide supplementary feed for livestock, and thus the crop and livestock models are linked.

The livestock model is not described elsewhere so needs a bit more attention here. A seasonal carrying capacity is calculated from the amount of grass and crop residues generated each season (dependent on rainfall). Functions relating stocking rate to carrying capacity set the recruitment and mortality rates of the livestock, and hence numbers of livestock. Feedback to the ecological section sees the livestock consuming the grass. Purchases of livestock can also augment herd numbers, these being dependent on the amount of disposable income. Sales of livestock occur at the rates usually found in communal areas. The livestock values are calculated from the full set of products provided by livestock (as determined by Campbell et al., 2000). Management scenarios that can be simulated within the livestock section include reducing the area available for livestock owned by the local people through increasing the amount of state forest leased for grazing, and reducing the access of the livestock of local people to the state forest. Starting populations of cattle are set at a mean of six livestock units per household.

The area and population sector covers the growth of the population, its distribution between state forest and communal land, and the conversion of woodland to meet the crop production needs of the growing population. Thus this sector also simulates the amount of land under cropland and woodland in each of the land units. Forest dwellers can be expelled within the model to simulate the impact of enforcement of the land ownership rules. The area of the state forest is 68 000 ha, and an equivalent area of communal area has been used. Dambos are set as occupying 15% of the landscape in the state forest and communal area. The population growth in the model is set at 3% p.a., with starting populations of 4200 persons in the state forest and 13 600 persons in the communal land. Household sizes are set at 8 and 6.2 persons per household in the state forest and communal area, respectively. Thus the starting population density in the state forests and communal land is 6.2 and 20 persons km^{-2}, respectively. Field size per household is a function of population density, with the starting sizes being 9.8 and 4.5 ha per household in the state forests and the communal area, respectively, reducing to 2 ha per household at population densities of 50 persons km^{-2}, as found elsewhere in Zimbabwe (e.g. Scoones et al., 1996).

The carbon sector is described in detail in Kundhlande et al. (2000). It involves calculating all the biomass being stored, as living biomass or as construction wood, converting this to carbon and then calculating the value.

The NPV sector is simply the calculation of NPVs from the annual values calculated in the various sectors. At the time of the study the market exchange rate between the Zimbabwean dollar (Z$) and the US dollar was US$ 1 = Z$ 10.

For the figures presented in this paper, a 60-year simulation period was used, but the different papers have used simulation periods suitable to their objectives. Certain components of the model were checked for reality by comparing the simulated outputs against what is known about such systems. For example, the livestock holdings per household at higher human population densities, as found after 50 years of simulation, were compared to those currently occurring in densely populated communal areas (Scoones et al., 1996).

3. Overview of the papers in the special section

The first paper presents the ecological model that forms the basis for most of the other papers in the volume, and discusses the impacts of various harvesting regimes on the woodlands (Gambiza et al., 2000). The paper demonstrates the importance of the interactions between timber extraction (or any forms of opening up the canopy, e.g. through heavy elephant pressure) and fire. Alternative stable states are proposed: either closed woodland or fire-maintained wooded grassland, and suggestions for using livestock to reduce fire loads, and thereby improve woody plant biomass, are presented.

The second paper has evaluated the benefits that local people obtain from the woodlands, including poles for construction, fuelwood, thatching grass, grazing and wild fruits (Grundy et al., 2000). These authors use the integrated ecological-economic model to simulate benefits obtained by forest dwellers (the people in the state forest) and communal dwellers (the people in the communal area adjacent to the state forest). The authors examine various management scenarios for the state forest, from expulsion of all forest dwellers at the one extreme to various co-management scenarios at the other extreme. Their model suggests that the solution yielding the greatest net benefit to the user groups, in aggregate, is likely to be joint management of the resource base without expulsion of the forest dwellers. However, the transaction costs of establishing such an option may be too great. Serious long-term consequences (beyond 50 years) for expanding rural populations confined by the limits of their defined resource base are predicted.

The third paper explores household decision making in terms of how households constitute their portfolio of activities (crop production, livestock production, woodland gathering, urban incomes) (Luckert et al., 2000). Thus it differs from the paper by Grundy et al. (2000), which models extraction levels by people in a relatively static fashion, with extraction levels simply being a function of availability of the resource. In Luckert et al. (2000), the household production model is influenced by fluctuating rainfall, increasing populations, and relationships to the natural resource base. Simulations show that, although welfare decreases over the 50-year simulation period, the resource base appears to be able to sustain the increased pressure. The authors note that further research is needed on: resources expended by households by sector, perceptions of risk, and differentiation within and among households according to gender and wealth. The results show the importance of considering how households allocate resources between multiple sectors, as these options may buffer their welfare from rainfall shocks and increasing population pressures.

Many people leave trees in their arable fields, and this phenomenon is the subject of the fourth paper (Chivaura-Mususa et al., 2000). The model produced in this paper was used to investigate the range of goods and services provided by trees in arable areas, and whether the value of these goods and services outweigh the loss of maize production caused by trees. The authors show how the optimum number of trees shifts in relation to soil type (decreases on better soils), mean annual rainfall (decreases with higher rainfall) and quantity of crop inputs (decreases with higher inputs). The conflict that has arisen between the extension service, which advocates the removal of all trees, and many smallholder farmers, who want to retain trees for the goods and services they provide, is due to the undifferentiated nature of extension messages. The messages need to take into account the resource endowments of the farmers, with removal of trees being valid in areas of high rainfall and with farmers who have access to plenty of fertiliser.

The fifth paper looks at some of the services provided by woodlands, in particular carbon sequestration, and the paper provides economic values for water (Kundhlande et al., 2000). The authors demonstrate that the value of carbon sequestration outweighs many of the local use values. Although the values of carbon sequestration in both the woodlands of the communal lands and the state forest are substantial, they are of the same order of magnitude as converting these lands to individually held agricultural land. This, and the lack of readily available markets in which individuals can be compensated for maintaining some land under woodland as a store for carbon, create strong incentives for households to convert woodlands to agriculture. Expelling forest dwellers from the state forest makes little difference to the carbon sequestration values of the region.

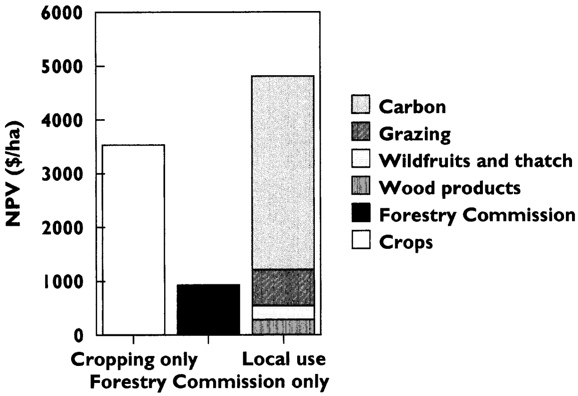

Fig. 2. NPVs for various land uses, calculated on a per hectare basis for a 60-year period at 6% discount rates. The cropping value is for maize production, the Forestry Commission value is for grazing leases and timber concessions, and the local use value is for subsistence use of the woodland (grazing, thatch, wild fruits, wood) and carbon sequestration values.

The final paper investigates the economics of grazing in the smallholder sector, and criticises the emerging paradigm that elevates the opportunistic strategy of management (the status quo) above those strategies based on more conservative stocking rates (Campbell et al., 2000). Using a spreadsheet-based model, various scenarios are investigated, and it is shown that a conservative scenario out-performs the opportunistic scenario and the newly proposed tracking and buffering scenario (the latter scenario involves selling/purchasing or moving cattle so that population numbers track feed supplies). In these highly variable systems from the semi-arid savannas, opportunism can result in massive livestock mortalities, which represent significant economic losses. This model is not linked to the integrated STELLA model, but the livestock values that have been calculated in this paper were used for the valuation of cattle in the integrated model.

4. Land use in dry tropical woodlands: the options

4.1. From protectionism to joint management or abandonment?

The historical role of forest departments has centred on protection of the forests and timber production (Matose and Wily, 1996). Protection has often been translated into exclusionist policies, where local people and their livestock are precluded from the forest. Recently, throughout the world there has been an upsurge in interest in joint management of forests between the state and local people (Hobley, 1996; Matose and Wily, 1996; Wily, 1997; Arnold, 1998; Grundy et al., 2000). In the Zimbabwean context, there are tremendous political pressures to give land to people; the land issue having been at the core of the fight for independence (Alexander, 1994; Rukuni, 1994). The controversy around land centres on the largely white-owned commercial farms, but there has also been discussion about state land, including forest land, being designated for resettlement (Nhira et al., 1998). In this section, we examine the ecological and economic impacts of redefining the use regimes within state forests.

4.2. Converting woodland to cropland

Crop production gives high returns to land (Fig. 2; Adamowicz et al., 1997). The cropping values are much higher than the commercial values derived by Forestry Commission from grazing leases and timber concessions, and much higher than the use values derived by local people. It should be noted that the economic value derived by Forestry Commission in this comparison is quite high, and is at the expense of the woodland. The 40% removal of harvestable trees every 30 years results in the woodland rapidly being converted to a gulliver–grass system (by 140 years, if hot fires are not prevented) (gullivers are multistemmed shrubs). Two items may be missing in the above simplistic comparison of woodland values and cropland values. Firstly, it is unclear as to what proportion of the cropping value is due to subsidies by government in the form of pricing structures for inputs and outputs, and drought relief. It is clear that large-scale commercial farmers would never use Mzola State Forest for crop production, given the paucity of the soils and the extremely unreliable rainfall. The state provides drought relief very often in these regions (Frost and Mandondo, 1999). Secondly, the service functions of the woodland are not incorporated. Some of these functions include cultural values, modifying the hydrological cycle and carbon sequestration. One of the stated reasons for protecting the state forests relates to protecting watersheds (Nhira et al., 1998). However, there is almost no quantitative data on any of these services, and therefore it is difficult to evaluate them. The carbon sequestration is included in Fig. 2. It is apparent that if Zimbabwe could capture a market for carbon, then the value of the woodland for local use plus carbon is higher than that of cropland (Kundhlande et al., 2000). Key areas of research should be the comparative value of land for cropland and woodland, and analyses of this should incorporate the public costs of subsidies to cropping in semi-arid climates, and the public benefits of woodland services. Future use values, especially those related to the rapidly expanding tourism industry, also need to be considered, as numerous large-scale private owners in Western Zimbabwe have converted their ranching enterprises into tourism-based enterprises. Wildlife values were not considered in this model as Mzola State Forest has no commercial activities based on wildlife at present.

4.3. The centrality of livestock in these semi-arid systems

The results presented in this volume show conclusively that people, or at the very least their livestock, can improve the economic and ecological performance of state forests in the miombo landscape (Gambiza et al., 2000). The ecological impacts are summarised in Fig. 3. In these scenarios, the Forestry Commission cuts the harvestable trees every 30 years, starting in year 5, at which time 40% of the harvestable trees are removed (and small trees are reverted to gullivers because of high impact logging). In the status quo, where some cattle are present, there are seven hot fires in the 60-year simulation of the woodlands of the state forest, and the woodland ends up with about 12 harvestable trees ha^{-1} and 600 gullivers ha^{-1} (Fig. 3a). If there is no limit placed on the number of cattle allowed in the state forest, only two hot fires occur, the gulliver population at the end of the simulation is almost double that of the status quo, while the pole population is more than double (Fig. 3b). For the scenario where livestock are excluded, the hot fire frequency is very high, and the tree populations are very much reduced. Under these circumstances, the lack of livestock results in high fuel loads, hot fires and reduced recruitment and growth of trees (Fig. 3c). By comparison to the state forest, the woodlands of the communal area experience very few fires (only one fire in the 60-year period, after a very good rainfall year). The livestock are also playing their part within this system.

The positive economic impacts of livestock in the system are only a result of the value of the livestock themselves, with their removal resulting in reduced total NPV within the system (Fig. 4). This illustrates two points. Firstly, livestock within the smallholder sector are a very valuable resource, given their multiple functions (Scoones, 1992; Abel, 1997; Campbell et al., 2000). Secondly, the feedback of the changes in ecology caused by the livestock make almost no economic impacts on other uses of the woodland. For the use of the woodland by the Forestry Commission, this result is because the major value of the woodland is in the timber harvest in year 5, and future harvests are discounted. In addition, the harvestable tree component of the woodland is very small, and small changes in this component cannot be expected to make big economic differences (especially when such changes may only be detected far into the future). For the other resources, households are only using small portions of the available resource, so any change in the total resource makes little difference to the measured economic output.

4.4. Expulsion of forest dwellers

Expulsion of forest dwellers from the state forest makes little ecological impact on the woodland. If this is combined with excluding the cattle of the communal dwellers, then the ecological system is, if anything, degraded, given the resulting increasing frequency of fires. Economically, the Forestry Commission does not increase the value it derives from the woodland by expelling the forest dwellers (Fig. 5). If anything, the value declines because of the increased enforcement costs that may be associated with expulsion and maintaining the woodland free of people (the enforcement cost was held constant in the comparisons in Fig. 5). Expulsion reduces the total

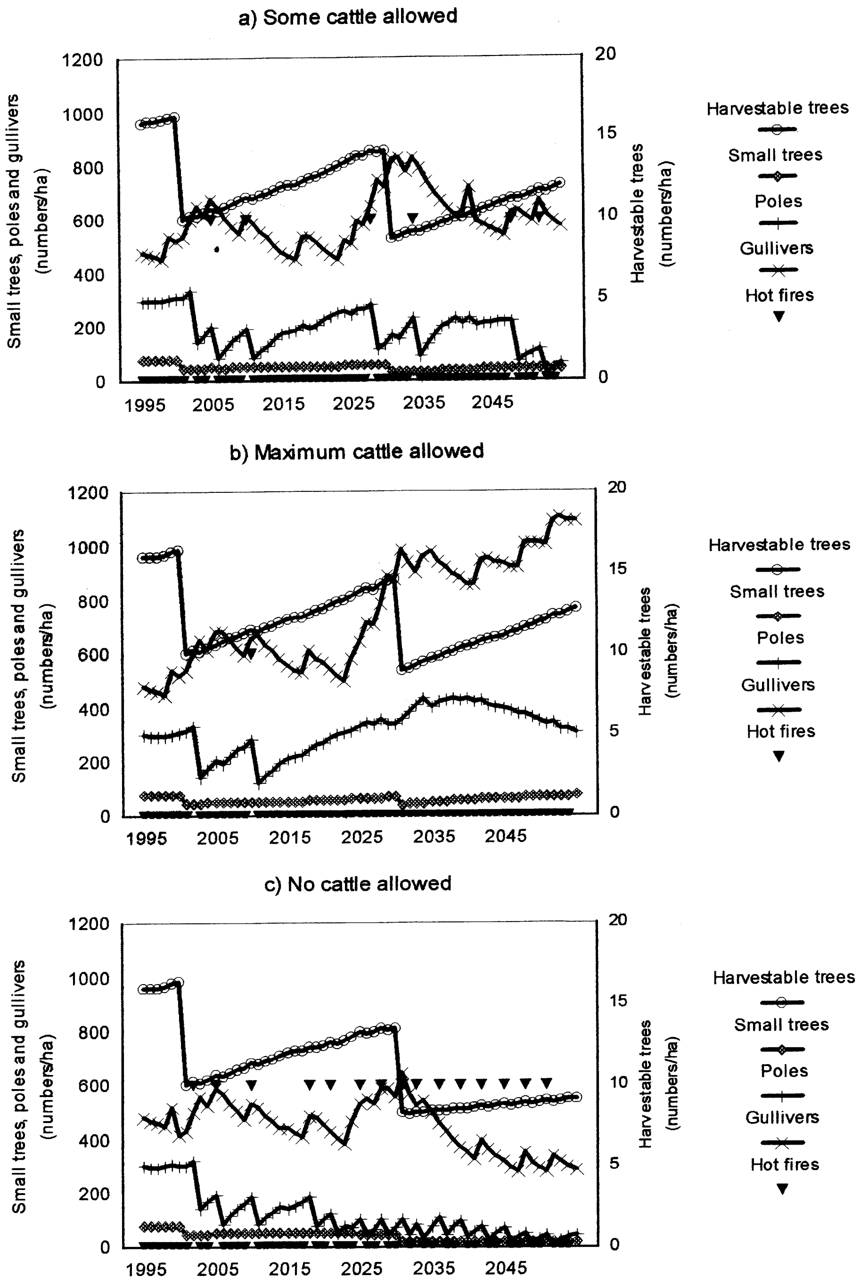

Fig. 3. Sixty-year simulations of the woodland in the state forest, showing the numbers of different kinds of woody plants and fire, in relation to the degree to which livestock are permitted in the system. Forestry Commission cuts 40% of the harvestable trees every 30 years, starting in year 5. Gullivers are multi-stemmed shrubs.

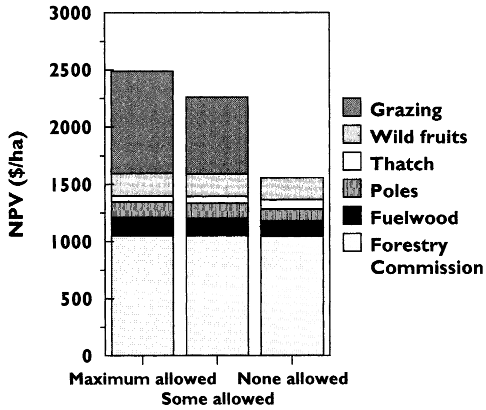

Fig. 4. NPVs for the state forest under various levels of livestock grazing, calculated on a per hectare basis for a 60-year period at 6% discount rates. The Forestry Commission value is for grazing leases and timber concessions, and the local use value is for subsistence use of the woodland (grazing, thatch, wild fruits, wood).

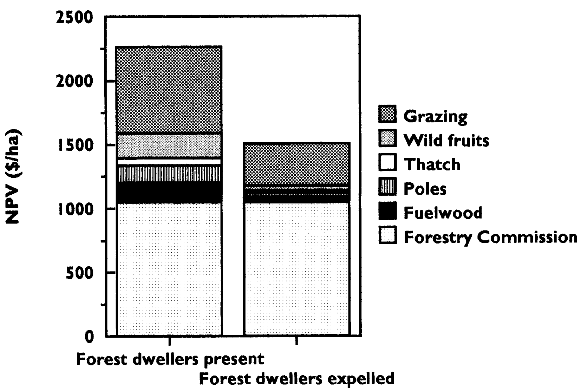

Fig. 5. NPVs for the state forest when forest dwellers are present and excluded, calculated on a per hectare basis for a 60-year period at 6% discount rates. The Forestry Commission value is for grazing leases and timber concessions, and the local use value is for subsistence use of the woodland by forest and/or communal dwellers (grazing, thatch, wild fruits, wood).

use value of the woodland, as the products provided by the woodland are no longer used by the forest dwellers. The local use values remaining in the woodland after expulsion are related to the use of the woodland by the communal dwellers.

The above discussion should lead one to conclude that expulsion makes little sense from the viewpoint of the Forestry Commission. However, what is not taken into account in such a conclusion is that as soon as Forestry Commission relaxes the current control on in-migration, it is likely that the woodland will be rapidly depleted in the face of massive in-migration. In other areas of Zimbabwe that have recently been opened up, in-migration can result in population growth rates of up to and greater than 10% p.a. In our model population growth rates were set at 3% p.a. If we make this 10% p.a. for the forest dwellers for a period of 20 years, and thereafter reduce it to 3%, the woodland is totally removed within an 80-year period, whereas for a constant 3% growth rate, the woodland lasts for at least 130 years. The woodland destruction in the scenario with the 10% growth rate is conservative, as the use of the woodland is confined to local households; often more important in the newly resettled areas is the complete lack of institutions to govern woodland use (e.g. Goebel, 1997). Thus, in areas where there is rapid in-migration, deforestation is higher than that which would be expected on the basis of subsistence household needs, because wood often enters the market, often facilitated by outsiders rather than the settlers.

5. Does modelling provide a framework for integration?

Modelling is seen as a methodology that can provide a framework for the integration of work in different disciplines (e.g. Cowling and Costanza, 1997; Higgins et al., 1997). The modelling exercise has allowed us to identify several key points. First, it has highlighted the complexity of actual situations that arise with reference to resource use by demonstrating the linkages between different sectors, and the link between ecology and economics. Secondly, the value of this modelling exercise as a learning tool in understanding the implications for local resource user groups of different management decisions has been established. A third and useful outcome has been the identification of the gaps that exist in our base of knowledge on both the ecological and economic perspectives. There is a glaring lack of data on various details of resource use and resource ecology, which need to be investigated further. Despite this lack of data in several key areas, which leaves some stages of the modelling process open to educated guess, it has been possible to develop a model that depicts a real-life situation on the ground.

The modelling exercise has also identified five weaknesses in the approach adopted. Firstly, the drivers of change in the model are largely ecological (through the impacts of rainfall) and population growth. Economic and technological drivers of change are likely to be at least as important. For instance, rapid changes in resource use have occurred in response to structural adjustment programmes (Reed, 1996; World Bank, 1996). Secondly, households have been treated as being undifferentiated, despite considerable evidence to the contrary (e.g. Cavendish, 1997). Detailed information is required on the distribution of benefits amongst different kinds of households, and the model needs to reflect differentiation. We need to be able to investigate how different kinds of households influence resource use, and how woodland state impacts different kinds of households. Thirdly, our integrated model lacks a dynamic component with respect to economic behaviour. The household decision model of Luckert et al. (2000) incorporates household decisions in relation to risk and dynamics over time, but this has not been incorporated into the integrated model. In addition, the household decision model lacks an optimisation component. Future work needs to make improvements on these deficiencies. A more dynamic approach to household decision making would likely result in simulations that showed more rapid shifts between different productive activities, with consequent impacts on the resource base. Fourthly, we question whether the modelling framework makes a total integration of the disciplines. The sociological/anthropological perspective on resource use is lacking in our integrated model, and would require considerable effort to include it. Thus the complexities of local institutional control on resource use, as reflected in the writings of Mukamuri (1995), Mandondo (1997), cannot be incorporated in the current model. Finally, the fifth weakness, or potential weakness, relates to the researcher–policy interaction. The modelling process should (or could) be used as a consensus building process between researchers and policy makers, and among stakeholders (van den Belt et al., 1998). However, we have found that the model soon gets too complex for easy comprehensibility by policy makers (let alone the authors of the model!). In three presentations on the model, researchers have readily and enthusiastically taken up the ideas and approach, while policy makers have been much more reticent about the modelling approach. A considerable amount of effort is required to keep the model simple, and to keep the modelling process tractable to policy makers.

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