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The Impact of Policy on Resource Use in Mozambique: A Case Study of Savane

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Abstract. The study was carried out to analyse the impact of alternative management regimes and changes in sales quantities and prices of Non Timber Forest Products (NTFPs) on the well-being of stakeholders, and on the conservation of the woodlands. A dynamic game theoretic model was developed and used to simulate human population and forest dynamics, harvesting costs, household consumption and prices of forest products. Data from field surveys were used for the simulations. Because stakeholders interests are often in conflict, the chosen modelling approach allows for an evaluation of management regimes. The results indicate that stakeholders and resource conservation social and economic well-being are improved through sound forest management practices. The analysis shows also that regulated forests management regimes in which both profits and social benefits are taken into account are potentially more beneficial to the household sector than the open access regime. Sensitivity analysis indicates that an increase of 100% in the quantity of forest products sold or in the selling prices of NTFPs, *ceteris paribus*, leads to an increase in per capita benefits of the local communities. However, this increase is not enough to lift the households within the communities above the poverty line of one dollar a day per capita.
Key words: game theory; forest management regimes; NTFPs; Mozambique; local communities

O Impacto da Política de Utilização dos Recursos de Moçambique. Estudo do Caso da Savana

Sumário. O presente trabalho visa analisar o impacto de regimes alternativos de maneio e de mudanças nas quantidades vendidas e preços de Produtos Florestais Não Madeireiros (PFNM) sobre o bem estar dos vários intervenientes e na conservação florestal. Modelos de teoria de jogos foram desenvolvidos e utilizados para simular a dinâmica das populações humana e florestal, custos de exploração, consumo familiar e preços de produtos florestais. Dados recolhidos no campo foram utilizados nas simulações. Este tipo de modelos permite uma avaliação dos regimes de maneio quando os interesses dos vários intervenientes são

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conflituosos. Os resultados indicaram que o bem estar social e económico dos intervenientes e a conservação dos recursos podem ser melhorados através de práticas de maneio florestal apropriadas. A análise mostrou também que regimes de maneio florestal centralizados onde benefícios económicos e sociais são tomados em conta são potencialmente mais benéficos para o sector familiar que o regime de acesso livre. A análise de sensibilidade mostra-nos que um aumento em 100% na quantidade vendida ou nos preços de PFNM, sob condição *ceteris paribus*, leva a um aumento nos benefícios *per capita* das comunidades locais. Contudo, este aumento não é suficiente para elevar os benefícios das famílias comunitárias acima da linha de pobreza de um Dólar Americano por dia per capita.
Palavras-chave: teoria de jogo; regimes da gestão florestal; NTFPs; Moçambique; comunidades locais

L'Impact de la Politique de l'Utilisation des Ressources au Mozambique: Étude d'un Cas de la Savane

Résumé. L'étude analyse l'impact des régimes alternatifs de gestion (coopératif, non coopératif), les changements de quantité de vente et le prix des produits forestiers non ligneux (NTFPs) sur le bien-être des dépositaires, et sur la conservation des régions boisées. Un modèle théorétique de jeu dynamique a été développé et employé pour simuler la dynamique de la population humaine et forestière, coûts de moisson, consommation des ménages et les prix des produits forestiers. Les données recueillies sur le terrain et la littérature ont permis l'élaboration des simulations. Puisque les intérêts des dépositaires sont souvent en conflit, l'approche modelante tient compte d'une évaluation des régimes de gestion. Les résultats indiquent que le bien-être social et économique des dépositaires et la conservation des ressources peuvent être améliorés par des procédures de gestion forestière saines.

Les résultats indiquent que le scénario coopératif de gestion est potentiellement salutaire aux communautés locales si correctement mis en application, améliorant de ce fait leur vie.

L'analyse prouve également que les régimes réglés de gestion de forêts dans lesquels les bénéfices économiques et sociaux sont pris en considération sont potentiellement plus salutaires au secteur du ménage qu'au régime de libre accès.

L'analyse de sensibilité indique qu'une augmentation de 100% de la quantité de produits forestiers vendus ou des prix de vente de NTFPs, *paribu de ceteris*, mènent à une augmentation des avantages *per capita* des communautés locales. Cependant, cette augmentation n'est pas suffisante pour élever les ménages au sein des communautés au-dessus de la ligne de pauvreté d'un dollar par jour et par habitant.
Mots clés: jeux dynamiques; régimes de gestion forestiers; NTFPS; Mozambique; communautés locales

Introduction

Sustainable forest management

The Mozambican new National Forestry and Wildlife Law (1999) empowers local communities to own and participate in the management of natural resources through community-based natural resources management (CBNRM) initiatives. Establishes a process of participatory management of resources in which a management council (*conselho de gestão*) is created, which includes members of the community, local government, private operators, and other associations.

To date the State intends to manage the natural resources as joint ventures with the private sector and the local communities. The first Community Based Natural Resource Management

(CBNRM) project experience in Mozambique was launched in 1994 in the community of Bawa, in the Tete province (WILY and MBAYA, 2001). The relative success of this programme has encouraged the rapid spread of new projects over the country. For instance, four years after the establishment of the Tchuma-Tchato project, about 40 projects were being implemented by different government institutions and local and international NGOs through the financial support of international donors (ANSTEY, 2001).

Objectives and problem statement

The general objective of this study is to assess the social-economic and environmental impacts of the use of woodland resources and identify the most appropriate management regime in a way that satisfies the achievement of the goals of the stakeholders in Savane. This study has the following specific objectives: (i) identify the most appropriate management regime and evaluate the social-economic and environmental impacts; (ii) test a sectorial policy instrument to improve the understanding of the interaction between stakeholders and the influence of different factors in management regimes.

This study was motivated by the fact that the game theoretic model developed by SUMAILA *et al.* (2003) did not take into consideration the household benefits from NTFPs, human population dynamics, the allowable cut established in the management plans, the effects of transactions costs on the cooperative management regime, charcoal production efficiency variation, greater off-miombo employment opportunities and tree diameter class segregation. To date, it is unknown what will be the social-economic and environmental impacts if these aspects were taken into consideration, and if either new agricultural incentives are put in place or if the commercial sales or prices of Non Timber Forest Products (NTFPs) were increased.

Methods

Study site

Savane is located at Dondo District, which is the major supplier of construction material (poles and thatching grass) and charcoal within to Beira city. It is located at the centre of Mozambique along the Beira Corridor, is relatively rich in both forest and wildlife natural resources and the miombo forest area covers 15,000 ha (34 m^3/ha). The area was managed as a timber forest concession by MOFLOR Company ("Moçambique Florestal") until 2002 and currently is managed by the government as open access area.

High levels of damage took place in the forest cover as a result of harvesting wood for fuel, timber harvesting, building materials, and through forest clearing for agriculture. The typical household average farm size is equal to 2.6 ha, the average family size is equal to 6 and 1,858 habitants live in the study site (INE, 2001; MLAY *et al.*, 2003).

Dynamic game theoretic model

Three principal game theoretic models (management regimes) are used to study the use of miombo woodland resources, namely a command model, a cooperative model (joint management or Community Based Natural Resource

Management) and non-cooperative model (separate management – status quo). Each is briefly presented below.

a) Command model

This model assumes that the regulator, such as a central or local government, can dictate the behaviour of the household and commercial sectors directly (decisions are centralised). The society wide net benefits are maximised through the choice of the amount of labour to be used by each sector in each year over the horizon of the model. The amount of labour employed defines the volume of wood products to be harvested by each sector. This is the decision variable that guides governments in managing these resources.

The maximisation of the total annual discounted net benefits (B_t) in a given time period is represented in the equation (1) and it is subject to the ecological and household constrained.

$$\underbrace{Max}_{L_h, L_c} \sum_{t=1}^{T} [B_t] \rho_{t-1} D \qquad (1)$$

In the above equation:

$$B_t = \begin{bmatrix} B_c(H_{a,t}) + B_h(H_{a,t}) + B_s(\theta_c H_{a,t}, \theta_h H_{a,t}) \\ + B_e(\beta H^c_{a,t}, \beta H^h_{a,t}) \end{bmatrix}$$

$$\rho_{t-1} = \frac{1}{(1+r)^{t-1}}, \rho_0 = 1, t = 1, ..., T.$$

$$D = \frac{r(1+r)^t}{(1+r)^t - 1}$$

Where ρ = discount factor; r = discount rate; and D = factor to convert the Net Present Value of the benefits to an annual value over the harvesting period.

Depending on the values assigned to parameters θ_c, θ_h and θ, different scenarios of the command model can be looked at. Here, we look at three scenarios, namely the scenario in which the regulator is concerned with both social and environmental benefits but favouring the household sector (θ_c =0, θ_h =1, and θ=1), the scenario in which only environmental benefits are considered ((θ_c =0, θ_h =0, and θ=1) and the scenario in which only social benefits favouring the household sector are considered ((θ_c =0, θ_h =1, and θ=0).

b) Cooperative model

Under the cooperative model (CBNRM), it is assumed that the two users (household and commercial sector) have incentives to cooperate through joint maximisation of their benefits which are expressed as equivalent annual income (EAI) as shown below. This relationship is subject to the ecological and household constrained.

$$\underbrace{Max}_{L_h, L_c} \sum_{t=1}^{T} \left\{ \left[\alpha \rho_{h,t-1} B^h_{a,t} + (1-\alpha) \rho_{e,t-1} B^c_{a,t} \right] - T \right\} D,$$

$$0 \le \alpha \le 1 \qquad (2)$$

The value assigned to the parameter α will reflect the relative weight given to each sector under cooperative management to maximise their combined EAI's from exploitation of the woodland resources. T is the transaction cost of management of miombo woodland in a participatory way.

c) Non cooperative model

In the non-cooperative model each of the different user groups or stakeholders (commercial sector and household) is assumed to operate independently without taking into account the interest of other stakeholders. This model will be used to mimic an open access management regime (status quo), currently the dominant arrangement

under which miombo woodlands are being presently exploited in the eastern and southern Africa region. The constrained maximisation problem for household is presented in equation (3). This relationship is subject to the ecological and household constraints.

$$\underbrace{Max}_{Lh} \sum_{a=2}^{3} \sum_{t=1}^{T} (\rho_{c,t-1} B_{a,t}^{h}) D \qquad (3)$$

Similarly, the non-cooperative management problem facing the commercial sector can be stated as follows, subject to the ecological and household constraints.

$$\underbrace{Max}_{L_h, L_c} \sum_{a=3}^{4} \sum_{t=1}^{T} (\rho_{c,t-1} B_{c,t}) D \qquad (4)$$

The three models can be solved by introducing modified Lagrange multipliers and applying non-smooth convex optimisation (see Flåm, 1993). Simulation of the models is based on the numerical approach applied in SUMAILA (1997)[1].

Data collection

The target population is defined as households who use miombo woodlands for agriculture and/or for extraction of wood and non-timber forest products for household consumption and sale. In this study the sample unit was a household. For data collection, the sampling method involved a random selection of households from listings prepared by village leaders in accordance with the definition of the target population. According to FAO (1990), if the total number of households is bigger than 1000, the suggested sample should be at least equal to 50 households. The total sample size for this study was 54 households, which were selected from villages or zones in Savane, out of a total of 2,233.00 listed households. Since conditions were considered to be more or less uniform, inter-village variation was assumed minimal and hence there was no need for stratified or multi-stage sampling.

To accomplish this research a combination of methods was used to generate the required information. Thus the data were collected from both primary and secondary sources. A structured questionnaire, checklists for formal interviews and informal discussions, and participant observations were the methods used to gather information from primary sources. The questionnaire was used to collect data from sampled households in face-to-face interviews. It investigated aspects of household consumption of wood products and NTFPs, activities, labour distribution by sex and age, management of miombo trees, and selling activities.

The data related to crop yields, wood and NTFPs prices were collected at the Provincial and District Directorate of Agriculture and Fisheries. Appraisals in various urban markets and rural roadsides gave latest market prices of construction material (poles, bamboo and grass), fuelwood (charcoal and firewood), logs, and honey which came from the study area. The surveyed farmers did not give the information regarding crop yields, due to the fact that farmers often had difficulty recalling within-year information on resource use, especially when the operations were conducted several months preceding the date of interview.

In the survey, the transaction cost was determined based on the objectives and working experience of the Pindanganga community-based management programme (60 km away from Savane).

Charcoal efficiency was measured based on a sample of 23 earth kilns. The subsistence income for the community was estimated based on the total number of households in the community, the typical household size and composition by age and sex, the consumption basket of food and non-food items, the minimum *per capita* caloric requirements established, and local markets prices.

Data requirements and sources

The data requirements for the model are presented in Table 1. The majority of the coefficients used were derived from the survey results. Data on population, area under forest and agriculture covers, miombo employment and growth, and commercial harvesting costs have been obtained from secondary sources.

The annual human population growth rate in the study site during the first 20 years of the simulation period is equal to 1.2% *per* year, followed by 1.5% of growth rate for the subsequent 10 years and 1.5% for the last 10 years of the simulation period (INE, 2001).

Table 1 - Data requirements for the simulation model in Savane

Data Type	Units	Savane
Amount of thatching grass sold	Bundles/yr	1,500
Average basal area	m^2/ha	5.2
Average family size		5
Average farm size	Ha	1.3
Charcoal production efficiency	Percentage	13.7
Chicken price	$/unit	0.82
Chickens quantity sold by the community	Unit/year	9,718
Discount factor		[0.909;0.89]
Existing agric land	Ha	2,903
Forest area	Ha	15,000
Goat price	$/unit	12.4
Goat quantity sold by the whole community	Unit/year	662
Harvesting cost by commercial sector	$/$m^3$	2.5
Off_miombo_labour	Percentage	0.005
Pig price	$/unit	8.2
Pigs quantity sold by the whole community	Unit/year	207
Price grass	$/kg	0.01
Price of charcoal	$/$m^3$	1.7
Price of poles	$/$m^3$	2.05
Price of standing miombo	$/$m^3$	11.5
Regeneration (survival rate)		0.012 (0.92)
Agricultural revenue per hectare	$/ha	117.7
Subsistence income for community	$	732,531
Transaction cost (fixed cost)	$/ha	2.26
Total man-days/year in the community	Mandays/yr	2,172,378
Wage rate	$ per year	405.6

Results

Basic simulation results

The basic simulation results were found by introducing the filed data into the dynamic game theoretic model. The impact of management regimes on the stakeholder's benefits, resource use and conservation is presented under this section.

a) Impact of different management regimes on stakeholders benefits

The effect of management options presented above on equivalent annual discounted total net benefits of the stakeholders from miombo activities vary in terms of quantity and distribution between the two sectors (Table 2). The difference in benefits between the two sectors reflects the difference market values of the products harvested. For both sites, non-cooperative management regime gives the highest annual discounted net benefits from harvesting wood products for commercial sector. Since the non cooperative arrangement is the most beneficial to the commercial sector, from private consideration the sector would be unfavourable to government intervention or cooperative arrangement unless the intangible benefits and the penalties for non compliance exceed the additional benefits emanating from non cooperation. The option leading to highest equivalent annual discounted net benefits from miombo activities to the household sector is the non cooperative management regime.

The regulated option for environmental reasons leaves all stakeholders worse off than all alternative management regimes and hence the least attractive. This is the option favoured by those strictly for conservation of biodiversity. Since it provides least economic and social benefits to the communities will have to encroach on the resources as necessary.

Table 2 - Effect of management regime on Equivalent Annual Net Discounted Benefits of stakeholders from sale of miombo wood and NTFPS products in Savane

Management Regime[b]	Equivalent Net Discounted Benefits (US$ per annum)			Household EANDB[c]
	Commercial [a]	Household	Total	
NC	(1) 290,689	(1) 62,820	(1) 353,509	0.015
COOP	(3) 258,372	(3) 43,795	(3) 302,167	0.011
CM-E	(5) 15,587	(5) 2,235	(5) 17,821	0.001
CM-S	(2) 290,447	(2) 61,826	(2) 352,273	0.015
CM-SE	(4) 208,713	(4) 35,371	(4) 244,084	0.009

[a] The figures in parentheses represent the ranking of the management regime on the basis of EANDB's within each sector.

[b] NC = Non-cooperative, COOP = Cooperative, CM-E = Command environment, CM-S = Command social, CM-SE = Command social and environment

[c] Household EANDB (Equivalent Annual Net Discounted Benefits) = US$ per *capita* per day

In terms of total benefits for two sectors, results seem to suggest that non cooperative and CM-S (command social) management regimes give the highest stakeholders benefits. Within the regulated management arrangements, depending on site specific conditions, the management with social concerns or with social and environmental concerns are potentially beneficial to local communities. The failure of these centralised options may have resulted from among other factors not taken into consideration from the lack of flow of such benefits to communities leaving in the proximities of such resources in the form of investment in economic and social infrastructure. Therefore decentralization of forest resource management to local levels with in built mechanism on benefit sharing between the regulator and the communities have the potential to improve welfare. The other alternative is partnership arrangement between the commercial sector and local communities in managing and harnessing forest resources in areas in the proximity to these communities. The Mozambican current land law and forest and wild life management policy provide a legal basis for putting such arrangements into practice.

The *per capita* benefits are the extra net income after the minimum subsistence requirements are met. They were accounted for in the model and for all management regime represents less than three percent of a Dollar *per* day (99% below the poverty line).

b) Impact of different management regimes on wood products harvested

The average volume harvested annually leading to maximum discounted benefits under each management arrangement for the stakeholder's is presented in Table 3. As expected, the trends correspond to those of benefits derived from these products. In comparison with the non cooperative model which represents the current practice, least volume is harvested under the command regime incorporating environmental benefits. For the household sector, the highest volume of wood products is harvested under non-cooperative.

Table 3 - Effect of management regime on resources used and conservation in Savane

Management Regime	Converted Land (ha) [a]	Standing Miombo (ha)	Charcoal Bags	Harvested Volume (m^3)[b]		
				Com.	HH	Charcoal
Non-cooperative	(1) 137	(4) 548	(1) 13,455	4,523	6,166	4,387
Cooperative	(3) 109	(3) 829	(3) 9,568	4,449	4,559	3,120
Command environment	(5) 10	(1) 14,625	(5) 1,002	485	459	327
Command social	(2) 132	(5) 583	(2) 13,025	4,518	5,969	4,247
Command social and environment	(4) 73	(2) 1,552	(4) 7,136	3,242	3,270	2,327

[a] The figures in parentheses represent the ranking of the management regimes.

[b] Com. = Commercial, HH = Household.

The household harvesting volumes in the dynamic game theoretic model is not restricted accordingly to allow cut established by the management plans of the sites. This was done to reflect what is happening in the field where this sector is operating depending on weather conditions, charcoal market demand, labour availability, and resources availability. Within the model structure, the harvesting volumes for the commercial sector are limited to a maximum of 5,000.00 cubic meters *per* year according to the Savane management plans, respectively. For the commercial sector, the average annual harvest under the regulated regime for environmental reasons is about 9.7% of the harvest under open access.

The best outcome with respect to ecological health of the woodland is achieved under the command environment regime for both sites, followed by the command regime incorporating social and environmental benefits. The cooperative management option is the third best option. The environmental concerns mean that a larger area of forest cover has to be maintained to meet peoples needs, while protecting the environment. The deforestation is highest under command social regime. As expected, the regulated system incorporating only environmental concern leads to least deforestation for both study sites, but it is the option least attractive to the household and commercial sectors.

Average annual forest area converted to agriculture for both sites is lowest under the command regime incorporating environmental benefits. Depending on site specific conditions such as resources availability, soil fertility, human population size and dynamics, the management options which leads to more conversion of forest land to agriculture are non cooperative, cooperative and social.

Policy impact under alternative management regimes

A general increase in the current commercial sales or market prices of NTFPs could be brought about by, for instance, improvement in road infrastructure, new markets closer to the local communities or removal of explicit government taxes on NTFPs. To assess the impact of such an increase, the Savane model is simulated with an arbitrary increase by 100% on the current selling amount of NTFPs (Table 4) and an increase by 100% on the market selling prices of NTFPs (Table 5).

The relative results on the impact of increasing commercial sales amount or prices of NTFPs (honey, chickens, pigs, goat and thatching grass) on annual discounted net benefits from miombo activities are presented in Table 4. These values were obtained by comparisons made in relation to the basic simulation results (values in brackets), and in addition the non cooperative model results are used as reference results for assessing the other management regimes.

An increase in the commercial sales of NTFPs (scenario I) will lead to changes in the ranking of the management regime within each sector, while an increase in market prices of NTFPs does not lead to a change on the ranking.

Table 4 - Relative effect (%) of an increase by 100% in commercial sales of NTFPs (I) and an increase by 100% in market selling prices of NTFPs (II) on discounted net benefits from miombo activities under alternative regimes in Savane area[a]

Forest Managt. Regime[b]	Commercial Annual Benefits		Household Annual Benefits		Total Annual Benefits		Benefits per Capita per Day	
	I	II	I	II	I	II	I	II
NC.	100.0 (0.2)	100.0 (0.0)	100.0 (0.0)	100.0 (-0.3)	100.0 (0.2)	100.0 (0.0)	100.0 (0.0)	100.0 (-0.7)
COOP.	88.6 (-0.1)	88.9 (0.0)	69.3 (-0.5)	69.2 (-0.5)	85.2 (-0.1)	85.4 (-0.1)	69.5 (-0.9)	69.0 (-0.9)
CM-E	5.8 (8.0)	5.9 (10.5)	3.8 (7.9)	3.9 (10.7)	5.4 (8.0)	5.6 (10.5)	3.9 (8.1)	396.1 (11.0)
CM-S	100.0 (0.3)	99.9 (0.0)	97.1 (-1.3)	95.9 (-2.3)	99.5 (0.0)	99.2 (-0.4)	97.4 (-1.3)	95.5 (-2.6)
CM-SE	71.6 (0.0)	71.8 (-0.1)	56.3 (0.0)	56.2 (0.0)	68.9 (0.0)	69.0 (0.0)	56.5 (0.1)	56.1 (0.1)

[a]The figures in parentheses represent the percentage of change at the end of simulation compared with the basic scenario.

[b] NC = Non-cooperative, COOP = Cooperative, CM-E = Command environment, CM-S = Command social, CM-SE = Command social and environment.

Table 5 - Relative effect (%) of a 100% increase in commercial sales (I) and 100% increase prices of NTFPs (II) on average annual volume of miombo wood products harvested under alternative management options in Savane[a]

Managt. Regime	Converted Land[a] (ha)	Standing Miombo (ha)	Amount of Charcoal Bags		Harvested Volume (m^3)					
					Commercial		Household		Charcoal	
	I	II	I	II	I	II	I	II	I	II
NC.	100.0 (0.2)	100.0 (-0.2)	100.0 (-0.6)	100.0 (-0.6)	100.0 (0.2)	100.0 (-0.0)	100.0 (0.2)	100.0 (0.4)	100.0 (0.2)	100.0 (0.4)
COOP.	79.6 (-0.2)	79.6 (-0.2)	152.5 (0.3)	152.5 (0.3)	98.1 (-0.1)	98.4 (0.0)	73.5 (-0.4)	73.4 (-0.3)	70.7 (-0.3)	70.6 (-0.3)
CM-E	8.0 (7.9)	8.0 (8.0)	2704.2 (0.8)	2684.2 (0.0)	11.8 (10.3)	11.6 (8.2)	8.1 (9.5)	8.0 (8.2)	8.1 (9.5)	8.0 (8.0)
CM-S	97.1 (0.5)	96.4 (-0.3)	2395.0 (2137.7)	107.5 (0.5)	100.0 (0.3)	100.0 (0.0)	96.8 (0.2)	96.2 (-0.2)	96.8 (0.2)	96.2 (-0.2)
CM-SE	53.3 (0.7)	53.3 (0.7)	285.0 (0.0)	284.8 (-0.0)	71.5 (0.0)	71.6 (-0.1)	53.0 (0.0)	52.8 (0.1)	52.9 (0.0)	52.8 (0.1)

[a] The figures in parentheses represent the ranking of the management regime on the basis of annual net discounted benefits within each sector.

[b] NC = Non-cooperative, COOP = Cooperative, CM-E = Command environment, CM-S = Command social, CM-SE = Command social and environment.

With regard to discounted net benefits to the commercial sector, raising the commercial sales of NTFPs or market prices by 100% reduces annual discounted net benefits under all management options compared to the non cooperative regime. The largest reduction is observed under the command model with environmental concerns, where the discounted net benefits relative to base scenario are reduced by 27% for environmental management regime. These results conform to *a priori* expectation since selling NTFPs contributes to household economic benefits derived from miombo forest for the householder sector. This scenario is in favour of the household sector, meaning that in addition to the restriction on harvesting implied by the environmental concern, the commercial sector is indirectly penalised by the social consideration favouring the household sector.

The household annual discounted net benefits from selling of wood products from miombo activities show decreased behaviour across all alternative management regimes and the total *per capita* per day (selling of wood and non wood products) increased, compared with basic runs. The command regime, accounting only for environmental benefits, is the least beneficial, with discounted net benefits being decreased by 47.2% and 0.64% relative to the base scenario. The net benefits attain their highest value under the social and environmental management option. The observed increase in household benefits *per capita* per day from miombo activities is caused by an increase in harvesting of NTFPs and less converted area to agriculture. Using the non cooperative model as a reference (the current management practice) the command model incorporating environmental benefits is the least beneficial, while the command with social and environmental concerns and the cooperative models are the most beneficial. The increase by 100% in commercial sales and prices of NTFPs leads to an increase in household *per capita* benefits between 3% to 8% and it is not enough to reach the poverty line (one US Dollar per day per person), showing that forest policies on NTFPs by themselves in Savane do not address the poverty problem of the local communities. In terms of *per capita* benefits, raising market prices of NTFPs has a similar effect as the effect of increasing the amount of NTFPs sold.

The impact of increasing the commercial sales or prices of NTFPs in mitigating deforestation is most pronounced, as expected, under the command model incorporating environmental benefit. This management option shows the highest percentage of the area of standing miombo woodlands at the end of the simulation. The increase in commercial sales and prices are least effective in mitigating deforestation under the non cooperative model. These results seem to suggest that the management options which will minimise conflicts (command social environment and cooperative model) between multiple objectives will be the most beneficial.

Discussion

The dynamic game theoretic model developed in this research differs from the model developed by SUMAILA and KOWERO (2003) by taking into account the following aspects: dynamics of human population, demand for poles is

restricted compared with charcoal, demand from the commercial sector is restricted according to the allowed harvest cut established in the community management plan, the effect of transaction costs on the cooperative management regime which affects the harvesting levels of the two sectors, charcoal production efficiency, harvesting technology efficiency, the dynamic of non-miombo activities over time, highlights the conflict between householder and commercial sectors through variation in diameter class of tree species used for logs, charcoal, firewood and poles, and the model accounts for the benefits from the NTFPs.

The mechanism of diameter class segregation included in the model allows to constrain the timber harvested by the commercial sector, according to the Forestry and Wildlife Policy which states that the trees can be harvested for logging only if they have a DBH of more than 30 cm. It also highlights the conflict between the charcoal producers of the household sector and the commercial sector for the some tree sizes.

MLAY *et al.* (2003) found that the cooperative management regime is the second best management option in terms of private benefits and total benefits for the two sectors in the Mozambican provinces of Dondo, Nhamatanda and Gondola-Manica. In this research, the cooperative option is ranked as the third option (and therefore less attractive) due to inclusion of the transaction costs in the analysis.

Implications of alternative management arrangements

The alternatives analysed for managing miombo woodland resources reflect either on-going practices or practices in their early stages of introduction. The experiences of centrally regulated regimes in Mozambique have not been effective in redressing deforestation, land degradation and conservation. Although the government has the obligation to defend society-wide interests, in natural resource conservation and use, the experience shows that the policies adopted and instruments used for their implementation have been ineffective. The fact the social and economic benefits implied by the regulation are not felt at community level gives an incentive for non compliance which in turn is facilitated by lack of institutional and financial capacity for enforcement (MLAY *et al.*, 2003).

The fact that the regulated management regimes, which take into account social needs or both social and environmental needs are potentially more beneficial to the household sector than open access, suggests that if these benefits were to flow to the local communities, non compliance to sustainable forest management activities could be minimised. This can be guaranteed under decentralised management with local community participation but with clear definition of a benefit-sharing arrangement. The cooperative management regime which already has a legal support for property right protection needs to be promoted in association with policies and regulations which bring incentives to increase the benefits from activities related with NTFPs, such as honey production, keeping domestic animals, and the sale of thatching grass.

The results show that improvements in well-being and resource conservation

can be achieved with sound management practices. Our results show that the regulated management regimes incorporating social or social and environmental benefits provide higher benefits to the household sector than the open access regime. MLAY *et al.* (2003) have found a similar trend results for centre of Mozambique, while KACHULE found the same for Malawi.

The results of this research indicate that the levels of deforestation are greater under open access regimes. KAIMOWITZ and ANGELSEN (1998) using analytical models also found similar results. The cooperative management regime, taking into account the transaction costs, shows that both the local communities and the commercial sectors can gain under this arrangement. Although the commercial sector will have to forgone some direct benefits in favour of the household sector, the cost saving which results from a reduction in conflicts between the two sectors can induce this cooperation in management and utilisation of the woodland resources. The stakeholders benefits found in this study are inferior to the benefits found by MLAY *et al.* (2003). This can be explained by inclusion in this model of transaction costs, diameter class segregation and population dynamics over the rotation period. In the case of Mozambique, where the Forest and Wildlife Law permits communities to enter into partnership with the private sector in its exploration of natural resources, the results show that such cooperation is potentially beneficial to local communities if properly implemented.

Sectoral policies in the form of commercial sales and prices of NTFPs manifest their impact on the woodland resource mainly through the household sector activities in the form of a increase in household benefits from harvesting wood and non-wood products. The amount of wood products harvested has reduced slightly.

The impact of the management regime and or policy intervention on the welfare of stakeholders and on the ecology of the woodland resources will depend on the natural resource endowment, and the initial socio-economic conditions on the ground. Policy changes in the household or commercial sector are likely to affect the state of affairs in other sectors. While the general direction of policy or institutional change can be predicted, the actual impact will reflect the initial conditions which are site specific. In addition, the results show that there is no management regime capable of satisfying all goals of the stakeholders, meaning that some trade-off between goals is necessary. This means that a clear definition of priorities is necessary.

Concluding remarks

This study shows that improvement in well being of rural communities and resource conservation can be achieved with sound management practices. The cooperative management option or CBNRM is potentially beneficial to local communities if properly implemented and can improve the rural livelihoods and the woodland resource condition. Sectorial policies targeting NTFPs can lead to an increase in *per capita* benefits of the household sector by 1 to 5%. Under *ceteris paribus* condition increasing NTFPs selling quantities or prices can improve the well-being of the rural communities by 10 to 25%, but cannot reach the

poverty line (one US Dollar *per capita* per day). The study is deterministic and thus cannot be expected to give a perfect picture of the world under investigation. Nevertheless, the results of this paper should give the relevant forest managers some food for thought.

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[1] Detailed description of the model is given at the PhD thesis of the author, who can be

contacted for details (University of Stellenbosch, South Africa).