DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

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AN ECONOMIC DETERMINATION OF THE OPTIMAL PRICE AND HARVEST RATES FOR SUSTAINABLE COMMERCIAL INDIGENOUS TIMBER MANAGEMENT IN ZIMBABWE: A Case Study of Mzola in Matebeleland

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Abstract

A number of reports (see Judge, 1975, World Bank, 1993, Forestry Commission, 1995, Mushove, 1994) show that Commercial Indigenous Timber (CIT) appears to be exploited at an unsustainable rate. Over-exploitation and wasteful utilization of the forest resource may be due to undervaluing of the resource and wrong pricing mechanisms. The main objective of this study was to determine the optimal price and the Maximum Sustainable Economic Yield (MSEY) which will maximize the Net Present Value of the forest resource. This study differs from previous studies because it does not just explain the problems and causes of over exploitation of the forest resource, but it goes beyond by determining the prices and the MSEY which will encourage sustainable CIT management.

To achieve the study objectives, we use the residual approach to determine the residual stumpage value (the value of a standing tree in the forest) of teak and mukwa. The results show that both teak and mukwa are undervalued by 76% and 77% respectively since the FC is charging Z$450/$m^3$ for teak and Z$700/$m^3$ for mukwa yet the results of this study show that the stumpage value of teak is Z$1900/$m^3$ and that of mukwa is Z$3119/$m^3$. This method was also used by Mushove, 1994 and he found that mukwa was undervalued by 63%. However, the residual approach has the major weakness of calculating a residual stumpage value which depends on the logging, transportation, and processing costs of the firms. If the firms are inefficient the resulting residual value will be low thus rewarding inefficiency. The residual approach also determine a static value which does not reflect the scarcity value of the resource and does not help in achieving intertemporal allocative efficiency.

To overcome these weaknesses a model which incorporates biological and economic information (Bioeconomic Model) was developed to determine the MSEY and the Marginal User Cost (MUC) over time. The results show that in order to achieve intertemporal allocative efficiency of the resource, the exploitation rate should fall progressively until the harvest rate equals the growth rate of the resource and the price of the resource should increase as the resource become scarce. The results at 5% discount rate show that a maximum Net Present Value of Z$26 930 961 can be earned in 24 years. The price per cubic meter will increase from the current Z$700/$m^3$ to Z$1500/$m^3$ in real terms during the same period.

This study has not concentrated effort on the institutions and the political economics which underline the allocatory and pricing decisions of state owned and communal resources but it has established criteria which the Forestry Commission can use to reduce political manipulation of prices.

It is recommended that the Forestry Commission should charge per tree fees to encourage efficient utilization of the forest resource. It is also recommended that the price calculated using the Bioeconomic model should form the minimum prices below which timber may not be sold.

AN ECONOMIC DETERMINATION OF THE OPTIMAL PRICE AND HARVEST RATES FOR SUSTAINABLE COMMERCIAL INDIGENOUS TIMBER MANAGEMENT IN ZIMBABWE: A CASE STUDY OF MZOLA IN MATEBELELAND

Introduction

Forests play an important role in: watershed protection, income generation, employment creation, and in providing food, fodder, fibre, fuelwood, small timber and medicine for the poor who depend on forests for their basic needs. Forests also provide global services such as biological diversity, and carbon dioxide sequestration. In this study we will concentrate on the exploitation of Commercial Indigenous Timber (CIT) on state forests by private concessionaires.

Exploitation of indigenous hard wood is carried out by private concessionaire companies and is regulated by the Forestry Commission (FC) under the Forestry Act (for gazetted forests) and the Communal Land Forest Produce Act (for communal areas). Exploitation of indigenous forests began in the 1890s to supply the mines and the railways and became so extensive that regulation became necessary, leading to the initial Forest Act in 1949 (McGregor, 1991).

Concessions are operated in all farming sectors. In the communal areas the local authorities draw up concession agreements on the advice of the FC, which then supervise them. Royalties, depending on the species, are paid to the local authorities and fees are paid to the FC for their administration cost for supervision. These fees were supposed to fund research into the regeneration of indigenous forest but have not yet been used (World Bank, 1993).

Commercial timber exploited from indigenous woodlands in communal areas is principally from *Baikaea plurijuga* (Zambezi teak or mukusi) and *Pterocarpus angolensis* (mukwa) and, to a less extent, *Guibortia coleosperma*. Teak and mukwa are mostly found growing in association in dry deciduous forests on the Kalahari Sands. These soils are not fertile, and the nitrogen content is particularly low in areas disturbed by cultivation. Productive woodlands of this type cover an area of nearly 2 million hectares (World Bank, 1993). Of these, 638 000 hectares are in communal areas and 343 000 hectares are on private land. The Parks and Wildlife department controls 568 000 hectares and the FC controls about 439 000 hectares (Judge 1986).

In this study we determine the stumpage values of teak and mukwa and use biological and economic information to determine the optimal price and the maximum sustainable economic yield (MSEY) which will maximize the net present value (NPV) of the forest resource. In the subsequent sections we discuss the problem, objectives of the study, and the research hypotheses.

Problem statement

A number of reports from around Zimbabwe mention destructive and wasteful harvesting of commercial indigenous timber by concessionaires. Despite a lack of adequate data, indications are that little indigenous hardwood remains and by 1977 demand was already exceeding supply (World Bank, 1993). The F.C has since observed that due to high demand from indigenous forests in Zimbabwe, which have been, and still are logged extensively, sustained supply was questionable (F.C, 1995). Important tree species such as Pterocarpus Angolensis (mukwa), Baikiaea Plurijuga, and Guibourtia Coleosperma are in danger of extinction. Using extraction rates lower than those estimated in the World Bank study (1993), Mushove (1994) estimated that exploitable timber will be exhausted by the turn of the century. In another study, Muir (1989) estimated that indigenous hardwoods in Zimbabwe may be exhausted in ten years.

A number of factors have contributed to the over-exploitation of the commercial indigenous timber. The mechanisms which are used to set the stumpage fees and to control exploitation are not those which will encourage the best and most efficient use of the resource. It looks like the stumpage prices set are not based on any economic or ecological analysis (World Bank, 1993). It is not known how much commercial indigenous timber is extracted from private small-scale farms, or the present value of the standing stock. Prices

Conceptual Framework

The Analytical Approach

The indirect or analytical approach for appraising stumpage fees can be subdivided into the "investment" method and the "derived residual value" appraisal method. The "derived residual value" approach (which was be used in this study) estimates the residual stumpage fee by taking the border price of timber, whether exported in raw state or processed form, and deduct all costs of cutting, transport, and processing with an item for "normal" profit. The residual stumpage fee corresponds to the maximum price that a concessionaire would be willing to pay for the privilege of harvesting trees (Winpenny, 1991). The Stumpage fee is the price sometimes charged for the privilege of harvesting timber, and is usually below the stumpage value (the real value of a standing tree in the forest).

Dynamic Optimization Approach (Hamiltonian or Bioeconomic Model)

The optimal harvest of a renewable resource or the extraction of an exhaustible resource is a dynamic allocation problem, that is the firm or resource manager is concerned with using the best harvest or extraction rate through time. However, the choice of the harvest rate varies among privately owned forests on private farms, common property forests and open-access forests.

The Sole Owner

Mzola forest is a state forest and the Forest Commission (F.C) manages the exploitation of this forest resource. Since the F.C is the sole owner, we can make economic assumptions that imply that the F.C should adopt objectives that aim at maximizing social welfare.

The Objective Function

One of the main objectives of this study is to determine the optimal harvest rate that maximizes the sum of the intermediate values of Net Present Value (NPV) over the time horizon during which exploitation will take place.

Since the F.C controls all the CIT logging operations (including the evaluation of bidding concessionaires) we can assume that the F.C uses monopolistic pricing, that is

$$p(h_t) = \alpha - \beta * h_t \qquad (1)$$

Where $p(h_t)$ is the inverse demand price and h_t is the volume of CIT harvested. Assuming that the price per cubic meter of extracted logs is $p(h_t) = \alpha - \beta * h_t$ per cubic meter, the F.C attempts to utilize a harvest rate $h = h_t$ that leads to the largest value of the sum of the discounted streams of revenue over time.

The objective of the F.C can be represented mathematically as:

$$NPV = \text{MAX}_{h_t} \sum_{t=0}^{t=infinity} [p(h_t) * h_t] e^{-\delta t} \qquad (2)$$

where h_t is the harvest rate (or control variable) in m^3 per year $p(h_t)$ = the inverse demand price ($p(h_t) = \alpha - \beta * h_t$) per m^3, and δ = the social discount rate.

However, this objective must be satisfied subject to the change in the resource stock over the time horizon. This constraint can be represented by the following difference equation describing the change in the resource stock:

$$x_{t+1} - x_t = F(x) - h_t. \qquad (3)$$

Where x_t = state variable, describing the resource stock at time t,
x_{t+1} = resource stock at time t+1,
h_t = the harvest rate (also known as the control or instrumental variable in optimal control theory), and
$F(x)$ = is a function describing the growth rate over the time horizon.

2: $\delta H/\delta x_t = e^{-\delta t+1}\lambda_{t+1}(F'(x)+1) - e^{-\delta t}\lambda_t = 0$

$$-\frac{[e^{-\delta t+1}\lambda_{t+1} - e^{-\delta t}\lambda_t]}{e^{-\delta t+1}\lambda_{t+1}} = F'(x) \quad (8)$$

$$\lambda_{t+1} = \frac{\lambda_t}{e^{-\delta}(F'(x)+1)} \quad (9)$$

3: $\delta H/\delta(e^{-\delta t+1}\lambda_{t+1}) = x_t - x_{t+1} + F(x) - h_t = 0$ **(10)**

These are the necessary conditions that must be satisfied by any harvest rate (h_t). Equation 15 show that the quantity harvested must decline as the Marginal User Cost λ_{t+1} increases. The second derivative (equation 16) require some explanation. When differentiating with respect to x_t we look at terms with x_t. However, if we back up to the (t-1) term we would find $-x_t$ pre-multiplied by $e^{-\delta t}\lambda_t$. This accounts for the term $-e^{-\delta t}\lambda_t$ in the second derivative. This equation (16) implies that the biomass of the resource should be maintained so that the change in the net natural growth rate equals the negative of the percentage rate of change in prices (Conrad and Clark, 1987).

Economic Interpretation Of The Maximum Principle

In the formulation of our problem we introduced λ_t as an unknown function. The principle economic fact arising from the derivation of the necessary conditions above is embodied in the definition of (λ_t) as being equal to the marginal revenue.

$$\frac{\delta(p_t * h_t)}{\delta x} = \lambda_t$$

Because $p_t * h_t$ represents the value of the resource stock at time t, this definition identifies λ_t as the marginal value of the capital stock x at time t. For example if the resource stock level is reduced by harvesting one unit, its value at time t will be reduced by λ_t. The loss in value when a capital asset is reduced by one unit is called the Marginal User Cost (MUC). Therefore, λ_t is the marginal user cost along the optimal trajectory x^*_t. The variable λ_t is sometimes called the shadow price of capital (Clack, 1976). "Shadow price" refers to the fact that the asset's value is not its direct sale value but the value imputed from its future productivity.

Economic Interpretation of the Hamiltonian

The hamiltonian expression

$H(x_t, h_t, \lambda_t) = p_t * h_t + \lambda_{t+1}[F(x) - h_t]$ has an important economic interpretation. The two terms on the right hand represent value flows. H(p, h) is the Revenue or flow of accumulated "dividends" and $F(x) - h_t$ is the flow of "investment in trees" $dx/dt = F(x) - h_t$. To express this investment flow in value terms it must be multiplied by the shadow price λ_t.

Consequently the Hamiltonian $H(x_t, h_t, \lambda_t)$ represents the total rate of increase of total assets (accumulated dividends plus capital assets). The maximum principle then asserts that an optimal control (h_t) must maximize the rate of increase of total assets. However, before the optimal choice of h_t can be determined, we must know the shadow price λ_t. In a sense the maximum principle reduces the optimal control problem to the problem of determining the marginal user cost λ_t (Clark, 1976).

The Concept of User Cost

In Mzola forest the F.C does not incur production costs since trees are just growing except for silvicultural and logging administration costs. Nevertheless, the fact of scarcity itself imposes costs in the intertemporal setting. Consumption in the current period comes at the expense of satisfaction forgone in the future. The user cost of the current consumption is defined as the value of that forgone future satisfaction. An increase in the harvest rate(h_t) reduces the available resource in the next period x_{t+1}. Thus λ_t is an inter-temporal cost, which is

The rough sawn timber is then sold to Wilgrow Norton and Timberland at the following prices:

1) super grade $5 000/m^3
2) grade A $3 500/m^3
3) grade B $3 200/m^3
4) grade C $2 500/m^3.

According to the foreman, the product mix is in the ratio 1:2:2:3 for super grade:grade A:grade B:grade C, respectively. If we use these ratios then the weighted unit price of rough sawn timber will be $3 237/m^3.

If we take rough sawn timber in Mzola as the final product, then we can estimate the unit value of a standing Mukwa tree in the forest by subtracting the unit processing cost from the unit price of the final product. This gives a residual stumpage value of Mukwa as $3 119.17/m^3.

Discussion

Although one of the most recommended method of setting stumpage fees (competitive bidding) is used, the royalties are still lower than the minimum acceptable stumpage fees. The above result show that both teak and mukwa are under-priced since the royalties charged by the FC are lower than the residual stumpage value. The current royalty charges for teak in Lupane and mukwa in Mzola are $450/m^3 and $700/m^3, respectively. Therefore, teak is undervalued by 76% (or $1 450/m^3) while mukwa is under valued by 77.6% (or $2 419.17/m^3) and we accept the hypothesis that the stumpage prices charged by the FC is lower than the residual stumpage value of the two forest resources.

Low forest fees mean that forest pricing policies are pointing the wrong way signalling abundance rather than future scarcity. This is mainly due to the fact that bidding can only set resource value that reflect the marginal user cost if there is enough competition. However, in Zimbabwe the CIT industry is characterized by the presence of a few dominant enterprises (PG for example) who easily set the upper limit stumpage value.

The current stumpage value is artificially depressed since middle men and millers are getting large profits from sale and resale of timber to which little or no value has been added. For example Wilgrow in Mzola sells grade C rough sawn Mukwa to Wilgrow Norton and Timberland at $2 800/m^3. However, the same product in Norton is sold at $3 500/m^3 to other customers. Thus Wilgrow in its transfer price to its subsidiary Wilgrow Norton is not charging a competitive price.

Contrary to Mushove's (1994) view that transportation of a commodity from one point to another adds nothing useful to the commodity but often reduces quality and increase costs, Timberland transports round timber with its barks from Lupane to Bulawayo a distance of about 180km and still makes a profit. This is because the off-cuts and bark constitute an important source of heat energy which is used to cure logs in the Kilns. Some of the off-cuts with bark are sold to local communities and small pieces are laminated to produce laminated doors. The saw dust is mixed with sand-sealer to make a fluid which is used to seal holes in doors, thereby making maximum utilization of the extracted timber. From the above calculation a total of 28m^3 are transported at a total cost of $20 000 per month. Since 12% of the volume transported is bark (that is 3.36m^3) it means $2 400 is spent each month to transport bark. However, off-cuts are a cheaper source of energy than alternative sources.

Since the costs are based on the figures given by the companies, the calculated stumpage value is greatly affected by the efficiency of the companies. The results can be improved if costs are based on averages of costs of operations of normal efficiency, so as not to reward inefficiency.

Low forest fees encourage wasteful utilization of forest resources and wasteful logging and processing. Information in the records of Wilgrow show that the average volume which is finally paid for, and carried to the processing site (the extracted volume) is 175m^3 per month. However, the calculations above show that the three men crew can harvest 43 trees per day with an equivalent volume of 36.802m^3. Therefore, of the 522m^3 harvested per month only 175m^3 are finally used. Assuming that there is no timber poaching (that is there is

Discount rate
In this study discounting is done to allow for the comparison costs and benefits which occur at different time periods. The discount rate has an effect on the rate of resource exploitation. A zero discount rate imply that society is indifferent between consumption now and in the future. In this analysis a discount rate of 5% (based on the average long term interest on tresury bills in Zimbabwe, see Hansen, 1994) was used. Sensitivity analyses were done at 4%, 6%, 8%, 10%, and 12% to see the effect of the changes in the discount rate on the NPV.

Table 1. Summary of Parameter Values

Parameter	Symbol	Estimated Value
Biomass		
Resource stock	X	20 408.845m3
Carrying Capacity	K	132 170.000m3
Growth Rate of Mukwa		
Intrinsic Growth Rate	r	0.04
Inverse Demand Function		
Intercept	α	144 324.7
Gradient	β	-55.4
Discounting	δ	
Discount rate		0.5

Results of the optimization model
Parameters given in Table 1. above were used to determine the optimal price and harvest volume of mukwa that will maximize NPV.

The NPV
The results show that at the 5% discount rate the resource can be exploited continuously. A maximum NPV of Z$29 930 961 can be earned in 24 years.

Exploitation
The results at a 5% discount rate show that mukwa can be harvested continuously at a progressively declining rate. The volume harvested decreases from 1296.55m^3 in the first year to 1294.02m^3 in the twenty-forth year. A NPV of $46 006 172 will be earned during this period. Thereafter the exploitation rate will be equal to the growth rate of the resource thus keeping the resource stock constant.

Currently the concessionaire is harvesting an average of 522m^3 per month which gives an annual allowable cut of 6 264m^3 . Therefore the current rate of exploitation is almost five times the MSEY. This is because the FC uses "pulse" exploitation where the resource is exploited heavily for 5 to 10 year and after that exploitation is stopped for 60 to 90 years.

The results of the model also ignore the requirement by the FC which allow only trees with a DBH of 35cm or above to be harvested. The exploitable volume of mukwa (that is the volume of trees with DBH above 35cm) in Mzola forest is about 6 112.72m^3. Therefore, the volume of the resource that should be maintained is 14 296.13m^3. If we impose the DBH constraint, then mukwa should be harvested for ten years after which exploitation should stop. A total NPV of Z$9 947 693 will be earned during the ten year exploitation period. Exploitation may continue after the ten years, provided the exploitation rate is equal to the growth rate of the

Effects of the discount rate on the marginal user cost

The marginal user cost (the cost of harvesting the resource now to the future) at higher discount rates (6%, 8% and 10%) were higher than at a lower discount rate of 4%. Therefore, the cost to the future of harvesting a resource at a high discount rate will be high.

Effects of the discount rate on the rate of exploitation

The results show that the resource will be exploited at a greater rate if the discount rate is high and the exploitation rate will be lower at a lower discount rate. Therefore the resource stock will be depleted faster at a high discount rate than at a lower discount rate.

Effects of the discount rate on the Growth rate

Since the resource is exploited at a faster rate at high discount rate, the resource growth rate will be lower at higher discount rate. At high discount rate the resource is overexploited thus reducing the resource's ability to grow. At a lower discount rate of 4% the resource is exploited at a lower rate and the resource stock is high. Therefore, the growth rate of the resource is highest at 4%.

Discussion

The results from the optimization model show that the Net Present Value (NPV) is maximised when the discount rate is low. The results also show that the price of the resource must increase as the resource becomes scarce and that the resource is overexploited if the discount rate is high. The MUC (the cost of current resource use to future generations) is high if the social discount rate is high. Although these results are consistent with natural resource economic theory, the sensitivity analyses show that the optimal solution is sensitive to changes in the level of discount rate. Therefore, it is important to use an ideal discount rate since a slight change in the discount rate results in a large change in the optimal price, and harvest rates.

Conclusion

A number of reports (see Judge, 1975, World Bank, 1993, FC,1995, Mushove, 1994) show that CIT is being exploited at an unsustainable rate. The main objective of this study was to determine the optimal price and the Maximum Sustainable Economic Yield (MSEY) which will maximize the Net Present Value of the forest resource. This study differs from previous studies because it does not just explain the problems and causes of over exploitation of the forest resource, but it goes beyond by determining the prices and the MSEY which will encourage sustainable CIT management.

To achieve the study objectives, we use the residual approach to determine the residual stumpage value (the value of a standing tree in the forest) of teak and mukwa. The results show that both teak and mukwa are undervalued by 76% and 77% respectively. This method was also used by Mushove, 1994 and he found that mukwa was undervalued by 63%. However, the residual approach has the major weakness of calculating a residual stumpage value which depends on the logging, transportation, and processing costs of the firms. If the firms are inefficient the resulting residual value will be low thus rewarding inefficiency. The residual approach also determine a static value which does not reflect the scarcity value of the resource as the resource approach extinction.

To overcome these weaknesses a model which incorporates biological and economic information (Bioeconomic Model) was developed to determine the MSEY and the Marginal User Cost (MUC) over time. In summary the results of the dynamic economic model show that an efficient allocation of a resource with a constant marginal extraction cost involves rising marginal user cost and falling quantities harvested. The results also show that mukwa is undervalued and the current harvest rate is greater than the MSEY.

Policy Implication

The results show that the price should increase as the resource becomes scarce to reflect the scarcity value of the resource. As the resource becomes scarce the price rises and concession will be given to those who value them most. Thus the results can be used to encourage efficient utilization of the resource and reduce wasteful harvesting and processing.

Mozambique.

The second limit is that the bioeconomic model used in this study does not have a cost function. The bioeconomic model assumes that the FC incur zero costs in the management of CIT logging. This is due to the fact that time series data on the cost incurred by the FC specifically for CIT management could not be obtained. The only cost available is the salary of the timber-measurers. However, the salaries could not be used for the regression analysis to get the cost function due to the following reasons: 1) the salary has been constant during the concession period making it impossible to regress volume harvested against a constant, and 2) logging in Mzola started in January 1997 thus giving data for only 6 month. This is a short time series which will suffer from degrees of freedom.

Therefore, the results can be improved by constructing a cost function using national data on the monthly costs incurred by the FC in CIT management and volume harvested.

In chapter five we calculated the residual stumpage value based on the logging, transportation, and processing costs. However, stumpage prices that reflect harvesting, transport, and processing costs only undervalue the forest resources since they ignore the environmental role of forests. Therefore there is need to do a Total Economic Valuation (TEV) of the forest using conventional, implicit, and artificial markets. Valuation of the environmental resource is a fundamental task for sustainable development due to the following reasons:

1) It measures the rate at which the resource is being used up, and signals the growing scarcity to their users,
2) valuation can provide a truer indication of economic performance, and
3) quantification carried out carefully can provide a more secure basis for policies to induce more careful environmental use.

The objective is to integrate environmental concerns into the conventional economic decision making processes by providing policy analysts with better information upon which to base decisions involving alternative land uses. The optimal stumpage price of the forest resource that will encourage sustainable utilization can only be determined after determining the TEV of the forest resource.

Further studies can also be done in order to determine ways of co-ordinating concessionaire and informal craft activities. The results show that the concessionaires in Mzola utilizes large logs above 0.9m. On the other hand people in the informal craft cut large trees to take small logs. Therefore, there is need for research to determine ways which the FC can use to improve efficient utilization of the forest resource by co-ordinating the activities of the private concessionaires and the informal craft.

In the study utilization by the local communities and squatters is not taken into account. In the past, when land and other natural resources were plentifully available, due to low population densities, there was no unacceptable clash between the need to protect the environment and the demand of the rural populations. However, as the population increases the demand of land for agriculture and settlement also increase. The demand for land does not stop at the borders of national parks and protected forest. Intervention by the F.C or Local Authority usually lead to conflict (as is happening in Mzola). However, some of the conflicts are a result of the poor convectional nature conservation strategies. These strategies are based on the concept that absolute protection is the goal, that fauna and flora should be sealed off and protected from anthropological intrusion. National parks and protected forests should exist not just to protect animal and plant communities but should also serve human needs.

Integrated nature conservation might be the solution. Therefore there is need to do research to develop policies targeted at reducing the conflicts between protection and exploitation of the forest resource by getting the rural population more closely involved in the development of long-term nature conservation strategies. This may lead to the solution of the squatter problems faced by the forest commission in Mzola.

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