YIELD REGULATION BY AREA-VOLUME CHECK METHOD: A CASE STUDY AT SAO HILL IN TANZANIA

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Summary

Sao Hill is the largest forest project in Tanzania with 30,000 hectares planted by 1983. Its final target is 65,000 hectares. It supports a state owned sawmill and a pulp and paper mill. Managing this forest on a non-declining yield basis is the main objective. Since the forest structure is abnormal, yield regulation is necessary. A feasibility study was conducted using the area-volume check method which is currently identified as a feasible model. It is suggested that management of this forest on the basis of non-declining yield is possible. Where computing facilities are limited this method of regulating yield may be more useful than using simple but rigid formulae.

Introduction

Sao Hill Forest is the largest state owned industrial plantation project in Tanzania with 30,000 hectares planted by 1983. The final target is to have a total of 65,000 hectares. The main species are pines (*Pinus patula, Pinus caribaea, Pinus elliottii*) and eucalypts (*Eucalyptus gradis, Eucalyptus saligna* and *Eucalyptus maidenii*). A state owned sawmill viz. the Sao Hill Sawmill Ltd., is already working in the forest with an annual log throughout of 45,000 m^3 and also a pulp and paper mill, that is the Southern Paper Mills Company Ltd with an initial annual log input of 300,000 m^3 has become operational since May 1985. Since these wood industries have no alternative sources of roundwood and currently demand for their products exceeds supply "balanced quantity" (Nersten, 1969) or non-declining yield as a forest management objective is rational.

The forest structure is abnormal as a result of irregular annual afforestation programmes (see appendix IV). The forest manager is thus confronted with the problem of regulating yield in volume and in time to meet the industrial demand.

Yield Regulation Techniques

Numerous techniques for regulating yield of a forest are cited in the literature (Chapman, 1950, Knuchel, 1953, Hummel and Grayson, 1957, Davis, 1966; Hiley, 1967, Mathur, 1968; Osmaston, 1968). Most of them were developed to suit specific local conditions, specific silvicultural systems and solve specific managerial problems and they are not necessarily appropriate to this situation. The appropriate yield regulation technique for Tanzania involves

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a combination of area and volume control. Timber scheduling models which seem of interest include the area-volume check method, mathematical programming and simulation. The availability of computing facilities being limited to the Sao Hill manager, the area-volume check method was selected as a practical technique worth a trial (Mgeni, 1979). Among others, Hennes, Irving and Navon (1971) have discussed this model in details. They found that the model was superior to formula techniques but inferior to linear programming.

The formula techniques tested were the area control method, Hanzlik Formula, and Austrian Formula. The 'modus operandi' of the area control method being referred here is to calculate an annual or periodic cutting area by dividing the total area of the whole forest in question with a fixed rotation age. Since the formulation of other two formula techniques tested can be found in several books on the forest management (see for instance Chapman, 1950; Davis, 1966; Osmaston, 1968), they are not presented here. However, the main lacuna of many formula techniques is their calculus being based on a normal forest (Ware and Clutter, 1971), a situation not applicable to many yield regulation problems. To find an optimum harvesting schedule among several alternative schedules available within the given management objectives and constraints, mathematical programming particularly linear programming has been of growing interest in forest management (Curtis, 1962; Leak, 1964; Loucks, 1964; Kidd, Thompson and Hoepner, 1966; Nautiyal and Pearce, 1967; among many others). Linear programming is applicable in situations where management objectives and constraints can be expressed in the form of linear equations. To handle big dimension problems using mathematical programming demands availability of computer facilities, a restraining bottleneck to many Third World forest managers.

YIELD REGULATION AT SAO HILL

Forest Inventory

Sao Hill Forest is subdivided into three spatial operational divisions viz. Division I, II and III. Prior to 1975, Sao Hill Forest Project was constituted by the Current Division I. With the conception of establishing a pulp and paper mill based on Sao Hill Forest plantations, more land had to be acquired. Thus in 1975, areas covered by Divisions II and III were gazetted as forest reserves. Since the afforestation scheme had not been completed by the time of this study, yield regulation was investigated in a form of a feasibility study. Division I investigated in a form of a feasibility study. Division I (prior to 1975, Sao Hill Forest Project) with the forest structure approximating that of the whole forest when the final afforestation is accomplished was chosen for the study.

The compartments were stratified into stands on the basis of five year age and site classes. There are four site classes that is I (33m*), II(30m*), III(27m*) and IV(24m*). The age classes were 0(0 years), 1(1–5 years), 2(6–10 years), 3(11–15 years), 4(16–20 years), 5(21–25 years) and 6(>25 years). A stand denoted as 4 II meant it is in age class 4 and site class II. Systematic

* Dominant height at 20 years of age.

sampling was applied to provide information on site class, standing volume and crop health of each stratum or stand. Since the planting rows and columns are very distinct in Division I systematic sampling was viewed as being faster than any other sampling technique in terms of inventory time. Constrained with time, systematic sampling was chosen mainly on this merit.

Forecasting of stand Volume and thinning

Based on forest inventory results, future volumes were forecasted for each category or stratum for six five year periods. The only available growth and yield model for Sao Hill being a normal yield table (Adegbehin, 1977), in fully stocked stands, the periodic volume increment and thinning volume were extracted from it. Due to low planting survival in some stands, understocking is experienced. Since there is on variable yield table to handle forecasting in such understocked stands, Gehrhardt's formula (Mgeni, 1983) was used in estimating the periodic volume increment while thinning volumes were calculated by reducing the thinnning volume indicated by the yield table by a ratio of the stand's projected standing volume to normal volume at the same age. Thinnings and clearfellings were assumed to be carried out at the beginning of each five year period. A clearfelled stand was assumed to be artificially re-generated the following year with the site class remaining unchanged. The normal rotation was assumed to be 30 years.

In each period, possible thinnings were calculated followed by increament estimation as explained above, in both cases the units are in cubic metres per hectare. Prior to the first five year period of yield forecasting, a mean volume and age were calculated for each stand in the year of inventory taking. Arbitrarily fixed, the first five year period began two years after forest inventory taking. Defining VO = stand's volume in the year of taking inventory; VI = two year stand's volume increment immediately after inventory taking; V2 = stand's volume at the beginning of each five year period; V3 = stand's thinning volume; V4 = stand's volume remaining after thinning and; V5 = stand's five year volume increment; all in cubic metres per hectare; the stand forecast proceeded as chronologically expressed by the following equations:— In period 1, V0 + V1 = V2; V2 – V3 = V4; V4 + V5 = V2 of period 2. This calculation was carried up to the sixth five year period as illustrated in appendix I. The denotion of the stands are as previously defined. Since stands clearfelled in periods 1 to 3 will be due for thinning during the regulation period, they are also included in the stand forecast and denoted by S1, S2 and S3 respectively for each site class.

Computing the non-declining yield

The following constraints were imposed:—

- the conversion period was set to 30 years, that is one normal rotation;
- a range of 19 to 31 years in the age of final felling was accepted as such crops produced dimensions of roundwood acceptable to the existing sawmill;

- an improved–that is more regular –age class distribution at the end of the conversion period was demanded;

- during the conversion period, each hectare could be scheduled for clearfelling only once.

The stands were ranked in order of priority to constitute a clearfelling sequence using age, stocking, site class, health conditions and accessibility as criteria in ranking. The following rules of thumb were applied:–

- since trees reach marketable dimensions earlier on better sites, stands on such sites received a higher priority for being clearfelled than those on poor sites;

- in the same site class, stands were clearfelled in age descending order;

- the stand with a low stocking in such way that the trees would not fully utilize the space received a high priority for being clearfelled provided timber dimensions were marketable;

- any stand being inaccessible for wood extraction during the forecast period was excluded from the calculation;

- stands with poor health crops received the highest priority in being clearfelled; and

- where there are more than one species, any indicated preference should be included in the above rules.

The periodic volume increment in the previous five years for the whole of Division I was used as an initial allowable cut estimate which was 70,110 m^3. Thinning being a silvicultural operation was considered first in each period. The difference between the allowable cut and the total thinnings gave volume obtainable from clearfellings. The stands were then scheduled for clearfelling in sequence of their priority ranking until this volume from clearfelling was met. The procedure may be further clarified by giving an example as illustrated below:–

Period 1: due thinnings (m^3) were 29,125; volume to be obtained from clearfelling (m^3) = D = 70,110 – 29,125 = 40,985. Following the felling sequence ranked according to the rules of thumb given above, the first stand to be clearfelled was 4 II at the age of 19 years with an area of 93.0 hectares (ha) and from the stand forecast its standing volume at that age is 511 m^3 with no due thinnings. The area of the stand 4 II to be clearfelled (x) was calculated using the following formula with symbols as already defined : –

$$X = \frac{D}{V2 - V3} = \frac{40{,}985}{511 - 0} = 80.2 \text{ ha}$$

The area of the stand 4 II remaining uncut : 93.0–80.2 = 12.8 ha. This area was carried forward to period 2 where it received a first priority for clearfelling at the age of 24 years.

Period 2: due thinning volume was (m^3) 38,786; volume to be obtained from clearfellings is (m^3) = D = 70,110 – 38,786 = 31,324. The first stand to be clearfelled in period 2 is 4 II at the age of 24 years with an area of 12.8 ha and from the stand forecast V2 = 564 and V3 = 103; Hence,

$$X = \frac{D}{V2 - V3} = \frac{31,324}{564 - 103} = \frac{31,324}{461} = 67.9 \text{ ha}$$

As stand 4 II was only 12.8 ha, another stand for clearfelling was needed. A new D had to be recalculated first that is 31,324 – (12.8 x 461) = 25,423. According to the felling sequence stand 3 1 was the next at the age of 20 years with an area of 10.0 ha and from stand forecast V2 = 404 and V3 = 84; Hence,

$$X = \frac{D}{V2 - V3} = \frac{25,423}{404 - 84} = \frac{25,423}{320} = 79.4 \text{ ha}$$

As stand 3 I was only 10.0 ha, another stand was needed for further clearfelling and another D had to be recalculated. The new D was 25,423 – (10.0 x 320) = 22,223. Again according to the felling sequence, the next stand was 3 II at 21 years of age with an area of 297.0 ha and V2 = 383 and V3 = 82.

$$X = \frac{D}{V2 - V3} \quad \frac{22,223}{383 - 82} = \frac{22,223}{301} = 73.8 \text{ ha}$$

The area of stand 3 II remaining uncut and carried forward to period 3 was 297.0 – 73.8 = 223.2 ha. Such a calculation was repeated period by period up to the sixth period. There were three possible outcomes to this calculation of regulating yield, that is:–

– the initial allowable cut that is 70,110 m^3 was sustainable within the constraints of minimum and maximum clearfelling ages;

– the initial allowable cut was too high with the result that no crops were available for clearfelling in the later year periods; and

– the cut was set too low and crops reached the upper limit of age before being scheduled for clearfelling.

In fact the initial allowable cut estimate of 70,110 m^3 produced the last eventuality mentioned above and the computations had to be repeated with a higher allowable cut. In all four cutting trial strategies devised iteratively were carried out. Chronologically, these cutting strategies were:–

– Cutting trial 1: equal five year periodic out-turns of 70,110 m^3 as illustrated above;

– Cutting trial 2: equal five year periodic out-turns of 100,000 m^3;

– Cutting trial 3: equal five year periodic out-turns of 75,000 m^3 period 1 and 120,000 m^3 for each of the period 2 to 6 inclusive; and

– Cutting trial 4: a five year periodic out-turns of 100,000 m^3 in period 1; 90,000 m^3 in period 2; 105,000 m^3 in period 3; and 120,000 m^3 in periods 4 to 6 inclusive which was accepted as being laudable scheduling strategy (see appendix II).

The above illustrated procedure of regulating yield using area-volume check method can be computerised (Chappelle, 1966).

Discussion

The different cutting strategies attempted produced different results as summarized below:–

– some cutting strategies led to either lengthening (trial 1) or shortening (trials 2 and 4) of the rotation age;

– some cutting strategies did not improve the area distribution of the forest according to age classes (trials 1 and 3);

– some cutting strategies led to the postponement of thinnings in period 6 (trials 2 and 4);

– some cutting strategies led to the fall of yields in certain periods which is contrary to the non-declining yield or balanced quantity (trial 4); and

– some cutting strategies (trials 1 and 2) left some stands unclearfelled within the conversion period.

Cutting strategy 4 (see appendices II and III) was accepted as a compromise on the improvement of forest structure, rotation age constraint and the non-declining yield concept. The cut in period 2 Violated the non-declining yield constraint because there were insufficient old stands to be clearfelled. However, it should be possible to achieve a non-declining yield by minor adjustments between the coupes schedules for periods 1 and 2.

The likely source of error in a yield forecast of this kind are:–

– misclassification of the stands;

– assumptions made not withstanding for the whole planning period (cutting policy; market demands, assumptions embodied in the stand forecast, growth and yield model used, etc); and

– catastrophies (fire, disease and insect epidemics).

The area-volume check method partly depends on the manager's judgement in scheduling priorities and it does not maximize profit or minimize costs of cutting strategy. However, it enables the manager to visualise some of the consequences of a given cutting strategy such as the level of re-investment needed for regeneration, the wood supply available to the industry, and the level of revenue etc. Where computing facilities are limited, as in Tanzania, the area-volume check method may be very useful in helping the manager in making decisions on scheduling cutting strategies. Continuous monitoring of the assumptions made in such yield regulation technique is imperative in order to get feedback on the model and improve it 'mutatis 'mutandis' as feedforward. As computing facilities improve mathematical programming and simulation models should be developed as they overcome some of the weaknesses inherent in the area-volume check method.

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APPENDIX I

Stand forecast

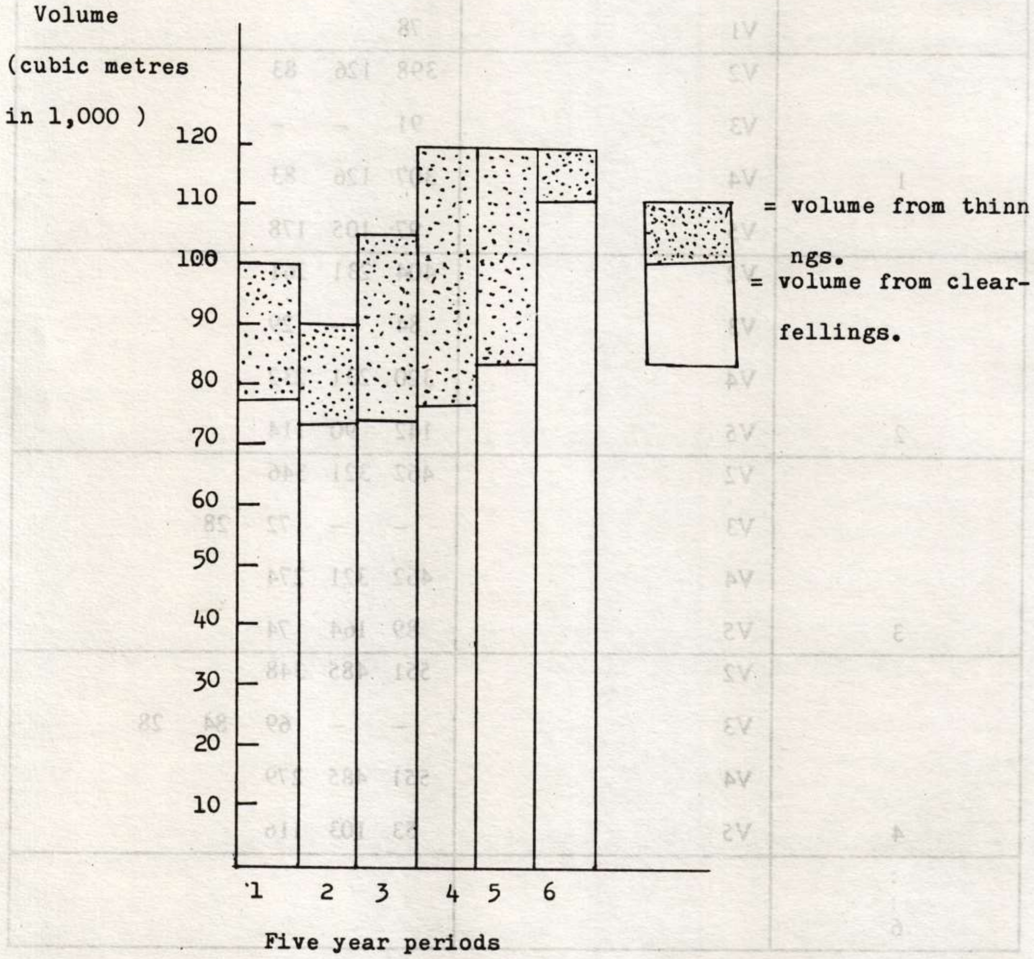
Species : *Pinus patula*. Site class : I

5 year period	stand	3I	2I	1I	S1	S2	S3
	Mean age (years)	13	7	4			
	V0	320					
	V1	78					
1	V2	398	126	83			
	V3	91	–	–			
	V4	307	126	83			
	V5	97	105	178			
2	V2	404	231	261			
	V3	84	–	29			
	V4	320	231	232			
	V5	142	90	114			
3	V2	462	321	346			
	V3	–	–	72	28		
	V4	462	321	274			
	V5	89	164	74			
4	V2	551	485	348			
	V3	–	–	69	84	28	
	V4	551	485	279			
	V5	53	103	116			
⋮ 6							

V0 = volume in the year of taking inventory; V1 = 2 year volume increment; V2 = volume at the beginning of the period; V3 = thinning volume; V4 = volume remaining after thinning; V5 = 5 year volume increment; All volumes are in cubic metres per hectare. S1, S2, S3 = new stands established from old stands clearfelled in periods 1, 2 and 3 respectively.

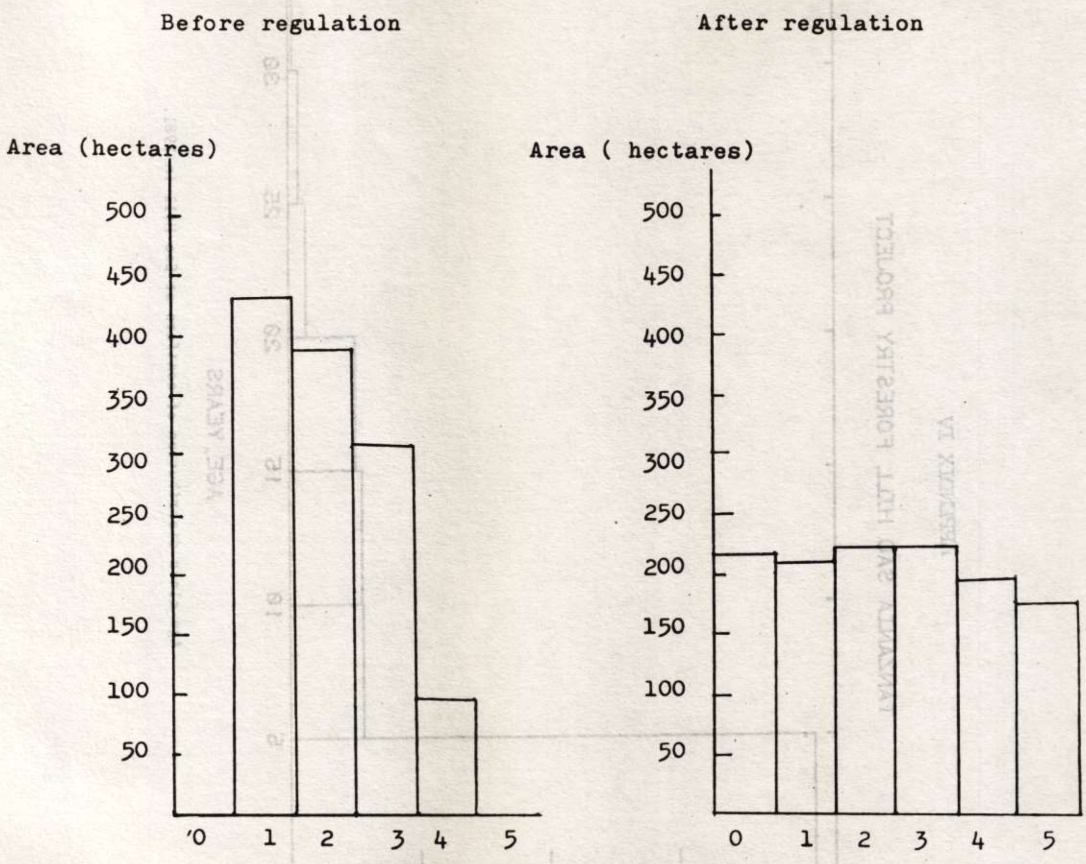
APPENDIX II

Yield forecast



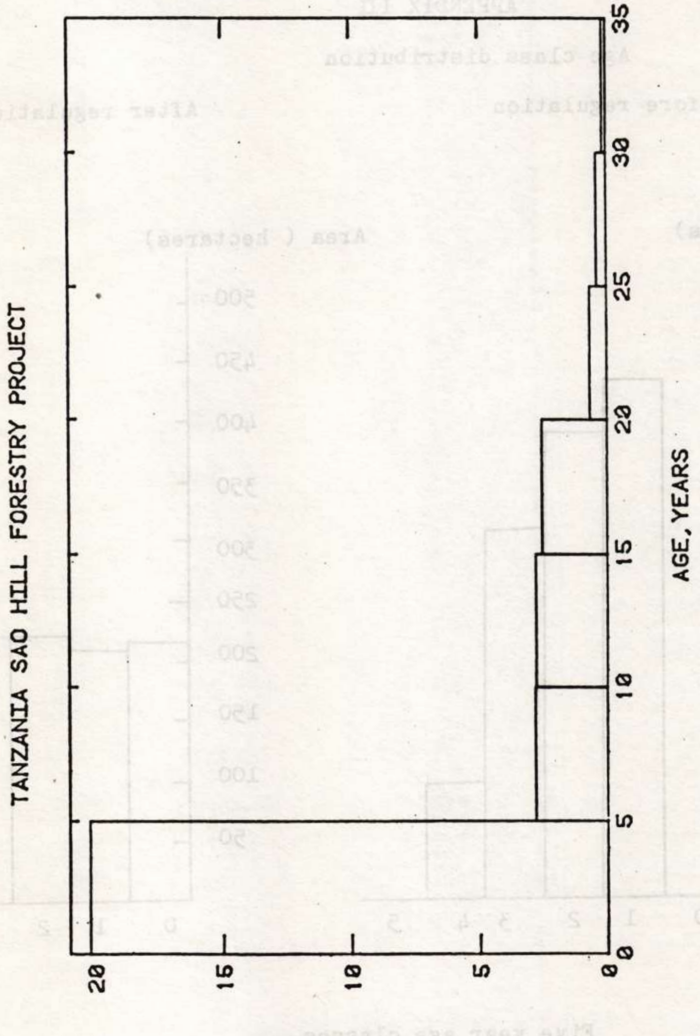
APPENDIX III

Age class distribution



Five year age classes

APPENDIX IV



Age class distribution of conifers at Sao Hill in 1981.