New Forests **16:** 89–99, 1998.

A financial analysis of a small scale *Gmelina arborea* Roxb. improvement program in Costa Rica

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Accepted 31 October 1997

Key words: Central America, smallholder forestry, genetic improvement, seed orchards

Application. Tree improvement activities for and by smallholder farmers, particularly in Central America, have largely been limited to low-intensity activities such as seed stand establishment. The main reason for this appears to have been the common view that higher-level tree improvement is not economically justifiable for relatively small-scale planting programs. We describe a financial analysis which suggests that seed orchard programs are often economically justifiable at annual planting rates of 125 ha or less. On this basis, we recommend that tree improvement above the seed stand intensity be more widely adopted in support of smallholder tree planting. The main application of the study would therefore be to justify such policies and, thereby, to improve the quality and productivity of smallholder plantations.

Abstract. A financial analysis of a small-scale *Gmelina arborea* improvement program in Hojancha, Guanacaste Province, Costa Rica is described. The program consisted of a clonal seed orchard, made up of ramets of plus-trees, and three progeny tests/seedling seed orchards. A 5% discount rate was used. The total discounted/compounded cost of the program was US$25423. The analysis demonstrated that this outlay would be justified at annual planting rates of between 31 ha per year (at 20% genetic gain in volume) to 125 ha per year (at 5% genetic gain) over the 20-year life of the orchard. These results demonstrate that the implementation of such small-scale, locally-based programs by community-based or locally-orientated organizations may often be justifiable.

Resumen. El documento presenta los resultados de un análisis financiero de un programa de mejoramiento genético de escala pequeña de *Gmelina arborea* en Hojancha, provincia de Guanacaste, Costa Rica. El programa consistió en el establecimiento de un huerto semillero clonal, conformado por ramets de árboles “plus”, y tres ensayos de progenies/huertos semilleros de plántulas. Se empleó una tasa de descuento de 5%. El costo compuesto total del programa fue de US$25423. El análisis demostró que tal inversión sería rentable con tasas anuales de plantación de 31 a 125 ha por año, a 20% y 5% ganancia genética en volumen, respectivamente, durante la vida útil del huerto (20 años). Estos resultados demuestran que, en términos financieros, se puede justificar la implementación de tales programas por organizaciones comunitarias.

Introduction

In recent years there has been increasing interest in strategies for smallholder tree improvement (e.g. Barnes, Simons and MacQueen 1992; Burley 1980; Chuntanaparb and MacDicken 1991; MacDicken and Bhumibhamon 1990; MacDicken and Mehl 1990; Mesén, Boshier and Cornelius 1994; Raintree and Taylor 1992; Simons 1992; Simons, MacQueen and Stewart 1994; Sinclair, Verinumbe and Hall 1994; Venkatesh 1988). Small-scale, locally-based approaches to tree improvement by or for smallholders would appear to have advantages over large-scale, centralized programs, e.g. it is easier to take into account local differences in species preferences, environment and ideotypes; farmers can be involved or take charge of the process more easily; overall genetic diversity may be enhanced; costs are likely to be lower because of short distances from base to field sites. Many studies have demonstrated the potential or realized profitability of industrial-scale tree improvement (e.g. Willan 1988; Zobel and Talbert 1984). However, such studies have not been reported for small-scale, locally-based activities in support of small to modest planting programs. This paper addresses this issue, taking as an example a *Gmelina arborea* improvement program for the Hojancha Canton Agricultural Center (CACH), in Guanacaste Province, Costa Rica. The Costa Rican Cantonal Agricultural Centers are cooperative-like organizations, originally established by the government, but now practically autonomous and self-financing. A part of their income is derived from affiliation fees paid by farmers.

The context: Forestry and tree improvement in Hojancha

The canton of Hojancha is located in the seasonally dry, Pacific northwest of Costa Rica. Its 230 km^2 are dedicated almost entirely to farming. Since the late 1970s, this activity, which historically consisted of production of cattle and, to a lesser extent, staple crops (Campos, Rodríguez and Ugalde 1992), has been increasingly supplemented by plantation forestry. By 1995, more than 1700 ha of plantations, around 50% of them of gmelina (José Miguel Valverde, CACH, pers. comm.), had been established, mostly as 2–3 ha blocks on small- and medium-sized holdings. Initially, farmers' interest in tree planting appears to have been largely a result of declining productivity and profitability of traditional activities, promotion of forestry activities by agencies such as CATIE and, particularly, CACH, and government reforestation incentives. More recently, however, farmers increasingly appear to be accepting tree planting as a 'mainstream' productive activity, undertaken in expectation of income from the final product rather than from government incentives. The installation by CACH of a small-diameter sawmill, which is now working at full capacity (José Miguel Valverde, CACH, pers. comm.), and provides a ready local market, is presumably partially responsible for this trend.

In the mid-1980s, CACH and CATIE initiated tree improvement activities in Hojancha. Currently, the program concentrates on gmelina, and consists of three main components: seed stands, two progeny tests of plus-tree material, one of which is under conversion to a seedling seed orchard, and a pilot program of vegetative propagation and clonal testing. Selected germplasm (at present available only from seed stands) will be supplied by CACH to smallholder farmers through the existing seed and plant distribution system. At the request of CACH, a long-term breeding strategy is being prepared by CATIE's Tree Improvement Project.

Methods

General approach

The aim of the study was not to financially analyze the activities carried out to date by CACH, but rather to use CACH as a model in the formulation of a simple program of activities whose analysis would permit some conclusions of general application to be drawn. For this reason, the program analyzed is based on the traditional configuration of clonal seed orchard plus progeny tests/seedling seed orchards. Some, but not all, of this program has already been implemented by CACH/CATIE. The rest may be implemented by CACH as part of the long-term strategy currently being drawn up. After defining what activities the program would consist of and when they would be carried out, costs were estimated, mostly from actual cost data collected over many years by the CATIE Tree Improvement Project. Gross returns were then estimated for various genetic gain scenarios. Both costs and returns were discounted or compounded to the base year using standard formulae. Following this, the break-even annual planting area was calculated, i.e. the annual area of improved plantations that must be planted in each year of orchard life in order to produce enough gain to justify the costs of the program (i.e. to give internal rates of return equal to the discount rate or net present value of zero). A real interest rate of 5 per cent was used throughout. As real interest rates from alternative long-term investments are unlikely to move above 1–2% (von Platen 1995), this is considered to be a conservative assumption. The year of trial establishment was taken as the base year for compounding and discounting purposes. All calculations were made using a spreadsheet file, copies of which are available from the senior author.

Description of the program: The base scenario

The program begins with the selection, on stem straightness and growth criteria, of 70 plus-trees within local gmelina plantations. The following year, 3 progeny trials, each with the same 50 families, are established. The remaining 20 families are assumed to be unavailable for planting because of seed collection or germination problems. Each trial has 15 randomized complete blocks, three trees per plot, 3 m × 3 m spacing, and a two-tree border around the entire trial. The trials are maintained according to local practice, and measured in year three before thinning. At year three, a consultant is employed to analyze the trial data. On the basis of the analysis, the best families are identified and ramets collected from the plus trees for the establishment of a clonal seed orchard, while the progeny trials are converted to seed orchards through a single heavy thinning. Seed production is assumed to start in year 7 in both seedling and clonal seed orchards. The first improved plantations are established in year 8, and harvested in year 18. The orchards are assumed to have a productive life of 20 years. With the exception of the consultant contracted to analyze the trial data, the program is implemented wholly by CACH, through a team consisting of the CACH Head Forester, a field assistant, and casual laborers.

Costs of the program

All activities that, in the absence of a tree improvement program, would be unnecessary to secure (unimproved) seed supplies were costed (Table 1). An overhead of 15% was allowed to cover administrative costs and maintenance/depreciation of infrastructure. Total present value costs of the program were estimated at US$25423 (Table 3).

Returns from the program

The forecasting of yield increases due to genetic improvement is perhaps the most problematic element in the financial analysis of tree improvement (Cornelius and Morgenstern 1986; Fins and Moore 1984; Friedman 1992; Ledig and Porterfield 1982). In the CACH program, as in most other programs that have been analyzed, data on realized genetic gain are not yet available. In addition, there are little reliable data on which to base estimates of current productivity, and in any case such historical data would be of dubious relevance as, due to inexperience, many plantations have been established on unsuitable sites and have received poor management, particularly as regards thinning. Rather than attempt to forecast gain, it was decided to make calculations for genetic gains in volume from 5–20%, applied to a plantation program

Table 1. Present value costs at 5% discount rate of one progeny trial/seedling seed orchard in a *Gmelina arborea* improvement program in Hojancha, Costa Rica.

Activity	Year	Total actual cost[1] ($US)	Present value ($US)	Source	Notes/ assumptions
Plus-tree selection @ $22/tree	−1	523	556	2	Two trees selected/day; note that total cost is total cost per trial for each of 3 trials
Seed collection @ $20/tree	−1	466	496	3	Five trees/day, two visits/tree note that total cost is per each of 3 trials
Nursery costs	−1	194	199	2,3,4,5	
Establishment @ $702/ha	0–1	1404	1416	2,3	Includes soil sampling, site clearance, planting, replanting
Maintenance @ $433/ha (average of first two years)	0–4	2098	1976	2,3	Includes fertilization, spot and general cleaning, stump pruning, firebreak
Measurement, analysis	3	936	808	2	Includes consultant time (2 days @ $300 p.d.)
Conversion to seed orchard (genetic thinning) at $232/ha	3–4	394	332	2	
Subtotal			5783		
15% overhead			867.45		
Total			6650.45		

[1] Wage rates: technician (B.Sc.) $16000 p.a., field assistant $8000 p.a., labourers $3500 p.a.; [2] CATIE Tree Improvement Project records; [3] MIRA data base (Ugalde 1989) database records; [4] Murillo and Valerio 1991; [5] Latin American Forest Tree Seed Bank (BLSF), CATIE

with the following mean characteristics: rotation length 10 years, with MAI of 20 m^3/ha/year and half of the total cumulative volume removed in thinnings. We consider that these assumed parameters are justified, as there is little doubt that, due to accumulated experience, future plantation management and site selection will improve substantially with respect to past practice. Timber prices were based on current gmelina prices of around $15/$m^3$ delivered to mill (José Miguel Valverde, CACH, pers. comm.). We halved these in order to reflect the approximate expected costs of harvesting and transport, as actual stumpage values were unavailable. All thinnings are assumed to be non-commercial. On these assumptions, improved stock with 20% and 5% gain produce gross discounted revenues (i.e. discounted to the beginning of the 10 year rotation) of US$553/ha and US$483/ha respectively, whilst the

Table 2. Present value costs at 5% discount rate for one clonal seed orchard in a *Gmelina arborea* improvement program in Hojancha, Costa Rica.

Activity	Year	Total actual cost ($US)[1,2]	Present value ($US)	Notes/assumptions
Collection of ramets	3	500	416	
Grafting	3	640	533	
Nursery costs	3 to 4	780	642	
Establishment	3 to 4	1404	1165	Includes soil sampling, site clearance, planting, replanting
Maintenance	4 to 7	2588	2002	Includes fertilization, spot and general cleaning, rootstock pruning, firebreak
Subtotal			4758	
15% overhead			713.7	
Total present value			5472	

[1] Wage rates: technician (B.Sc.) $16000 p.a., field assistant $8000 p.a., labourers $3500 p.a.;
[2] Source: CATIE Tree Improvement Project records

Table 3. Total present value costs at 5% discount rate of a *Gmelina arborea* improvement program in Hojancha, Costa Rica.

Component	Present value cost (US$)
Three progeny tests/seedling seed orchards	19952
One clonal seed orchard	5472
Total	25423

unimproved stock yields US$460/ha i.e. marginal gross discounted revenue varies from US$23/ha to US$93/ha. These increases accrue as a series of 20 annual returns, beginning 10 years after establishment of the first improved plantations, and ending 10 years after the abandonment of the orchards in year 27.

Break-even financial analysis

The annual planting program necessary to cover program costs was calculated using the following formulae:

$$A = \frac{PVC}{GDR} \quad (1)$$

where:

A = required annual planting program (ha)

PVC = total present value of costs of the program ($US)

GDR = the present value ($US/ha) of the series of 20 marginal discounted returns.

GDR was calculated as:

$$\sum_{t=8}^{27} \frac{MGDR_t}{1.05^t} \tag{2}$$

where:

$MGDR_t$ = marginal gross revenue per ha due to tree improvement accrued in plantations established in year t, discounted to year t;

t = year of planting (relative to program base year) of the plantations derived from each of the 20 annual seed harvests.

The analysis method assumes that improved growth rate will be used to produce more timber over the same rotation, rather than to reduce rotation length. It is also assumed that there will be no real changes in costs or stumpage values over time.

A sensitivity analysis was carried out by examining the effects of the following modifications: assumption of higher (25 m^3/ha/year) and lower (15 m^3/ha/year) site index; planting of just one trial, on the assumption that other trials exist in the region that have been paid for by other organizations; variations in timber price (±25%); a 4-year delay in the onset of seed production; variations in the productive periods (10 and 25 years) of the orchards.

Results and discussion

The break-even annual planting program required under the base scenario is from 31ha (at 20% improvement) to 125 ha (at 5% improvement) (Table 4). Evidently, an effective (i.e. one capable of achieving genetic gains of at least around 10%) gmelina improvement program in Hojancha of the type analyzed would be amply justified by the current planting program of around 100 ha. Of the factors considered in the sensitivity analysis, at least acting in isolation, only the reduction in orchard life to 10 years might alter this conclusion. It is, in any case, probable that program returns have been underestimated: neither returns from decreased cleaning costs (due to faster

Table 4. Results of a break-even financial analysis of a *Gmelina arborea* improvement program in Hojancha, Costa Rica (base scenario and sensitivity analysis)[1].

Assumptions	Marginal yield increase due to program (%) 5	10	15	20
	Break-even annualplanting requirement (ha)[2]			
Base scenario	125	62	41	31
Orchard life of 10 years	201	101	67	50
Orchard life of 25 years	110	55	37	28
25% increase in stumpage or unimproved MAI	100	50	33	25
25% decrease in stumpage or unimproved MAI	166	83	55	42
4 year seed production delay	152	76	51	38
Only one trial planted	60	30	20	15

[1] At 5% discount rate; [2] i.e. the annual planting rate at which internal rate of return = the discount rate and net present value = zero

early growth), the incorporation of first generation gains in the genotype of future germplasm production populations or possible income from second (commercial) thinnings have been considered.

Evidently, such returns will only be available to organizations in a position to make the necessary investment, i.e. with the capacity to divert part of existing funds and manpower into tree improvement activities over a period of around 7 years. Where such flexibility does not exist, it is doubtful whether a program of the sort described here could be implemented, except as a special project funded by national or extranational agencies.

The results have important implications for smallholder tree improvement in Costa Rica and elsewhere. Data held on the CATIE Tree Improvement Project Users' Network database indicates that in Costa Rica, farmers' organizations involved in tree planting are each establishing 60–350 ha per year. Although these figures are combined data for several species, usually one or two species predominate. In any case, assuming moderate to high levels of heritability and additive genetic variation, as found in on-farm progeny tests to date in Costa Rica (Cornelius, Corea and Mesén 1995; Cornelius and Hernández 1995; Cornelius, Apedaile and Mesén 1996; Cornelius et al. 1996) genetic gains of 20% or higher should be feasible. Under such conditions, small-scale programs of the sort described here would be justifiable even for minor species, providing that the costs incurred are likely to be broadly similar to the case described here, and providing that species characteristics are favorable. In cases where program costs can be shared between various organizations, each of which would establish one trial, the situation would be still more favorable (Table4). Although the conclusions of the present study are fairly robust to slower growth or lower reproductive precocity (Table 4), improvement of minor species with such characteristics should only be undertaken after careful analysis.

Broadly speaking, the findings of the present study are likely to be applicable to other countries. Indeed, given the relatively high labor costs in Costa Rica (see footnotes to Table 2), in other developing countries small-scale tree improvement may constitute an even more attractive way of improving yield and quality of smallholder forestry plantations. To date, tree improvement for smallholders in Central America has been characterized by the establishment of seed stands as 'interim' seed sources. Due, in part, to a general perception that higher level activities are only justifiable when annual planting rates are in the thousands of hectares, rather than tens or hundreds, there has been a reluctance to enter into higher-level activities, even of the simple sort reported here. The results of the present study suggest that this reluctance is unjustified. At the same time, however, it should be emphasized that the present analysis establishes only the financial feasibility of programs of this type. Their wider feasibility will depend on, among other factors, the degree of commitment, training and awareness of local personnel, and the presence of organizations able to fulfil the catalytic and supporting functions carried out by CATIE in the case of Hojancha.

Conclusions

The results of the study indicate that small-scale, locally-based tree improvement programs of the type described here are financially justified for annual planting programs of the scale being undertaken by many farmers' organizations and other community-based groups in Costa Rica. Providing that programs can be designed and implemented so as to allow gains of around 20%, these should be justifiable even for planting programs as low as 31 ha per year. However, even tree improvement programs producing gains in the order of 5% are readily justifiable for modest (around 125ha) annual planting programs of even medium-value species. We therefore recommend, when possible, that tree improvement activities beyond the seed stand level be implemented as a routine element of such planting programs.

Acknowledgments

The contributions of past and present staff of the CATIE Tree Improvement Project and of the Hojancha Canton Agricultural Center are gratefully acknowledged. The present study was supported financially by the British Overseas Development Administration (ODA) through its Technical Cooperation and Forestry Research Program (FRP R5399), and by the Norwegian Ministry of Foreign Affairs. The authors are grateful to Dr. Henning von Platen (CATIE/GTZ) for suggesting the approach taken to the break-even analysis. We also thank Dr. David Boshier (University of Oxford), Dr. Peter Kanowski (Australian National University), Dr. Francisco Mesén (CATIE) and Mr. José Miguel Valverde (CACH) for their constructive comments on the final draft. This publication is No. 400 in the CATIE Scientific Journal Series.

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