12. MODELLING TIMBER SUPPLY AND DEMAND ASSOCIATED WITH EXISTING TREE FARMS WITHIN LEYTE INCLUDING EXTERNAL MARKETS

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BACKGROUND

There appears to be a lack of timber markets for timber produced by smallholders in Leyte Province, with unacceptably low prices being received by growers. In community surveys, a concern of smallholders frequently detected was how to market their timber (Emtage 2004).

Market modelling was planned in the previous ACIAR smallholder forestry project (project ASEM/2000/088), but was one area in which the project failed to achieve the planned objective, due to difficulty in obtaining data on tree planting activity and a late start in market research. However, some timber market and supply chain research was commenced in the final year of the project (Bulayog and Mangaoang, in process), and provides an improved understanding of Leyte timber markets.

The planned research into Leyte tree farms, including the tree farm timber assessment and attitude and intentions survey, will provide valuable information for modelling timber supply. Development of ‘yield tables’ will allow prediction of timber turnoff from these tree farms for perhaps a decade into the future. It is envisaged that on-farm trials and demonstrations and extension activities will lead to improved silviculture, which will enable smallholders to produce timber more closely matching the demand of timber buyers. Also, the planned market research will be designed to gain a better idea of the product requirements of the timber industry, in terms of product specifications, volume which can be taken, minimum lot sizes of interest to buyers, species preferences, required timber quality, timber grading systems and prices which can be obtained. It is expected that these project activities will generate data which provides a sound basis for timber supply and demand modelling, which was not available in project ASEM/2000/054.

The optimal timber production and marketing arrangements can be viewed at the farm level as a resource allocation decision problem, and at the industry level as a scale of operation and locational efficiency problem. Due to the long-term nature of timber production, these problems must be viewed in the context of intertemporal efficiency.

An integrative framework is needed to examine timber marketing in Leyte Province. This paper discusses proposed modelling of supply and demand of timber produced in Leyte Province, the Philippines, with particular emphasis on timber grown on registered tree farms, and taking into account provincial and external markets. In this paper, a linear programming formulation of timber supply and demand is proposed, as a means to describe the provincial timber market, and to explore impacts of changes in timber production and in requirements of timber purchasers in the province. The proposal is somewhat ‘visionary’ in the sense that while all of the proposed analysis is technically achievable, what is achieved will depend on resources which can be devoted to this research activity.
RESEARCH OBJECTIVES OR QUESTIONS TO BE ADDRESSED, AND
RELATIONSHIP TO PROJECT OBJECTIVES

The objectives of this research are to:

- gain a better understanding of the Leyte Province timber market;
- develop a mathematical programming model of this market;
- use this model to derive optimal timber marketing arrangements given predictions of timber supply and demand by product type and location;
- draw implications for the economic benefits of changes in silviculture, sales in new markets, and availability of further processing or value-adding facilities; and
- generate policy and extension information.

The research is designed to provide economic estimates of the benefits of silvicultural demonstration activities on tree farms, and input to policy formulation in relation to encouraging the smallholders to improve their silvicultural management.

This research activity will address a number of questions, including:

- What are the benefits of adopting improved silvicultural techniques, to produce higher quality timber?
- Given estimates of the demand for timber of higher quality, what increased revenue relative to the revenue under current silviculture, is likely to be generated from off-farm sales?
- Will the additional revenue of improved silviculture cover the additional costs?
- Where should silvicultural improvements be concentrated, in terms of species, product types, and types (e.g. sizes) and locations of tree farms?
- Which markets, in terms of locations and product types, should be targeted?
- How would optimal stand management on tree farms change if new timber processing facilities were introduced in Leyte Province.

GENERAL RESEARCH APPROACH AND JUSTIFICATION

The mathematical optimization technique of linear programming is to be employed in this research. Linear programming modelling provides a powerful and well structured approach to examine the economic implications of changes in timber specifications produced by tree farmers and changes in market requirements. Linear programming (and in particular the transshipment formulation) is a convenient technique for representing market supply, demand, transport, storage, processing and cost and revenue aspects. In the LP model, timber production activities take the form of enterprises or activities, with production costs over time and sales revenues expressed as present values. The supply of timber (e.g. by timber type, location and time period) can be represented as ‘less than or equal to’ volume constraints, and the demand as ‘greater than or equal to volume constraints’. Costs can be attached to timber transport, storage or processing activities. An example to a transportation model of a regional timber industry is provided by Harrison (2002).

Linear programming has been chosen because it is an ideal means of integrating the smallholder production and timber purchaser information, to examine timber flow and revenue generation across species, product types and market outlets. Once a model is set up, it is a relatively simple task to seek optimal (profit maximizing) timber production and supply-chain solutions, and to ask ‘what if’ questions in relation to industry structure assumptions and parameter estimates.
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RESEARCH METHOD

The research method may be viewed in terms of formulating the LP model, defining assumptions and limitations of the basic model, defining potential extensions of the model, collecting data and adapting the data to the model, model testing, computer runs, interpretation and reporting of outputs, and deriving policy and extension recommendations.

Formulation of the Linear Programming Model

This section describes formulation of the overall linear programming model, in terms of defining timber production and transport activities, timber resource supply and demand constraints, and the objective function.

The linear programming model is designed to determine the revenue-maximizing allocation of timber from tree farms to timber markets. Supply and demand locations are represented by ‘basing points’ or representative point locations for tree farms and timber processors. The activity levels to be optimized represent quantities transported of the various timber products (species, product specification) from any source to any location in any year. The right-hand-side values define the timber supplies of tree farmers (which cannot be exceeded) and the timber demands of processors (which are to be met).

The model may be written in matrix-vector form as:

$$\text{maximize } Z = C^T X, \text{ subject to } AX \leq B,$$

where

- Z is the objective function (net revenue in PhP 1000)
- C is a vector of activity net revenues
- A is a matrix of technical coefficients
- X is a matrix of activity levels, and
- B is a vector of resource supplies and demands.

Particular elements of these matrices and vectors are now defined with respect to examples of constraints and the objective function. An example of a supply constraint is:

$$a_{ijkl} x_{ijkl} \leq b_{ijkl}$$

where

- $$a_{ijkl} = 1$$, defines the volume unit for sawn timber equivalent of species group i, of product and quality class j, transported from origin (basing point) k, to market l in year t (in m$^3$)
- $$b_{ijkl}$$ is the quantity of timber of species group i, of product and quality class j, available from origin (basing point) k, in year t (in m$^3$)
- $$x_{ijkl}$$ is the number of units of the timber of species group i, of product and quality class j, from origin (basing point) k, transported to market l, in year t. (The X values are decisions variables, the levels of which are to be optimized.)

An example of a demand constraint is:

$$a_{ijkl} x_{ijkl} \geq b_{ijkl}$$

where in this case $$b_{ijkl}$$ represents the demand for timber of species group i, of product and quality class j, required in market l in year t (in m$^3$). (To ensure the existence of a feasible
solution to the linear programming problem, an artificial activity would be added to allow for underachievement of this market demand.)

The objective function may be expanded as

\[ Z = \sum_i \sum_j \sum_k \sum_l c_{ijkl} \theta_{ijkl} \]

where \( c_{ijkl} \) is the revenue to the tree farmer, net of production, transport and selling costs incurred, from one unit of timber of species group \( i \), of product and quality class \( j \), transported from origin \( k \) to market \( l \), in year \( t \) (in PhP1000/m\(^3\)). (C values for timber production activities would be expressed as net present values per unit of production, and for transport activities as freight costs in constant price terms.)

In terms of balancing the model such that supply and demand constraints are met, provision will be made for slack in both these constraint types. Shortfalls in relation to market supply can be represented by dummy timber origins, and shortfalls in meeting market demand by dummy destinations, with ‘penalty costs’ attached to transport to and from these locations.

**Modelling Improved Silviculture**

Improved silviculture, such as an improved pruning and thinning regime, can be expected to result in higher quality timber, e.g. longer sections and fewer defects. This can be viewed as a different mix of timber products from the plantation. It is likely that more of the timber will be saleable in higher priced classes (e.g. 8 foot board lengths rather than 4 foot lengths), and less will be retained for on-farm use. At the same time, increased cost (particularly labour cost) will be incurred in timber production. Timber produced by differing silvicultural intensities can be treated as different activities in the model. In this way, the net financial benefits of improved silviculture to tree farmers can be estimated.

**Model Assumptions and Limitations**

The analysis is subject to the limitations of using a mathematical model to represent a real-world industry organization. Various limitations of linear programming have been identified in the literature, e.g. that the activities and their interrelationships must be treated as linear, additive and divisible, there is a single management objective of profit maximization, and that parameters are known with certainty (single valued expectations). In practice, most of these supposed limitations can be overcome by ingenuity in problem structuring and by use of advanced solution algorithms (such as mixed-integer and goal programming). The cost is that the model or linear programming ‘tableau’ becomes larger, and more difficult to check, and solutions are more demanding of computer time\(^1\).

It is assumed that the parameters of the model can be estimated with acceptable accuracy. For example, estimates must be made of the amounts of timber which reach the point of sale in each year over the planning horizon of the model. The planning horizon may be taken as the furthest point in the future at which timber now growing on tree farms would become ready for harvest. For harvests of native slow-growing species, it may be necessary to model harvest periods as say five-year intervals\(^2\).

\(^1\) A goal programming analysis of forestry options for the Wik indigenous community in Cape York, Queensland, Australia by Tyron Venn required a goal programming (GP) tableau with 38,244 rows and 34,885 columns, with 208,638 non-zero cells.

\(^2\) Increasing dimensionality (more rows and columns) due to increasing the number of time periods in an LP model can create major difficulties in terms of tractability of the model. This is why the NPV approach to revenue from timber production activities is adopted.
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Product type could include species, log dimension and timber quality, e.g. small gmelina logs with moderate curvature and defects; 4m long by 60 cm sedub minimal defect quality mahogany logs; cocolumber flitches. To make the analysis tractable, it may be necessary to limit the number of tree species and the range of product types and timber quality levels, e.g. to group high-quality slow growing hardwoods as a single species group. At least initially, the product types may be limited to roundwood or sawn timber (cf. poles, fuelwood).

The supply information available for modelling will be mainly from tree farms. However, other known tree plantings, such as CBFM, can be included in supply levels. Also, assumptions can be made about the quantity of timber to be sold or used on-farm (guided by information collected from the survey of tree farmers), perhaps treating ‘retained on farm’ as a market destinations for timber. Some under-representation of supply is likely because of the difficulty of identifying registered and unregistered tree farmers. The former are more readily identified (from CENRO lists), but some tree growers only register their plantations when they are ready to sell timber. Difficulties will also arise in estimating timber supply quantities from imports and illegal logging, and estimates made for these will of necessity be imprecise.

The model assumes that scale of operation and average cost for timber processing are independent. If a substantial increase in timber supply were to take place, this could lead to economies of scale in milling and further processing. It is in fact possible by trial-and-error solution to allow for inter-relationship between processing volume and processing cost.

The model seeks clean-slate solutions rather than taking account of the present timber flows and contractual arrangements between timber suppliers and users. This is not likely to be of concern, given the limited regular timber flows at present. In any case, existing arrangements can be accommodated by adding further demand constraints.

In some cases, the timber demand point will be at the tree farm, and in others at the yards of the timber buyer. This will affect who pays transport costs, though not necessarily the level of transport costs, and can be allowed for in model formulation.

The analysis will only indirectly examine the requirement of assembling timber lots from a number of growers, so as to meet minimum threshold volumes for sales to higher-priced markets. (Threshold volumes could be defined for sales from each supply basing point.)

Extensions to the Model

A number of extensions to the basic model are possible, but would be dependent on resource availability for this research activity, e.g. whether a postgraduate student is available to take on the project as a higher-degree thesis project. Some of the possible extensions are now briefly outlined.

Price – volume relationships in timber markets

The model could be adapted to allow for changes in timber price to growers in relation to volume of timber sold, e.g. market saturation, or higher prices due to increased economies from processing larger quantities. In a transshipment modelling context, interrelationships between quantity and price are often examined through trial-and-error computer runs.

Establishment of new processing facilities

The linear programming model could be readily extended to incorporate new markets, e.g. a

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3 The acronym 'sedub' represents 'small end diameter under bark' and defines a minimum saleable log size.
market for timber for plywood or cement board construction.

Trans-shipments of timber products

It would be a simple matter to include more than one timber processing step, and value adding, in the timber supply chain (as trans-shipments from one market to another), by making the initial market into a timber source, and allowing for demand at the next processing step. Thus, for example, a firm could purchase logs and then sell sawn timber to a furniture manufacturer.

Allowing for other forestry sale products

While initially farm timber sales will be limited to lumber, the model could readily be extended to allow for sale of other timber products – such as fuelwood from prunings and thinnings, and poles – and non-timber products.

Allowing for agroforestry systems

Agroforestry options could be built into the analysis, to compare the revenue from timber with that from other land uses, and hence to evaluation agroforestry systems rather than purely forestry stands.

Data Collection (Including Sampling) Strategy

The main types of data to be utilized in the analysis will include:

- Data from financial analysis of timber production on tree farms, including cost variations associated with alternative silvicultural regimes (e.g. pruning, thinning and weed control) to produce higher quality timber products.
- Predictions of timber (lumber) production by tree farmers, and of quantities by product type sold off-farm.
- Prediction of variation in timber product mix arising from improved silviculture (e.g. pruning, thinning and weed control to produce higher quality timber products), and associated changes in production costs.
- Estimates of the demand by product type by location and type of timber purchaser or processor, of prices which timber market operators are prepared to pay to growers.
- Estimates of the volumes of timber required to attract buyers from higher-value markets, e.g. for sale to Cebu City rather than in Leyte Province.
- Estimates of the transport of each timber type for each origin-destination combination (or cost per kilometre by product type) and of any other selling costs (e.g. commission).
- Prediction of the market response to increased timber sales and higher timber quality by tree farmers, in terms quantity-price relationships and potential new processing developments.

The strategies including sampling method for data collection will be arise mainly when related project activities are designed, which will generate data for this activity – particularly the tree farm demonstrations, timber market research, and forestry financial modelling. Data from other research activities (listed above) will be expressed in the form of coefficients for the linear programming model. Timber turnover quantities and product types will be derived from the tree farm stand inventory and product quality information, predictions of future tree growth, estimated harvest ages, and quantities to be sold or used on-farm. In this way, timber turnover volume by species and product class for each year, on a sawn timber basis, will be estimated for the supply coefficients.
The market research sub-project will be designed to provide constraint data on market timber demands by product type, and timber prices. It is envisaged that various types of markets for farm-grown timber will be identified (e.g. purchasers of construction timber, small-scale lumber retailers, softwood furniture manufacturers). Substantial budgeting will be required to derive the net revenue coefficients, which will form part of the financial modelling research activity. In the case of timber production costs under alternative silvicultural regimes, net present value (on a pesos per cubic metre of sawn timber basis) will enter the objective function coefficients.

While various problems might be encountered in estimation of supply data (e.g. in relation to estimation to areas planted on tree farms, and stand yield modelling), it is expected that the market analysis will be the greatest challenge, although the project team certainly has a better idea of market structure now than when the previous project commenced.

**Model Testing Activities**

Verification testing to ensure the model is correctly specified and data have been entered correctly will involve checking of parameters (resource supplies, input-output coefficients, objective function coefficients), trials to ensure that the model is feasible and linear programming solutions can be obtained, and computer runs to check that the optimal policies are sensible in terms of the information in the model. Validation will involve having people with expertise in various areas check that the results generated are sensible in terms of Leyte timber production and marketing systems and opportunities. Sensitivity analysis will check the impact of errors in parameter estimates in the model, and the stability of optimal solutions to future changes in parameter levels.

It is envisaged that initial model implementation and testing will be conducted using MicroSoft Excel. It may prove necessary to switch to the General Algebraic Modelling System (GAMS), a software package suited to complex linear programming, depending on the dimensions of the model which is developed.

**Computer Runs and Interpretation and Reporting of Outputs**

Once the model is judged to be operating as planned and acceptably reliable, a number of optimization runs will be conducted, under various assumptions, reflected in parameter levels such as product mix of tree farms (represented by the B vector) and farm timber production cost (C vector). In this way, alternative silvicultural regimes will be evaluated for tree farms (improved silviculture on current stands or on new plantings). Depending on resource availability, some of the extensions to the model outlined above may be undertaken, and hence additional information generated.

**EXPECTED RESEARCH OUTPUTS AND THEIR USES**

The linear programming analysis will provide mathematically optimal estimates of timber quantity and value flows, given the input information. This will indicate where timber of any specification produced at any location should be sold, taking into consideration transport costs and differences in prices in alternative markets. More importantly, by relating silvicultural system with market demand, the model will allow an economic comparison of alternative silvicultural systems. For example, information will be provided on whether greater labour effort on improved pruning or thinning is warranted. The analysis will reveal what modifications to silvicultural systems are financially viable, and this information will be used with other findings to evaluate plantation management policies, to feed into policy and extension packages generated by the overall ACIAR project.

The nature of the research findings cannot be predicted in advance. Anecdotal evidence
suggests that a small increase in weed control, pruning and thinning effort might have a substantial impact on stand yield and timber quality.

**LINKS WITH OTHER PROJECT ACTIVITIES**

This project integrates information from other components of the overall ACIAR project (financial modelling of plantations, tree farm silviculture demonstrations and monitoring, market research), to produce policy information about silvicultural management and timber marketing, and extension information for tree farmers about product types and silvicultural intensity. Some additions to data collection in other sub-projects may be sought. Findings of the linear programming analysis will complement that from other sub-projects in policy formulation and developing extension materials.

**RESOURCES REQUIREMENTS FOR THE RESEARCH**

Most of the data collection will be covered within other sub-projects. Even for a limited analysis, several person-months of researcher time will be required to ‘populate’ and test the model, carry out solution runs, and interpret findings. Postgraduate student involvement would be a cost-effective way to advance this analysis, and the research activity would lend itself well to a thesis project for a postgraduate research degree.

**DISCUSSION**

Linear programming is a powerful analysis technique for representing market supply and demand quantities by product type, and for identifying trading patterns which will optimize revenue generation from timber production and marketing. In this way, strategies to improve the quality of timber produced on tree farms can be evaluated in financial terms. That is, once an linear programming model is developed, populated with realistic data, and validated, a powerful tool will available to examine the implications of improved silviculture and of developments in the timber processing sector. The methodology is well suited to integrating findings from various other activities in the project to generate information relevant to policy formulation.

The above outline of modelling and analysis is to some extent an idealized scenario, and it is not clear to what extent this will be achievable. There are obvious challenges in data collection and model formulation, although all of the core steps and indeed extensions appear to be technically feasible. To a large extent, what can be achieved will depend on what researcher time and fieldwork resource inputs can be devoted to this research activity.

**REFERENCES**


