15. TRANSHIPMENT MODEL TO EXPLORE MARKETING OPTIONS FOR SMALLHOLDER FORESTRY ON LEYTE ISLAND, THE PHILIPPINES

Edwin Cedamon, John Herbohn and Steve Harrison

Transhipment modelling has been used to identify the optimal location of marketing facilities for many commodities. This approach is being used to analyse timber marketing options for smallholder tree farms on Leyte Island, the Philippines. The model is designed to evaluate the optimal location of smallholder timber processing and the economic benefits of pruning, thinning and improved planting stock. The analysis will provide input to support policy and investment decisions that are critical for smallholder tree farm enterprises.

Direct cash income from timber sale is one of the many motivations for smallholder tree planting in many developing countries (Dewees and Saxena 1997; Holding-Anyonge and Roshetko 2003) including the Philippines (Pasicolan *et al.* 1997; Magcale-Macandog *et al*. 199l; Cedamon and Emtage 2005; Polinar 2007). Despite the promise of smallholder tree planting as an alternative and additional source of income, current returns to smallholder tree farms are low for many reasons. One of the reasons is the lack of market information (Herbohn *et al.* 2007; Cedamon *et al.* 2007) and lack of a marketing mechanism favourable to smallholder tree farmers (Scheer 2004; Pasicolan and Macandog 2007).

Sawn timber is the major timber product produced by smallholders on Leyte Island. Smallholder farmers apparently lack information about what the market requirements are for sawn timber and as a result they do not manage their tree farms to optimize the output of these desired products. Pruning and thinning treatments are applied to stands to improve timber quality and increase volume (Shepherd 1986; Smith *et al*. 1997) but these methods have not been practiced by Leyte smallholders due to a poor understanding of their economic benefits. Smallholders lack the knowledge on how and where to market their trees and also don't know what the current value of their trees is which leads them to accept low prices offered by local timber merchants who purchase standing trees and process all the necessary felling and transport approvals.

A question on whether there is a revenue premium from the silvicultural treatment of pruning and thinning in smallholder tree farms is relevant to Leyte Island. Also, smallholder farmers need to know which method between chainsaw and bandsaw (the common timber processing systems in Leyte) has the highest returns and which market they should target for their products to optimize returns. There is also a need for timber entrepreneurs to know where harvestable trees are located and what volume is available. Mathematical optimization techniques have been used to answer questions like these. Transhipment modelling is a mathematical optimization technique which has been applied in many industries, including meat processing (King and Logan 1964; Hurt and Tramel 1965; Brown 1985), fish (Leyva *et al*. 2006), fruits (Kilmer *et al*. 1983), nuts (Baldwin *et al.* 1987) and wool (Ferguson 1971) to determine the optimal spatial organization of marketing facilities. The optimal spatial organization of marketing facilities can greatly reduce marketing cost to the benefit of domestic producers and consumers through higher better prices (Baldwin *et al.* 1987). One approach to optimizing spatial organization of marketing facilities is through transhipment modelling. A transhipment modelling[1] project is being undertaken for Leyte Island smallholder forestry to support policy and investment decisions. The purpose of this paper is to present the research questions being investigated in the transhipment model and the model formulation. Accomplished and continuing activities relevant to this project are discussed.

RESEARCH QUESTIONS

The ACIAR Smallholder Tree Farm Project[2] investigated some marketing issues experienced by smallholder tree farmers through a number of research activities including carrying out a timber inventory on tree farms, and conducting surveys of tree farmers and timber entrepreneurs. There is a wealth of data collected from these research activities that can be used to further investigate potential options for improving smallholder timber marketing on Leyte Island via transhipment modelling. The following questions are being investigated using the transhipment model.

Key questions:

1. How financially viable is improved thinning and pruning, improved stand management and improved quality of planting stock for smallholder gmelina and mahogany farmers?
2. What timber product class and what market destinations should be targeted in processing and marketing gmelina and mahogany timber from smallholder tree farms?
3. What marketing arrangements are financially feasible for smallholder tree farmers?

Specific questions:

1. How much sawn timber should be processed by tree farmers on farm, and how much should be processed at bandsaw mills by bandsaw millers?
2. What timber processing schedule and timber market flows provide the optimal revenue to the timber industry?
3. What is the farthest distance timber products could travel to the customers to financially break even?
4. What are the pessimistic, most likely and optimistic quantities of timber that should flow from each network node, that is from tree farmers and processors?
5. What are the ranges of timber supply and demand that warrant optimal revenue of timber industry?
6. What supply regions should be prioritized for smallholder tree farm expansion?

Under several scenarios, the following questions will be asked:

7. Is it feasible to produce kiln dried lumber from Leyte for supply to the Cebu furniture industry?
8. How much extra revenue could be generated if trees are pruned and thinned, and quality planting stocked used? and How much timber production cost (labour and cost of quality planting stock) would increase with improved silviculture and would the increase in revenue to smallholders justify this increased cost?

---

[1] The transhipment modelling project described in this paper is a PhD research project by the first author at the University of Queensland under the ACIAR John Allwright Fellowship.

[2] The ACIAR Smallholder Forestry Project is a collaborative research project of the University of Queensland, Visayas State University and the Department of Environment and Natural Resources titled ‘Improving Financial Returns to Smallholder Tree Farmers in the Philippines’, ACIAR Project No. ASEM/2003/052.

9. Is it feasible if there is portable sawmill with saw kerf smaller than chain saw (that is the sawn timber recovery rate output is higher than chainsaw) available for hire to smallholder tree farms? What is the financial viability of alternative saw mill types and how many of them are required?

MODEL FORMULATION

The overall LP model – a form of transhipment or locational efficiency model – is formulated in terms of defining timber production, lumber processing and transport activities, timber resource supply and demand constraints, capacities of supply regions and processing plants, and the objective function. Unlike the conventional transhipment problem which aims to minimize transport and processing cost, the model is designed to determine the revenue-maximizing allocation of timber from tree farms to timber markets. The revenue is the amount received by the industry on sale of final timber product net of timber production, harvesting, timber processing, transport and selling cost. Production activities and resource supplies in the LP model are defined for current and improved silviculture, current and improved stand management, and currently used planting stock and improved planting stock, to examine the financial viability of improved timber production on smallholder tree farms.

Each municipality on Leyte Island is considered to be both a supply and demand region and current location of sawmills represent transhipment points. The activity levels to be optimized represent the quantities of the various timber products transported (species, product specification) from any source to any market destination in a given year. The right-hand side values define the timber supplies of tree farms (which cannot be exceeded), the processing capacities of processors (which cannot be exceeded), and the timber demand by consumers (minimum quantities to be met). A constraint representing transhipment is introduced to define that whatever volume of timber flowing out from a sawmill should be equal to what it receives. Processing capacities of tree farmers and sawmills are introduced as upper bounds (cannot be exceeded) of timber flows from each node. The volume unit of timber flowing out from a particular node should be expressed in terms of units of final product demanded by customers. For this model, the volume of timber product flowing from the supply region is defined in terms of cubic metres (m^3) of lumber.

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

Maximize $Z = C^TX$, subject to $AX \leq B$, where
Z is the objective function (net revenue in PhP 1000)
C is a vector of activity net revenues (and C^T is the transpose of this vector)
A is a matrix of technical coefficients
X is a matrix of activity levels, and
B is a vector of resource supply and demand.

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:

$$a_{ijkp}\, x_{ijkp} \leq b_{ijk}$$

where $a_{ijkp} = 1$, defines the unit volume flow of logs of timber species *i* , in log class *j*, from supply region *k* to processors *p* (in m^3).

b_{ijkp} is the volume of log timber for species *i*, with log size class *j*, available in supply region *k* for processing by processors *p* (in m^3).

x_{ijkp} is the number of units of log timber of species *i* , with log class *j*, obtained from supply region *k* and processed by processor *p* (in m^3).

An example of demand constraints is:

$a_{ijkp}\, x_{ijkp} \le b_{ijm}$

wherein $a_{ijkp} = 1$, defines the unit volume flow of sawn timber of timber species *i* , in log class *j*, sawn at processors *p* for demand region *m* (in m^3).

b_{ijm} is the volume sawn timber for timber species *i*, with log size class *j* required by demand region *m* (in m^3).

x_{ijkp} is the number of units of sawn timber of timber species *i* , in log class *j*, processed in processors *p* for demand region *m* (in m^3) (The X values are decision variables, the levels of which are to be optimized).

Examples of processing constraints are the following:

Inflow constraint, $a_{ijkp}\, x_{ijkp} \le b_{ijp}$

Outflow, $a_{ijpm}\, x_{ijpm} = b_{ijp}$

wherein for inflow constraints

$a_{ijkp} = 1$, defines the unit volume inflow of log of timber species *i* , in log class *j*, from any supply region *k* to processors *p* (in m^3).

b_{ijp} is the volume of log of timber for species *i*, with log size class *j*, that can be received by processors *p* (in m^3).

x_{ijkp} is the number of units of log of timber species *i* , with log class *j*, from any supply region *k* that shipped to processors *p* (in m^3).

and for outflow constraints

$a_{ijpm} = 1$, defines the unit volume of sawn timber of timber species *i* , in log class *j*, shipped from processors *p* to any demand region *m* (in m^3in log equivalent).

b_{ijp} is the volume of sawn timber of timber for species *i*, with log size class *j* that was processed in processors *p* (in m^3in log equivalent).

x_{ijpm} is the number of units of sawn timber of timber species *i* , in log class *j*, shipped from processors *p* to any demand region *m* (in m^3in log equivalent).

The objective function of this model is summarized as follows:

$$Z = \sum_{i=1}^{2} \sum_{j=1}^{15} \sum_{k=1}^{62} \sum_{p=1}^{62+?} \sum_{m=1}^{62+?} r_{ijkpm} q_{ijkpm} - \sum_{i=1}^{2} \sum_{j=1}^{20} \sum_{k=1}^{62} \sum_{p=1}^{62+?} \sum_{m=1}^{62+?} c_{ijkpm} q_{ijkpm} \quad \text{Equation 1}$$

In equation 1, r_{ijkpm} represents the revenue per unit of sawn timber of species *i* and logs class *j* sold from supply region *l* and processed at processors *p* sold to demand region *m* processed. The notation c_{ijkpm} represents the total cost of sawn timber production per unit of sawn timber of species *i* and logs class *j* sold from supply region *l* and processed at processors *p* sold to demand region *m* processed. This cost includes timber production (timber growing), transport cost (off-road and on-road) and milling cost. The notation q_{ijkpm} represents the number of units (m^3) of sawn timber of species *i* and logs class *j* sold from supply region *l* and processed at processors *p* sold to demand region *m.* The parameter names and elements representing these notations are presented in Table 1.

Table 1. Indices of the LP model for production, processing and marketing of timber products from smallholder tree farms on Leyte Island

Parameter notation	Parameter name	Elements
i	Species	Mahogany, gmelina (2)
j	Log size class	Length class x diameter class (15)
	Length class	1.8 m, 2.4 m, 3 m, 3.7 m, 4.9 m
	Log diameter classes	21–30 cm, 31–40 cm, >40 cm
k	Log supply region	62 municipalities
m	Demand region	62 municipalities in Leyte and one in Cebu
p	Processor	Existing bandsaw mills and on-site processing by chainsaw

This model is subject to the following constraints:

$$\sum_i \sum_j \sum_k \sum_p q_{ijkp} \leq ST_{ijk} \qquad \text{Equation 2}$$

$$\sum_i \sum_j \sum_k \sum_p \sum_m q_{ijpm} \geq DQ_{ijm} \qquad \text{Equation 3}$$

$$IFq_{ijkp} \leq PC_p \qquad \text{Equation 4}$$

$$OFq_{ijpm} = IFq_{ijkp} \qquad \text{Equation 5}$$

$$q_{ijkp}, q_{ijpm} \geq 0 \qquad \text{Equation 6}$$

where ST_{ijk} = standing log supply volume of timber species *i* , of log class *j*, available in supply region *k*.

DQ_{ijm} = volume of sawn timber of timber species *i* , of log class *j*, required by demand region *m*.

PC_p = maximum volume of log that can be received by any processor *p.*

IFq_{ijkp} = $\sum_i \sum_j \sum_k \sum_p q_{ijkp}$, is the total volume inflow of logs of timber species *i* of log class *j* from supply region *l* to processor *p.*

OFq_{ijpm}= is the total volume outflow of lumber in log equivalent (m^3) of timber species *i* of log class *j* from processor *p* to demand region *m.*

q_{ijkp} = is the quantity of log of timber species *i* , of log class *j*, from supply region *k* to processor *p*.

q_{ijpm} = is the quantity of sawn timber of timber species *i* , of log class *j* from processor *p* delivered to demand region *m*.

Equation 2 specifies that the sum of logs volumes (m^3) obtained for any supply region for milling by processors should not exceed the volume of standing log supply in that particular supply region. The standing log supply is the net volume of logs from the stand that smallholders are planning to sell. Equation 3 states that the volume of sawn timber required by any demand region should at least be met. Equations 4 and 5 denote the processing capacities wherein Equation 4 specifies that the total volume that should be received by a particular processor should not exceed by its processing capacity. Equation 5 requires that the sum of sawn timber in log equivalents (m^3) flowing out from a particular processor should be equal to the volume of logs received by that particular processor. The non-negativity constraints are specified as Equation 6.

In terms of balancing the model so that supply and demand constraints are met, provision will be made for slack in both of these constraint types. Shortfalls in relation to market supply can be represented by dummy timber origins (e.g. tree farms), and shortfalls in meeting market demand by dummy destinations (timber merchants or timber processors), with 'penalty cost' attached to transport to and from these locations.

A scenario analysis will be run to evaluate financial viability of improved silviculture and use of high quality planting stock. This will require changes in technical coefficient to accommodate changes on timber production cost and yield per log size class due to improved silviculture. It may be that the selling price of any timber product may increase due to an increase in quality of timber product, e.g. a reduction of knots and reaction wood. The transhipment model is a 'static' analysis which assumes that the period of observation in the model is 'snapshot' of a long-run equilibrium. This model considers 62 supply regions, at least 62 demand regions, 2 species, 15 log classes, and at least 62 chainsaw processing points and a number of bandsaw processors, with an estimated minimum tableau size of 4320 columns by 4260 rows. Given the size of the model the Generalized Algebraic Modelling Systems (GAMS) is the optimization software being used. Figure 1 shows a screen shot of input file in GAMS window (Figure 1).

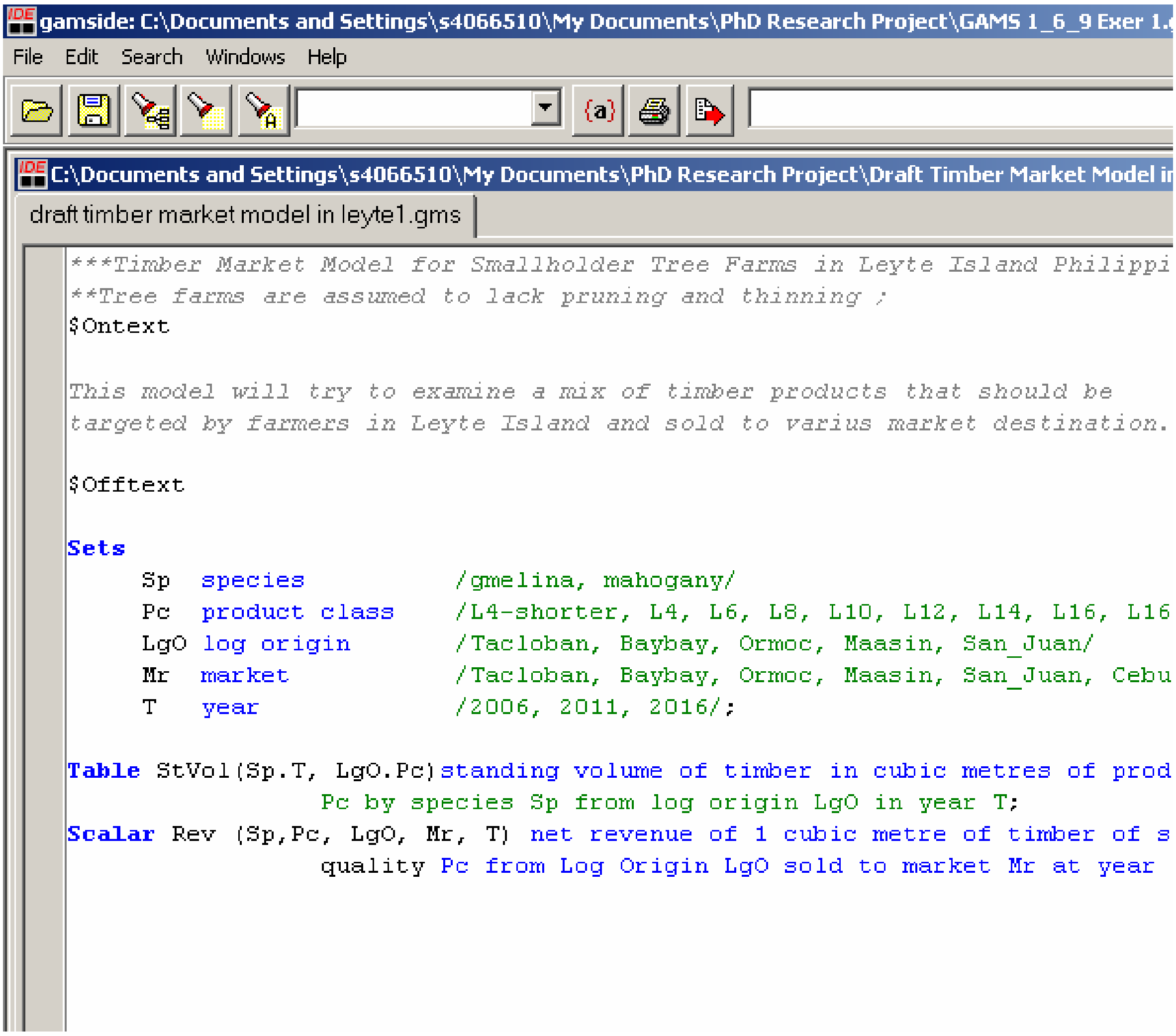

Figure 1. A screenshot of the prototype model in GAMS

ACCOMPLISHED AND CONTINUING RESEARCH ACTIVITIES

In terms of estimating parameters in the transhipment model for Leyte Island smallholder forestry, several activities had been or are still being conducted. These include analysis of timber enterprise survey data, an analysis of ACIAR tree measurement data, collation of the Barangay Chairmen Tree Farm Inventory data, interviews with selected tree farmers, interviews with key timber processors and chainsaw operators, collation of DENR archival records on timber shipments, and sawing trials. Data from the Barangay Chairmen Tree Farm Inventory have already been collated. Archival of records from DENR and interviews with key processors, chainsaw operators and selected tree farmers were conducted between August and December 2008 and analysis of the data gathered is continuing. Results from sawing trials and analysis of data from the timber enterprise survey are reported in other papers in these Proceedings. Analysis of tree measurement data to determine timber supply by log classes is continuing. A workshop with selected tree farmers, timber entrepreneurs, and representatives from DENR, LGUs and academics will be held on Leyte Island to validate results of the model and obtain feedback.

REFERENCES

Baldwin E, Babiker B and Larson D (1987) Spatial organization of marketing facilities in developing countries: a case study of oilseeds in Sudan. *Agricultural Economics,* 1(3): 209–227

Brown C (1986) The Implications of Variability in Supplies and Demand for Industry Organizational Efficiency Analysis, Doctor of Philosophy Dissertation, Department of Agriculture, The University of Queensland, Brisbane, Australia

Cedamon E, Cedamon J, Harrison S and Mangaoang E (2009) Timber entrepreneur's attitudes and plans relevant to smallholder forestry, Workshop Paper, ACIAR Smallholder Forestry Project, End-of-Project Workshop, Ormoc City, Leyte, the Philippines, 13–14 February. (These Proceedings)

Cedamon E and Emtage N (2005) Present tree planting and management activities in four rural communities in Leyte Province Philippines. *Annals of Tropical Research* 27(1): 11–18

Cedamon E, Harrison S and Herbohn J (2007) Timber market information on Leyte Island, the Philippines. *Annals of Tropical Research* 29(2): 61–73

Dewees PA and Saxena NC (1997) Wood product markets as incentives for farmer tree growing. In: JEM Arnold and P Dewees (eds) *Farms, Trees and Farmers: Responses to Agricultural Intensification*. Earthscan, London

Ferguson D (1971) Optimum Size, Number, and Location of Australian Wool Selling Centres, Master of Agricultural Science Dissertation, The University of Queensland, Brisbane

Herbohn J, Harrison S, Mangaoang E, Gregorio G, Cedamon E, Russell I and Vanclay J (2007) Improving the triple bottom line returns from smallholder tree farms in the Philippines: a systems approach. In: S Harrison, A Bosch and J Herbohn (eds) *Improving the Triple Bottom Line Returns from Small-scale Forestry,* Proceedings from an International IUFRO 3.08 Conference held in Ormoc City, the Philippines, *17–21 June 2007*

Holding-Anyonge C and Roshetko J (2003) Farm-level timber production: oriented farmers towards the market. *Unasylva* 212*(* 54): 48–56

Hurt V and Tramel T (1965) Alternative formulation of the transhipment problem. *Journal of Farm Economics* 47(3): 763–773

Kilmer R, Spreen T and Tilly D (1983) A dynamic plant location model: the East Florida fresh citrus packing industry. *American Journal of Agricultural Economics* 65(4): 730–737

King G and Logan S (1964) Optimum location, number and size of processing plants with raw product and final product shipments. *Journal of Farm Economics* 46(1): 94–108

Leyva C, Engle C, and Wui Y (2006) A mixed integer transshipment model for Tilapia (*Oreochromis* sp.) marketing in Honduras. *Aquaculture Economics and Management*, 10(3): 245–264

Macandog D, Menz K, Rocamora P and Predo C (1999) Smallholder timber production and marketing: the case of Gmelina arborea in Claveria Northern Mindanao. *International Tree Crops Journal* 10(1):61–78

Pasicolan P, Udo de Haes H and Sajise P (1997) Farm forestry: an alternative to government-driven reforestation in the Philippines. *Forest Ecology and Management* 99(1–2): 261–274

Pasicolan P and Macandog D (2007) Gmelina boom, farmers' doom: tree growers risk, coping strategies and options. In: S Harrison, A Bosch and J Herbohn (eds) *Improving the Triple Bottom Line Returns from Small-scale Forestry,* Proceedings from an International IUFRO 3.08 Conference held in Ormoc City, the Philippines, 17–21 June 2007

Polinar A (2007) Economic prospects of small-scale tree farms in Bontoc Southern Leyte. In: S Harrison, A Bosch and J Herbohn (eds) *Improving the Triple Bottom Line Returns from Small-scale Forestry,* Proceedings from an International IUFRO 3.08 Conference held in Ormoc City Philippines, 18–21 June 2007

Scherr S (2004) Building opportunities for small-farm agroforestry to supply domestic wood markets in developing countries. *Agroforestry Systems* 61–62(1–3): 357–370

Shepherd K (1987) *Plantation Silviculture*, Martinus Nijhoff Publishers, Dordrecht

Smith D, Larson B, Kelty M, and Ashton P (1997) *The Practice of Silviculture: Applied Forest Ecology, 9th Edition*, Wiley, New York

Wiersum K, Elands B, Hoogstra M (2005) Small-scale Forest Ownership in Europe: Characteristics and Future Potential. *Small-scale Forest Management and Policy* 4(1): 1–19