An Investigation into the Shorthaul Transport of Pulpwood in South Africa

by

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature:.

Date:.

Abstract

Ackerman PA. 2001. An Investigation into the Shorthaul Transport of Pulpwood in South Africa. M.Sc. in Forestry thesis. University of Stellenbosch. 178 pp

Shorthaul transport also known as secondary intermediate transport (SIT), a unique feature of pulpwood transport in South Africa, is an additional transport phase within traditional secondary transport. SIT originates at a roadside landing or depot and terminates at another depot, rail siding or merchandising area (not the final destination). The reason for the addition of SIT into the transport chain is identified as the steady decline of forest road conditions to the extent that highway vehicles are unable to reach roadside landings, necessitating the use of intermediate storage sites, from where the timber is once again loaded and transported to final destination.

An industry survey established that the decline of forest road conditions are related to excessively high road densities, insufficient funding for road maintenance/upgrading and the lack of understanding by landowners of the importance of maintaining forest road infrastructure. Total funding, by pulpwood companies on roads have shown an increase of R18.55 million from 1997 to 2000, however, subsequent surveys have indicated, that despite this increase in funding, the forest road conditions continue deteriorating.

Of the total annual pulpwood intake of 9.39 million tonnes for 1998, 3.7 million tonnes are subject to SIT. Of this 3.7 million tonnes, 2.5 million tonnes are transported from stump to depot and 1.2 million tonnes are transported from landing to depot. The survey identified the agricultural tractor and semi-trailer as the most favoured transport system between stump or landing and depot, responsible for transporting 2.22 million tonnes annually. For 1998, manual loading and three wheel log loaders accounted for the loading of 0.6 and 2.1 million tonnes respectively of the 3.7 million tonnes subject to SIT.

This survey information, assisted by newly developed terminology, was used to develop transport scenarios for the economic analysis of total cost of the different transport phases. A network analysis model and pixel-based geographic information system

(GIS) were combined to analyse the various transport scenarios within three study areas in the KwaZulu/Natal Midlands, employing SIT on poor, high-density road networks. The simple pixel-based GIS contained information on the forest road network, surface cover and slopes.

The results of the economic analysis highlighted the need for the reduction of road network density and for the improvement of the remaining network. This would eliminate the need for extended primary transport and allow the use of highway vehicles transporting from the compartment roadside to and past plantation exits. Results show an average annual cost penalty to the industry, by maintaining SIT, to be R43.25 million or R8.24/m^3. By not employing SIT the industry will potentially save R4.60 for every tonne of the 9.4 million tonnes consumed by the pulpwood processing plants during 1998.

Key words: Network analysis. Pixel-based GIS. Timber transport. Secondary transport. Secondary intermediate transport. Secondary terminal transport. Extended primary transport. Primary transport. Dirichlet tessellations. Shorthaul.

Note: Throughout this document a full stop **(.)** is used as a decimal separator.

Opsomming

Ackerman PA. 2001.'n Ondersoek na die kortafstand vervoer van pulphout in Suid-Afrika. MSc in Bosbou tesis. Universiteit van Stellenbosch. 178 pp.

Sekondêre intermediêre vervoer (SIV), 'n addisionele vervoer-fase binne tradisionele sekondêre houtvervoer, is 'n unieke kenmerk van pulphout vervoer in Suid-Afrika. SIV begin op pad, by 'n spesifieke vak of depot en eindig by 'n ander depot, syspoor of verwerkingsgebied (nie die finale bestemming nie). Aangesien die toestand van bospaaie toenemend verswak en omdat swaarpadvervoer nie langer vakke kan bereik nie, word vervoerkontrakteurs al hoe meer gedwing om van depots gebruik te maak waarheen hout deur middel van SIV vervoer moet word. Die hout word dan weer daar gelaai en na 'n verwerkingsfabriek vervoer deur middel van swaarpadvervoer.

'n Landwye opname het getoon dat die swak toestand van bospaaie toegeskryf kan word aan oormatige paddigthede, onvoldoende befondsing vir die instandhouding/ opgradering van paaie en 'n gebrek aan begrip vir die belangrikheid van die onderhoud van padinfrastruktuur. Die totale kostes aan padverbeterings en opgraderings in die pulphout bedryf, het van 1997 tot 2000 met R18.55 miljoen toegeneem. Verdere opnames toon egter dat ten spyte van hierdie verhoging in befondsing, die toestand van bospaaie steeds onbevredigend is.

Van die totale jaarlikse pulphout inname van 9.39 miljoen ton gedurende 1998, word 3.7 miljoen ton aan SIV blootgestel. Van dié volume word 2.5 en 1.2 miljoen ton onderskeidelik vanaf die stomp en pad na depots vervoer. Die opname het ook landboutrekkers met leunwaens geïdentifiseer as die gewildste houtvervoer middel tussen die stomp/pad en depots. Hande-arbeid en driewielbloklaaiers is op hulle beurt verantwoordelik vir die laai van onderskeidelik 0.6 en 2.1 miljoen ton pulphout wat deur middel van SIV vervoer word.

Inligting uit die opname ondersteun deur nuutgeskepte vakterminologie, is gebruik om verskillende vervoersisteme vir die ekonomiese analise van totale koste van die verskillende vervoerfases te bereken. 'n Netwerk analise model en pixel gebaseerde GIS is in kombinasie gebruik om verskillende vervoer scenarios in drie areas in Kwa-

Zulu Natal te ontleed, wat gebruik maak van SIV op swak bospaaie met hoë-netwerkdigthede. Die eenvoudige pixel-gebaseerde GIS het inligting weergegee oor bospadnetwerke, oppervlakbedekking en hellings.

Die behoefte aan die vermindering van paddigtheid en die verbetering van bospaaie as sulks, is deur die resultate van die ekonomiese ontleding na vore gebring. Dit sal die behoefte vir uitgebreide primêre vervoer uitskakel en die gebruik van tradisionele swaar padvoertuie moontlik maak.

Die resultate van hierdie opname toon dat die bedryf addisioneel gemiddeld R43.25 miljoen/jaar of R8.24/m^3 betaal vir die 3.7 miljoen ton wat onderhewig is aan SIV. Vir die totale 9.4 miljoen m^3 het SIV die maatskappye gedurende 1998 R4.60 meer gekos vir elke m^3 wat vervoer was.

Sleutelwoorde: Netwerkanalise. Houtvervoer. Sekondêre vervoer. Sekondêre intermediêre vervoer. Sekondere terminale vervoer. Verlengde primêre vervoer. Kortafstand vervoer. Pixel-gebaseerde GIS

Nota: In hierdie document word deurgans 'n punt (.) gebruik om desimale van heelgetalle te skei.

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Appendix

1. Introduction

In South Africa harvesting and transport account for between 50 and 70% of the cost of wood delivered to the mill gate (Brink *et al.* 1995, Brink 2000, Brink and Conradie 2000, Brink and Kellogg 2000,). Primary and secondary transport accounts for up to 55% of the mill delivered cost of pulpwood (Morkel 2000), while secondary transport on its own may account for up to 82% of the total transport cost. It is estimated that internationally total timber transport costs makes up 50-60% of the mill delivered cost (Conway 1976).

Secondary transport, in South Africa, has been divided into two components; namely *shorthaul* and *longhaul* transport. *Shorthaul* is part of secondary transport, but unique to South Africa. Unfortunately, the use of these two terms is confusing and there is a need to develop standard terminology. This lack of exact terminology has also created difficulties in the actual quantification of the economic impact of this mode of transport due to the overlapping of definitions in pulpwood operations. Due to the uniqueness of this transport system (*shorthaul*) and study, no formal literature survey section is included in the study.

To compound the problem of confusing terminology there seems to be acceptable and unacceptable *shorthaul*. Acceptable *shorthaul* is used to transport wood from stump or landing to rail siding or processing plant; and there are no intermediate stages of storage. Unacceptable *shorthaul* is the transport of wood from stump or landing to any intermediate site, be it a depot or another landing. It is referred to as unacceptable due to the multiple handling and storage of timber and the need for an additional phase of secondary transport.

To avoid confusion in the terminology outlined above, the terms presented in Figure 1 are used in this study. More detailed definitions are given in Appendix A. *Shorthaul* will thus be referred to as secondary intermediate transport (SIT) and *longhaul* will be referred to as secondary terminal transport (STT).

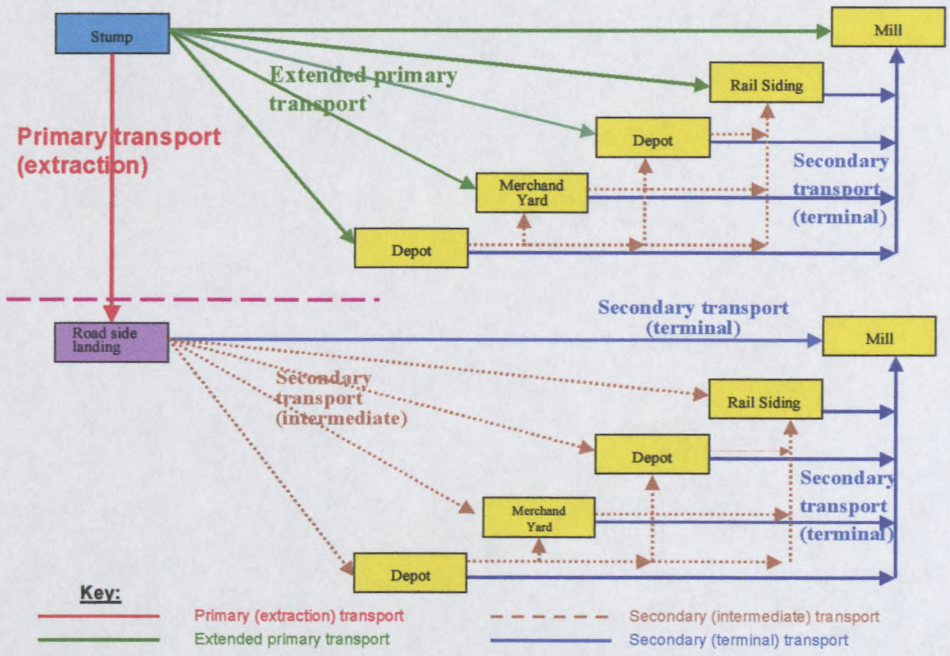

Figure 1: Schematic description of the phases of wood transport (primary and secondary transport)

Both types of secondary transport are used to transport pulpwood in South Africa and they may be used in combination or independently from each other. SIT denotes the transport of timber by road, over shorter distances, from the primary landing (or other intermediate site) to either centralized depots, rail sidings or merchandising yards. Equipment typically used are agricultural tractors drawing semi-trailers. STT refers to longer distance transport by road from a landing or centralized depot to the processing plant.

The long distance transport of roundwood occurs by both rail and road. During 1998, 5.4 million tonnes out of a total consumption of 9.4 million tonnes of pulpwood were transported by road, with the remaining 4 million tonnes transported by rail. Road transport distances range between 50 and 350 km, with the weighted average being 142 km for 1998, as opposed to 121 km during 1995. About 25% of the pulpwood in 1998 was hauled over lead distances greater than 250 km; while only 5% had lead distances less than 50 km (Morkel 1999 a and 1999 b). Typical equipment used for this mode of transport is the imported rigid vehicle linked to a drawbar-trailer with payload capacities of 40 to 42 tonnes.

SIT accounts for between 10 and 15% of the total delivered cost of pulpwood when used. Although SIT is not the largest cost component, it is the most expensive operation on a cost per t/kilometre basis; R2-4/t/km for an agricultural tractor and semi trailer configuration for SIT, versus R0.20/t/km for a large truck used for STT. According to Crickmay and Burne (2000), costs in the region of R10/t are being encountered in their "Contractor Upliftment Programme" data analysis. The longer the lead distance, the greater the cost with maximum costs being reported in excess of R22/t (Crickmay and Burne 2000).

A total of 3.7 million tonnes of pulpwood are subject to SIT for STT, in other words unacceptable *shorthaul*. At a conservative average annual cost of R10/t for SIT, the amount expended on SIT is in the region of R37.0 million/year throughout the pulpwood industry (Morkel 2000).

However, detailed information on the reasons for and the use of SIT is not available. Also, the economic impact of SIT on the total transport cost has not been analysed. Thus, two main objectives and a number of sub-objectives were set for this thesis and are the following.

Objective one: Determine the extent of SIT and related transport components in the South African pulpwood industry.

- A countrywide survey of all harvesting and transport company operations and contractors in the pulpwood industry was carried out.

The sub-objectives for the survey were:

- To establish where a case study for objective two could be conducted. To select a site that represents industry conditions and where, if changes are implemented, results are most likely to materialize.
- Determine the reasons for SIT from the contractor perspective.

- Gain insight into the equipment used to execute SIT.
- Establish the volumes moved by the different vehicles used for SIT.
- Determine from where SIT originates, stump or landing, and the volume of each.
- Establish trends on loading systems.
- Establish the financial input into road maintenance and upgrading by the two-pulpwood companies (Sappi and Mondi).
- Gain insight into the state of forest roads from a contractor's perspective.

The survey is limited to harvesting and transport related issues in the South African pulpwood industry.

Objective two: Analysis of the economic impact of SIT on roundwood pulpwood transport.

- The second objective of the study is to use a simple pixel-based GIS combined with network analysis to analyse the economic implications of SIT in the pulpwood transport industry.

The sub-objectives for the economic analysis were:

- Apply the present and selected transport systems over a range of forest road density reduction scenarios applied to three areas.
- Run the combined network analysis model to cost the individual transport elements for comparative purposes.
- Establish cost trends of the economic analysis.
- Find the most financially beneficial transport system.

The frame of reference of the economic analysis:

The analysis is conducted in three Mondi plantations in the Natal Midlands producing pulpwood. The study is only concerned with the difference in transport cost of different transport systems as applied to three areas.

Limitations of the economic analysis

- The analysis is limited to the roundwood pulpwood transport phase, identified as SIT, which occurs between the stump and plantation exit point.
- No forest road network optimisation was included in the analysis.
- The existing logging and transport systems, as they occur on the three areas, are used as starting points.
- Tree felling and timber preparation costs at stump are not included in the study.

2. Methodology

2.1. Part one

2.1.1. The survey

The survey of the main timber growing areas of the country, Natal, Zululand, Mpumalanga and the Highveld region, was carried out by means of a questionnaire. This method was considered to be the most practical in view of the large number of prospective respondents, spread over a large geographical area.

The survey was aimed at all the contractors and company-own operations, concerned with harvesting and transport of pulpwood, for both Sappi and Mondi. Mondi however is the only company still employing own-operations. Sappi and Mondi were chosen as the target companies because they are the only pulpwood consumers in South Africa. The other reason is that SIT is confined to the pulpwood transport industry.

To ensure a high response rate from prospective respondents, the questionnaire was compiled to be as concise, simple and understandable as possible. To ensure clarity complete definitions accompanied the survey. The respondents were expected to read through the definitions and then shape their responses accordingly.

To identify the participants for the survey, a list of all contractors and company own-operations was compiled. This was achieved by sending out questionnaires to specific people (mostly regional harvesting managers) within the two companies, requesting a list of people contracting for them during their 1998 financial year. Included was the request for a detailed list of all own-operation data. They were also requested to supply total expenditures for new roads, upgrades and road maintenance for the years 1997 to 2000, and the estimated budget for 2001.

A comprehensive list of all contractors and own-operations contained names and relevant contact details (Appendix B). Particulars of the contractors transport operations and volumes produced were recorded.

The questionnaires, with pre-addressed reply envelopes, were mailed in two batches: the first to Sappi's contractors in April 1999 and the second to Mondi's operations in June of 1999. The reason for the period between mailings was due to a delay in receiving a detailed list of contractors, and their particulars, from Mondi.

No follow-up questionnaires were distributed to non-respondents. A period of three calendar months was allowed for the return of the questionnaires. Those who had not responded by the due date, where contacted by telephone and asked for the reason for the non-return of the questionnaire. If a contractor had received no questionnaire, another was immediately mailed, if a fresh commitment was given by the person to return the survey as soon as possible. A further two weeks were allowed for responses. Once this had passed no more effort was made to retrieve outstanding surveys, although any surveys received since that date were dealt with in the normal way and included in the data.

If information supplied by the contractor was not clear, or seemed incorrect or contradictory, the respondent was contacted by telephone and the situation clarified.

2.1.2. Contents of the survey

During the compilation of the questionnaire a number of factors had to be considered. These factors determined the complexity and depth of the questions within the survey (Appendix C).

The most important factor was that the contractors varied greatly in general education and training. On the one hand there is the large corporate type transport contractor with a number of vehicles, and forestry is only one of his many work avenues. He is highly educated and informed and has been in the business a long time. Then there is the emerging entrepreneur, who due to outsourcing and rationalisation has been given the opportunity to prove his worth. He harvests and transports limited volumes for the company with labour intensive operations. His formal education is limited. The greatest advantage he has over his competitors is his local knowledge and years of experience in the job he is now contracted to do. Obviously there are many contractors in the range between the two mentioned.

Another factor to consider is the wide variety of systems operational at any time. There is no uniformity from one system to another between contractors. The systems vary from highly mechanised to very labour intensive, and from well-trained workers to a completely untrained workforce of temporary nature and similar commitment. Apart from the divergence mentioned, the term system and the building of systems are not well comprehended by a number of contractors. They in most cases have inherited what they have from previous company own-operations. This generalization does not apply to the more progressive contractors, and there are many.

When considering the above two factors, the time available to contractors and the general unwillingness of people to actually complete forms, the survey was kept as short and as straight-forward as possible in an attempt to get the information volunteered as authentic as possible. This was done possibly at the expense of more detailed data (e.g., load sizes).

2.1.3. The sample

The original intention was to reach all harvesting and transport contractors and all own harvesting and transport operations that were in operation with Sappi and Mondi during 1998. The products involved were all softwood and hardwood pulpwood produced by the companies.

All questionnaires returned, were included in the database, regardless of the size of the contract. The aim was to obtain the greatest representation as practically possible, bearing in mind that a large number of contractors would not respond regardless of prompting. The number of questionnaires sent out was 47 to Sappi and 65 to Mondi; a total of 112 questionnaires in all.

2.1.4. Data interpretation

All the data contained in the questionnaire was summarised into Excel for analysis and manipulations. The analysis of the data is generally based on direct comparisons of visual data in the form of results presented in graphs and tables. Due to not attaining a 100% response to the survey, volumes per operation had to be extrapolated to the full

9.4 million tonnes of pulpwood consumed annually (1998) by the processing plants. This total annual volume, and volume transported by SIT and STT were made available by Morkel (2000).

Statistical analysis was done to establish if there were significant differences in lead distances between wood moving from stump to depots and landings to depots, and between softwood and hardwood. A Student's t test was applied to this data. Averages weighted by volume were calculated in determining the average lead distance per region per transport phase and species. In the process of the statistical t-test, mean, minimum and maximum lead distances for each region, transport mode and species was determined.

To aid direct comparison between financial figures supplied by the companies on expenditure directed at maintenance and upgrade of roads, the Forestry Price Index (FPI) as produced by the South African Statistical Services (Anon 2001), was used to produce the real expenditure for the years 1997 to 2000 as expressed in the year 2000 values. The base year of 1995 was as calculated by the Statistical Services. As no FPI was available for 2001, it was excluded from the calculations. The four remaining years in this instance were considered sufficient to show meaningful trends.

2.2. Part two - economic analysis

2.2.1. Overview

The analysis of the survey emphasised that due to the poor and steadily declining condition of forest roads, an additional mode of transport has been included into the transport chain namely, secondary intermediate transport. The economic impact of this mode of transport, SIT, has not clearly been established by the industry. Morkel (2000) determined that 3.7 million tonnes of timber is being moved by SIT. Thus, this study will limit the economic analysis to SIT as defined in Figure 1.

2.2.2. The study area

2.2.2.1. Location

The study area consists of three estates owned by Mondi forests. The estates are located north and northeast of the town of Richmond in the KwaZulu/Natal Midlands. Richmond is approximately 30 km south of Pietermaritzburg (Figure 2). All three areas are situated close to the N2 highway running north and south through Natal.

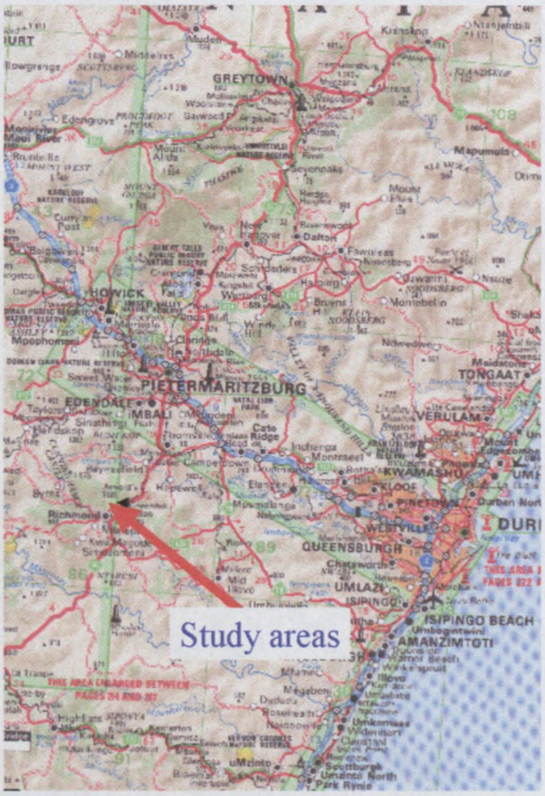

Figure 2: Location of plantation areas (Anon 1992 b)

This particular pilot study area was selected based on the following factors.

- Three areas as opposed to one were selected to test the reliability of the results.
- Operations typical of secondary intermediate transport and extensive use of depots occur.
- Use is made of typical secondary intermediate transport modes, such as agricultural tractors and semi-trailers.

- The areas show poor road conditions preventing the access of traditional road transport vehicles closer to the roadside at compartment level. No high payload vehicles enter the plantation.
- The three estates have high road densities, typical of the industry.
- This pilot study area is most likely to produce results due to clear identifiable transport operations within the systems employed.
- Recognition of the problem and willingness to seek solutions by members of the company's management team.
- A plan was being devised for road abandonment and upgrading. Thus, the company's personnel, in applying the research project results, showed interest.

2.2.2.2. Estate facts and figures

Table 1 gives the areas and species of the three estates.

Table 1: Estates by area and species

Surface Cover	Uplands (ha)	Highlands (ha)	Greenhill (ha)	Total area (ha)
Pines	139.5	93.7	314.5	547.7
Eucalyptus	371.3	948.3	1094.5	2414.1
Wattle	171.5	269.5	193.5	634.5
Sugar Cane	285.7	0	78.0	363.7
Mixed	45.3	15.5	66.5	127.3
TU*	21.7	26.5	51.7	99.9
Protection areas	90.7	214.0	484.5	789.2
Total areas	1125.7	1567.5	2283.3	4976.5

(* Temporary unplanted areas)

2.2.2.3. Plantation yields

Table 2 indicates the expected average yields per hectare per year for all three estates (MAI):

Table 2: Estimated average yield per hectare per year for the three species groups harvested (Le Roux 1999)

Species	MAI (m^3/ha/year)
Wattle	8
Pine	7
Eucalyptus	14

The above yields are used in the network programme as average volumes removed per ha annually for the estates. The network analysis programming makes provision for the removal of the mean average annual yield of each compartment yielding utilisable timber, per estate. Conversion factors to convert tonnes to m^3 are as published in Van Zyl (1994). The factors are 1.41m^3 and 1.10m^3 per tonne of hardwood (3 to 4 weeks dry) and softwood respectively (Rusk *et al* 1997). The weighted average conversion factor for the 9.4 million tonnes (11.6654 million m^3) is 1.241.

2.2.2.4. Categories of surface cover and related management strategies

Sugar Cane

Uplands and Greenhill have 363.7 and 78.0 ha of sugar cane, respectively. These areas will not be phased out of the management plans for the plantations. Current sugar cane harvesting and re-establishment levels will be maintained. Contractors do all the sugar cane operations as well as the balance of the timber harvesting and silvicultural operations on the estates.

Wattle

The original intention with the future of *Acacia mearnsii* was to re-establish all wattle areas to either pine or *Eucalyptus*, site depending. This decision has been revisited. With high prices been gained for the timber, particularly at the Sappi Saiccor dissolving pulp plant, provision has been made to extend the area under this crop where possible. There are however environmental pressures to limit the planting of this species, particularly in Natal.

Mixed areas

These are areas that have developed into jungles. These sites are not productive with a poor mixture of regeneration allowed to develop without any silviculture treatments being applied. As funding becomes available they will be rehabilitated and planted to commercially viable species with applicable silvicultural treatment. The total area of these jungles is 127.3 hectares.

Temporary unplanted areas

In all cases the percentage of unplanted area remain below 3%. Although it was difficult to obtain a company policy on what the benchmark was, this seemed to be well in control. The reduction of these areas is season dependent, particularly depending on the success of winter plantings (regeneration) in the summer rainfall areas.

2.2.2.5. Current harvesting systems

At present two contractors perform all harvesting operations. One contractor does the felling, debarking if necessary, crosscutting and stacking in 5 tonne (7.6 m^3) bundles on strip roads (extraction route) within the compartment. The second contractor is responsible for the removal of the timber from the stump area to the plantation sink/exit. This involves extended primary transport to the closest depot where the load is dumped and stored. An agricultural tractor and semi trailer transport system is used for this extended primary transport phase (Figure 3). The prepared bundles in field are choked with chains and winched on board using a cantilever system on the loading deck. The entire bundle of 7.6 m^3 is loaded in a single element. By lowering the deck and releasing the chains the timber bundle is unloaded.

Figure 3: Agricultural tractor with bundle system semi-trailer used in extended primary transport to depot

From the system of centralized depots, three-wheel log loaders (Figure 4), load timber onto agricultural tractor and semi-trailers units with payload capacities of 19.7 m^3 (Figure 5). This vehicle conveys timber to the plantation exit point. This exit point is also termed a sink in this study. In most cases the timber is unloaded once again at the sink, to be reloaded onto road transport vehicles, which comprise of rigid type trucks with drawbar trailers attached (Figure 6). These vehicles are capable of payloads of at least 40 tonnes or 45 m^3. They in turn transport the wood to the processing plants located on the eastern seaboard of the province.

Figure 4: Three-wheel log loader for loading at depot sites

Figure 5: Agricultural tractor and semi-trailer unit for transport from depot to plantation exit point

Figure 6: Rigid truck with draw-bar trailer

Adverse terrain factors do not play a role as impediments to logging of the three estates. As all primary transport is done by agricultural tractor and bundle semi trailers, this implies that the general slope classification of the estates is 35% and below. There is a certain percentage of the area that exceeds the maximum slope required for ground-based transport systems, although limited. However these areas do not influence the general systems applied. This timber, as part of preparation and extraction, is moved to an accessible area, loaded and transported by agricultural tractor and bundle semi-trailer to depot. The same procedure is used for marginal soil conditions.

2.2.2.6. Current road data

Company road classes with their definitions are listed in Table 3. The corresponding road classes for the study are also listed.

Table 3: Road classification definitions

Study road classification	Category/class	Company Class
#1	District road (provincial authority)	P
#2	Class one (main) plantation	A
#3	Class two (secondary) plantation	B
#4	Boundary routes (fire protection)	Unclassified
#5	Class three (routes) plantation	C

The roads database, compiled manually by company employees in order to initiate a road management system at the time of procuring the maps for the three areas reveals the following. (Refer to Table 4 for condition ratings)

- All provincial roads have gravel surfaces and a condition rating of two to three on a scale of one (good) to five (poor).
- Class one (main) roads were also gravelled but had condition ratings of four to five.
- Class two (secondary) roads had gravel surfaces and had similar condition ratings as for main roads.
- Class three (routes) roads can be divided into two categories; a) roads that had no gravel surface and have an average condition ratings of three. b) roads that do have gravel surfaces but average condition ratings of four. Gravelled, class three roads, were only found on Uplands. These roads were in a poor condition and have an average width (carriage way) of 3.0 – 3.5 m, as with roads on all the other estates.

In order to clarify the road condition rating system used by Mondi the following explanation is required. A standard system used by civil engineers in Southern Africa to assess unpaved roads, is to survey the total road length, link or arc of the road and visually estimate what percentage of the total road length is in poor condition (Thistle 1998). The definition of poor condition would be when a road no longer sustains the quality of service it was originally designed for. In this case the criteria would be a highway timber transport vehicle. The concept is illustrated in Table 4:

Table 4: Condition rating and serviceability condition

Road condition rating:(0=good, 5=poor)	Percentage of road in un-serviceable condition
1	20%
2	40%
3	60%
4	80%
5	100%

To summarise, roads with gravel surfaces were in poor condition due to overwork, by largely overloaded agricultural tractor and semi-trailer units, in wet weather and subsequent lack of road maintenance. Agricultural tractor and semi-trailer units are in general, due to the practice of fitting single tyres on dual or single rear axles, overloaded by 4 000 to 5 000 kg (payloads of 19 000 kg, tare weights of 11 000 kg and legal gross vehicle mass of 26 000 kg).

Ungravelled roads (class three) were in relatively better condition. Yet their alignment and general width have made them unavailable to high payload highway type vehicles. The gravelled class three roads are similarly out of reach of these vehicles due to the same reasons as above, as well as poor quality surfaces (potholes and erosion). Most roads, due to poor alignment and placement have become water transport channels. Poor grading techniques have resulted in the road surface sinking lower and lower below the surrounding terrain, and thus creating drainage difficulties.

2.2.2.7. Depot location

All depot sites are located on either district/provincial or class one (main), plantation roads. This confirms that roads with categories of two and lower, including boundary roads, are not accessible to larger highway type timber transport vehicles. However, in reality, all timber is transported to plantation exit point by agricultural tractors and semi-trailer and not highway type vehicles, implying inaccessibility to the depots by these vehicles.

The numbers of depot sites per plantation are indicated in Table 5.

Table 5: Number of depot sites per estate

Plantation	Number of sites
Uplands	5
Highlands	4
Greenhill	9

2.2.3. Economic analysis

2.2.3.1. Building the spatial database and information catalogues

The underlying technique used in producing the spatial database is a pixel-based geographic information system (GIS). The technique allows the use of a fixed grid network and allows the solution of large network problems (Pulkki 1996). According to Pulkki (1984), after reviewing the literature on the spatial delineation of data, he found the fixed grid method to be far more applicable than the polygon method for transport problem analysis. He based this statement on the fact that more emphasis should be placed on data manipulation and developing a low cost system, than on graphical resolution of output. Pulkki (1984) states that the grid method is superior to the polygon method when it comes to the manipulation of spatial data and allows a large amount of information to be displayed in tabular form.

The use of the fixed grid system allows for easy indexing of location. An additional advantage of a fixed grid system over geographical coordinates is that each pixel has the same area, and linear distances can easily be calculated between points. With geographical coordinates angular measurements would be required. Due to the above, easy storage of information in matrices by grid coordinates and the application of network analysis techniques are facilitated (Pulkki 1984).

Grid cell coordinates store map information. Each grid cell or pixel is referenced by a computer matrix coordinate for the grid. Thus (1,1) is the northwest corner of the grid. In this study the matrix coordinates are referred to as they are in computer notation and not in vector notation: i.e. (Y, X) and not (X, Y). Thus by being familiar with and having an understanding of the study problem and the environment, all relevant map information for the spatial database is obtained simultaneously and stored in a manner easily accessed for rectifying of errors, updating and later use.

2.2.3.2. Applying the fixed grid method

The basic stock and transportation system data for the three areas originated from Mondi Forest stock maps, (scale 1:5000) which were printed by their forest management unit in Pietermaritzburg.

Three maps were produced for each of the three study areas.

- A stock map, with contours at 10 m intervals, showing roads, compartment boundaries and species per compartment.
- A map with the road network for each area. No additional information was included, apart from each road being identified by a unique road number. This number could be used to source the detail of each road. This information was limited to road class (A, B, C or provincial), an indication of the degree of hardening and the overall condition of the road on a scale of one to five, with five being the worst condition.
- The slope classification of each area in colour coded polygons.

The map printers superimposed a grid or raster system on each of the maps. The grid is represented by pixels (cells) of 50 m by 50 m. On the 1:5000 scale maps this translated into a size of a 1 cm square cell. Each pixel represented an area of 0.25 ha.

The following factors were taken into account when deciding on the grid line spacing (Pulkki 1984, 1996 and Tan 2000):

- The accuracy desired in obtaining information such as, in the case of this particular study, road locations, and compartment boundaries within which certain species are located.
    - If too narrow, the volume of data is immense.
    - If too wide, loss of data would be significant.
- Matching distances between grid lines and the map scale to allow translation between the map and real distances and areas.
- The sizes and shapes of the plantations to be covered by the information matrices.
- The basic complexity of the information to be digitized.
- The computer resources available.

It is also beneficial to have the grid spacing based on the map scale i.e. based on 1:5000, (50 m grid), 1:10 000, (100 m grid) or 1:15 000, (150 m grid) as the case may be. This assists the drawing of the pixels onto maps and it keeps the matrix of manageable size.

Table 6 represents the dimensions of the spatial database per plantation area.

Table 6: Cell data for each area digitised

Area	Plantation size (ha)	Database dimension [rows (y) - cols (x)]	Total Pixels
Uplands	1125.7	115 x 110	12650
Highlands	1567.5	87 x136	11832
Greenhill	2283.3	122 x 145	17690

The input of data into the spatial database is a slow process. It is however extremely important phase of the work as the usefulness of the process is only as good as the quality and accuracy of the information stored in the database. Over and above this requirement, accuracy in the input of each item is required to limit the time spent rectifying errors in the data (Pulkki 1984).

Three pixel map layers were built for each area. One layer contained surface cover, the second layer contained information on road classes and the third layer contained slope classes. In the final analysis the slope class layer was not utilised. Originally the slope layer was to be used to assist with the determination of more accurate primary transport costs. However, it was decided that because there is only one primary transport method used, that slope analysis would not add any additional benefit to the study and was excluded.

When registering the surface cover, road and slope information to the database the map area covered by each grid cell was examined manually and the specific feature, being a road of certain class, type of surface cover or specific slope, inserted pixel by pixel into the database (Table 7). If the grid cell did not lie in the study area it was given a certain code. Otherwise, the absence/presence or descriptions of features were recorded for each grid cell in character data as outlined in Table 7. For road location, each grid location was labelled according to the highest road class (Pulkki 1996), present in that particular grid. The following is a summary of codes assigned to each grid cell location. For a visual presentation of the surface cover data in pixel map form refer to Figures 7, 8 and 9.

Table 7: Coding and colour of required information input into spatial database

Surface cover layer			Road layer		
Surface cover	Inserted character code	Code colour	Company road classification	Inserted character code	Code Colour
Out of area	9	Dark blue	Non-road area	0	
Protection areas	0	Black	Outside plantation area	9	Dark blue
Pines	P	Green	Provincial road	1	White
Eucalyptus	E	Light blue	A class road	2	Pink
Wattle	W	Yellow	B class road	3	Red
Sugar	S	Brown	Boundary roads	4	Blue
Mixed species	M	Pink	C class road	5	Green
T.U. areas	T	Red			

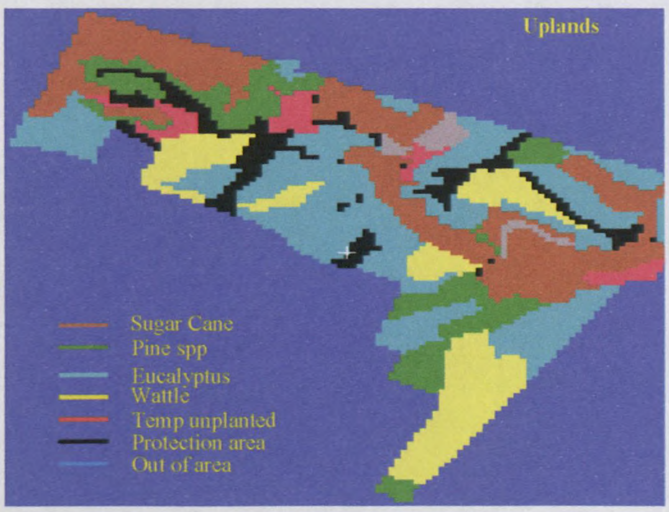

Figure 7: Surface cover pixel map: Uplands

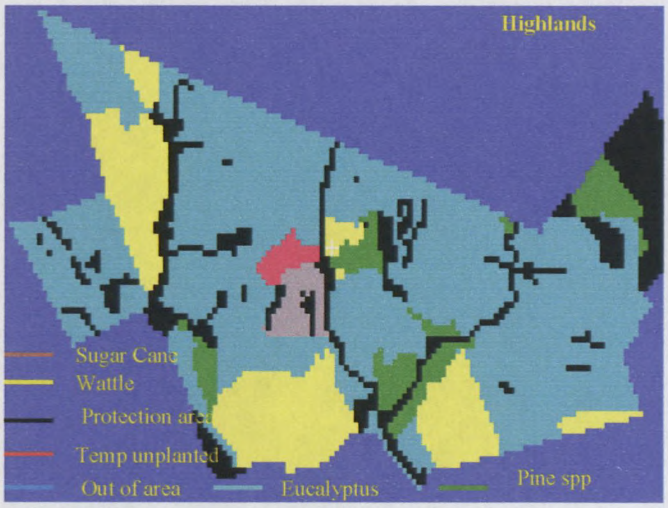

Figure 8: Surface cover pixel map: Highlands

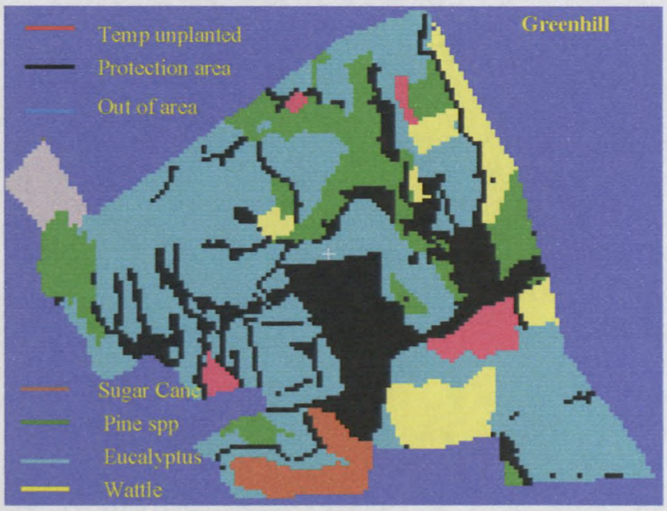

Figure 9: Surface cover pixel map: Greenhill

When examining the actual road route or surface cover boundary some adjustment are necessary to avoid the zigzag effect due to the location of the route or boundary in relation to the grid. If a grid cell bordered on two or more areas, the area assigned to the grid cell was the area making up the larger part or majority of the particular grid cell (Pulkki 1984). This is applicable to both roads and larger contiguous area edges, such as compartment boundaries. This is illustrated in Figure 10. Note cells marked (**#**) are not entered into the database as cell information. This is in contrast to cells with (**X**) which do indicate the path and cells, which have information, recorded. The route entered into the database is then the red pathway.

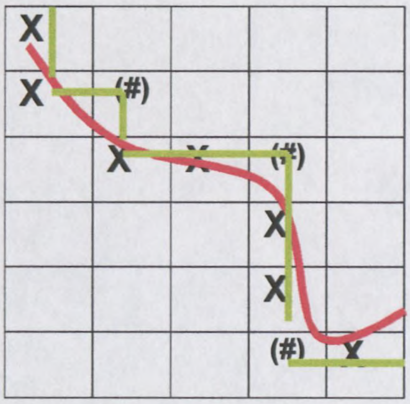

Figure 10: Actual road placement, grid cells recorded and grid map location.

According to a method developed by Pulkki (1984), all grid-referenced information recorded in this study is referred to as a spatial database. With the data readily available for each grid cell or pixel, in digital form, by just addressing the grid coordinates and data required, information matrices and files for the areas can be developed. The information matrices and files developed from the spatial database are also held as a part of it.

With data stored in the spatial databases the formation of information matrices follows, which are used for data manipulation and analysis. The information matrices can be thought of as map overlays containing some type of information of interest (these map overlays are developed in the network analysis programme and will be referred to again later). All of the information matrices are of character format.

To briefly outline the formation of an information matrix the following procedure, presented by Pulkki (1984), was applied in the study.

- A matrix space is reserved in the CPU workspace according to the type of data to be recorded in the matrix (character in this case).
- The spatial database is accessed and information as required is read into the CPU workspace.

- Working through information for all the grid cells, a code is assigned (as shown in Table 7) to each corresponding matrix location.
- Once all grid cell information has been examined the new information matrix of the area is stored.

Information files are files of descriptive information referenced to some feature recorded in the spatial database. For example, one file is the road node map for the three different areas of concern, showing in character form the road routes with classes. The other information catalogue is for ground cover. Refer to Figure 11 for an example of a portion of a road node map for the Uplands plantation.

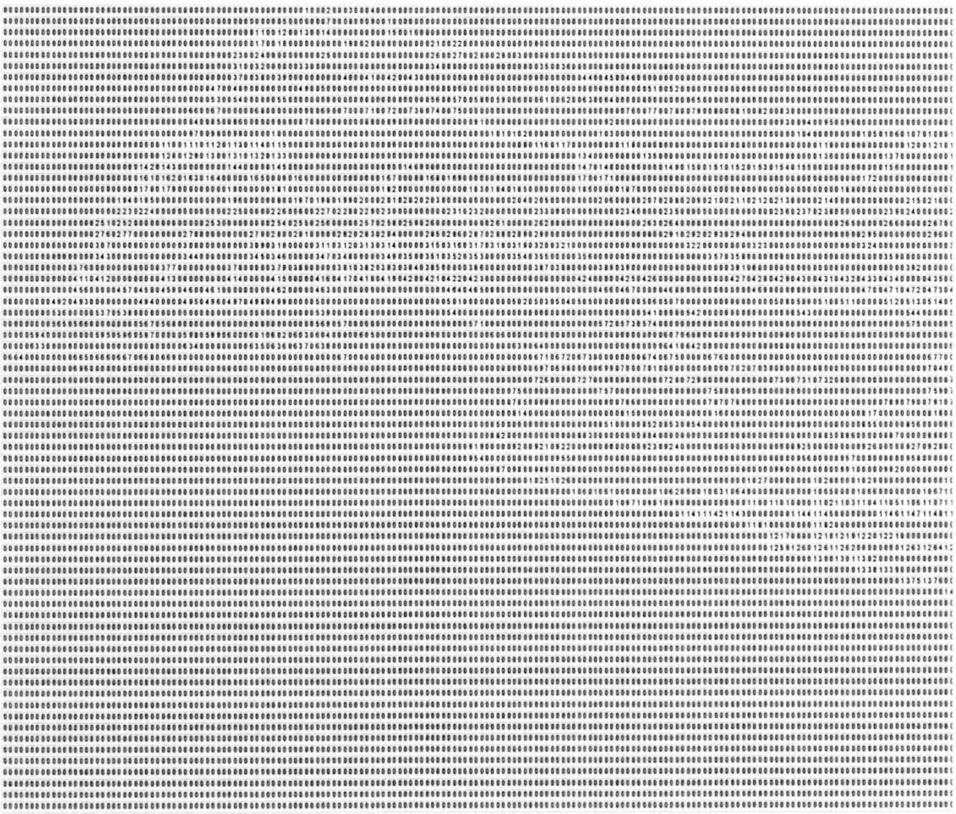

Figure 11: Portion of Uplands road node map information catalogue

2.2.3.3. Network analysis

Operational research (OR) is concerned with the application of scientific methods and techniques to managerial decision-making problems. The literature (Robinson undated, Dykstra 1976 and 1984, Dykstra and Riggs 1977, Pulkki 1984, McGaughey 1992, and Sever and Knezevic 1992) discuss the use of OR in solving forestry-related problems. Forest transportation and forest road network planning imply problems of the network analysis nature. Network analysis has been used to solve or provide solutions to problems concerned with road network placement and transportation with success and examples of these can be found in Pulkki (1987 and 1996) and Tan (1992).

In the context of mathematical programming, the term, network model, is used to define a broad class of techniques useful for solving a variety of problems, which deal with the geometry of position (Dykstra 1984). Taha (1982), Sessions (1992), and Sessions and Sessions (1992), stated that, in practice, network models seem to enjoy success in solving real-life problems. Taha (1982) also mentioned that possibly 70% of the real world mathematical programming problems are network related problems.

The most often used model in planning forest transportation and forest road networks is the shortest path (or route) model. This model consists of finding the shortest path or paths from source nodes to destination nodes through a connected network. Network minimisation models are useful in planning transportation networks where the objective is to provide some connection route between every pair of nodes at the lowest cost (Dykstra 1984).

According to Robinson (undated), Taha (1982), Dykstra (1984) and Session (1992), a network is made up of nodes and links. For example a start node and ending node describe a proposed road link. A collection of interconnected links between nodes makes a network. A node in this type of network is any feature that may be treated as the point of departure or destination of some path through a portion of the network. For example nodes are often towns, road intersections or in the case of this study the midpoint of a pixel or grid square. Thus, links will be the connections between adjacent nodes, pixels or cells (Tan 2000).

The aim in performing network analysis is to find the minimum total cost path through the network. The algorithm used or outlined below is based on discussions from (Taha 1982, Dykstra 1984 and Pulkki 1984). Times are determined between the destination node and all other nodes in the network incrementally. The times from all nodes to a destination node are then checked repeatedly by comparing the differences in times to each node minus the time to all directly connected nodes, to the time of connecting two nodes. If the difference is less than or equal to the time of connecting the two nodes, no shorter route can be found between the two nodes and the next route is checked. If the above condition is not met, a new minimum time is calculated to the adjacent node by adding the time of connecting the two nodes to the minimum time of the node used in the check. The process is repeated until no changes in minimum time are made (Pulkki 1996).

In the solution of small problems Pulkki (1996) reports that the above technique is quite efficient. With larger networks it becomes limiting due to memory requirements and processing time. In these cases the majority of the matrix would be unfeasible arcs between nodes. In a fixed grid network, each road node can only be connected up to a maximum of four other road nodes. This reduces the maximum data addresses considerably. Pulkki (1996) reports that the same technique can also be used in road locating, however, impediment values would be required to all eight surrounding nodes.

2.2.3.4. The combined analysis model

The algorithm applied in this study is as described and used in Taha (1982) and Pulkki (1984 and 1996)

The combined model programme was compiled in Microsoft Visual Basic 6. The combined programme is made up of three individual parts:

- Transport optimisation (network minimisation).
- Wood flow from forest pixels to depots <u>or</u> plantation exit point <u>or</u> depots and then from there to plantation exit point depending on the requirements of the analysis.
- Layer analyses to flow the timber out of the area taking into account the system of depots.

The three forms, as developed in Visual Basic, representing the three parts of the economic analyses are represented in Figures 12, 13 and 14 below.

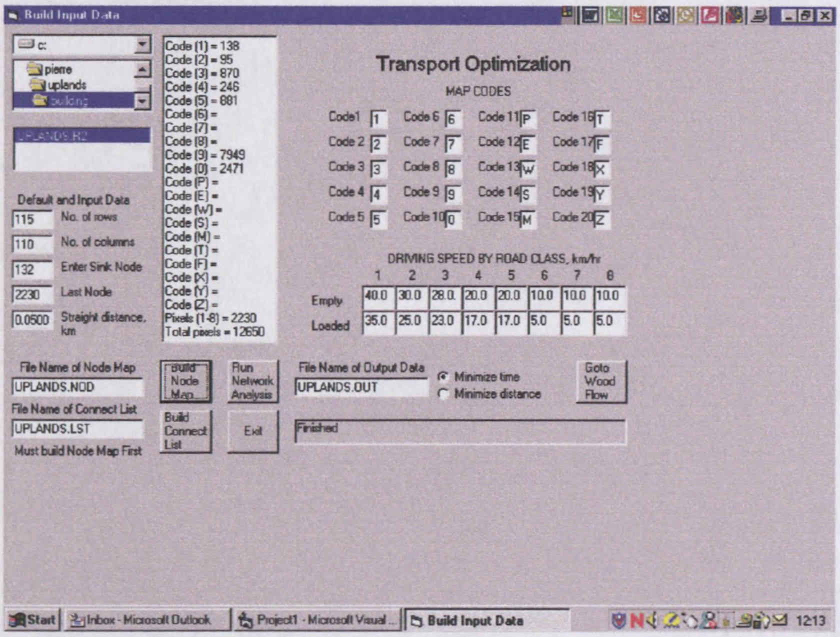

Figure 12: The Visual Basic data input form for the initiation and running of the network minimisation procedure of the network analysis programme

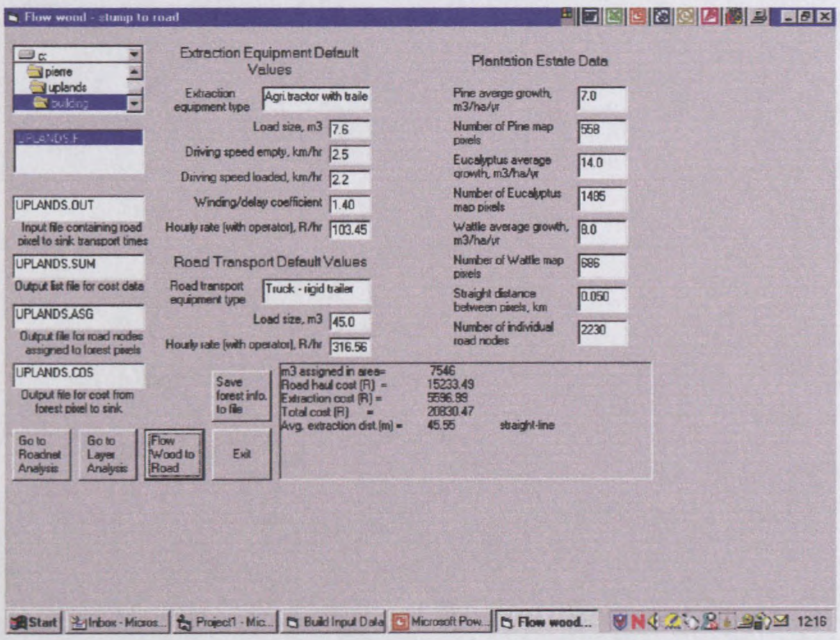

Figure 13: The Visual Basic data form catering for external inputs and inputs from the transport optimisation procedure to produce results (volume and cost) of the wood flow from stump to plantation sink

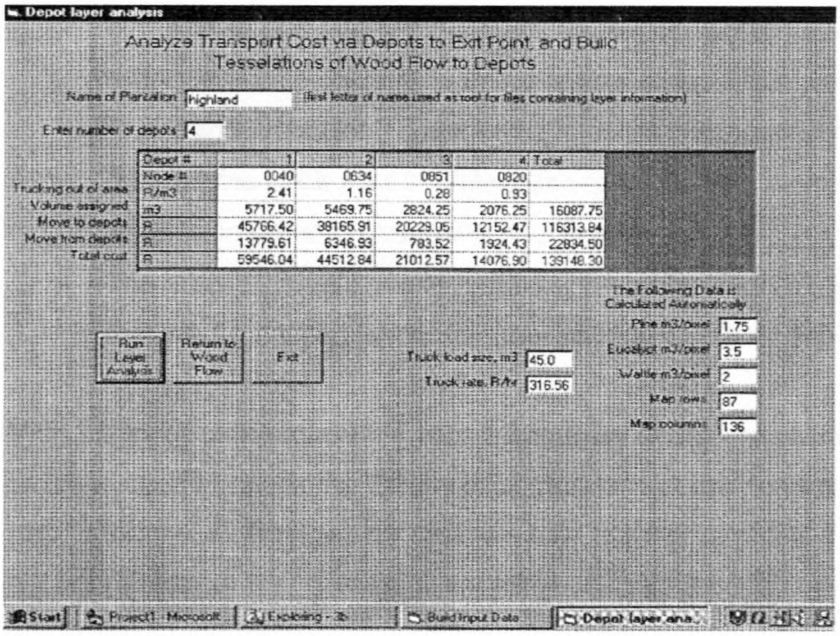

Figure 14: The Visual Basic data input form for layer analysis producing cost data for volume flow to and from depots per plantation and volume allocation to depots

2.2.3.5. Network minimisation

The transport optimisation procedure as illustrated in Figure 12 involves the optimisation of the transport of timber through the network by "time". That is, determining the minimum hauling times of the selected vehicle from a source node to all other road nodes in the network.

The following input data is required:

- The selected plantation's road pixel map for input of correct road map.
- The dimensions of this particular area's spatial database, to initialise the programme.
- The last node number of the database as reference.
- The plantation exit or depot node number as required by specific computer runs to determine a source node.

- The default straight-line distance for the individual pixel dimension, in the case of the fixed grid method it is 50 m; to give correct dimensions of each pixel and distance from pixel to pixel and diagonal straight-line distances (70.7 m).
- The road and surface cover code, which correspond to data in Table 7, for the programme to be able to distinguish road classes, which are linked to travel speeds, in order to determine haul times.
- The entry of travel speeds loaded and empty, in km/h for the selected vehicle that will be hauling timber to either plantation exit or depot.

With the input of the road pixel map a summary of data related to the map is produced which is used to check the validity or correctness of the database and provide road pixel information. It shows for example total number of pixels (Figure 11) in the spatial database and number of road pixels per road class (codes correspond to Table 7).

The first file produced with the running of the programme is the road node map (Figure 11), which numbers road nodes sequentially from upper left hand corner to lower right hand corner. This allows the programme to produce a list file (Table 8), which is then used as input for the network analysis. The algorithm developed for the fixed grid structure allows only arcs between adjacent pixels to be analysed. In this way only four nodes are tested for solution improvements in network analysis. If a road node is not connected to four other nodes, dummy arcs back to itself at very high impediment are set so that each node has four records (Table 8). In this way, as illustrated in Table 8, distances between itself and the four nodes around it are calculated. The distances between all nodes through the network are available for the network analysis procedure.

This data is entered and the network analysis programme, run. The basic network analysis procedure is as outlined in section 2.2.3.3. The results of the network analysis are reproduced in an output file, which tabulates the optimised times to haul timber from all road nodes to the desired plantation sink road node. The optimised time is the minimum time required to move from the sink to all other road nodes unloaded and return to the sink node loaded (Table 9). The minimum times take into consideration road classes and travel speed loaded and empty, and are calculated from a source node to all other nodes in the matrix by the network analysis programme.

Table 8: Connection list file example (input data to network minimisation)

Nodes		Road class		Distance (km)
From node	To node	From class	To class	
0001	0002	4	4	0.0500
0001	0006	4	4	0.0707
0001	0001	4	4	999.999
0001	0001	4	4	999.999
"	"	"	"	"
"	"	"	"	"
1669	1669	4	4	999.999
1669	1669	4	4	999.999

Table 9: Output file results; example from network analysis (network minimisation) procedure

Sink node road number	Road node number	Time (hours)
1518	0001	0.839
1518	0002	0.850
1518	0003	0.861
1518	0004	0.855
"	"	"
"	"	"
1518	1668	0.401
1518	1669	0.390

This data is the output from the network minimisation and is used for the input into the wood flow analysis.

2.2.3.6. Wood flow analysis

The wood flow procedure involves the flow of wood from the forest pixels to roadside (primary transport) or depot (extended primary transport) with selected extraction equipment and then onto the plantation exits with secondary transport vehicles. As mentioned above, the output file from the transport optimisation phase forms the input into wood flow analysis (Figure 13).

The extraction procedure takes into account load volume removed by the equipment per cycle from the forest pixel, the loaded and empty driving speeds of the equipment in-field and the winding coefficient to the roadside through the compartment.

The winding coefficient is necessary to simulate actual forest travel conditions. Extraction does not take place in straight lines in the forest compartment due to surface impediments and equipment tends to meander around these impediments. Straight-line distances are multiplied by a factor of 1.40 to simulate travel in compartments as calculated by Pulkki (1984).

The combined network analysis programme makes provision for the removal of the average annual growth from the estates. In this way all possible solutions for each estate are found and an overall average annual cost for each transport system is available. The programme calculates and produces a forest information file. The inputs required are from the spatial database, surface cover type per pixel and the MAI per pixel. The file therefore contains the volumes assigned by species per pixel. Linked with extraction equipment travel speeds, hourly cost, volumes per load extracted and the extraction distance, extraction costs are calculated per cubic metre delivered to the roadside or depot. Coupled with information from the network minimisation procedure (output file), the travel speeds and hourly cost of the road haul phase, allows the programme to minimise cost of extraction (or extended primary transport) and road transport to plantation sink or to a depot. This information is stored in an assignment file and thus contains the volume in m^3 assigned to each road pixel based on minimum total cost of extraction and transport to depot or sink. This file is in map format and will serve as a layer (as with cost information) in the layer analysis.

It is important to bear in mind that road classes and travel speeds on roads play an important role when volume, from the forest pixel is taken to roadside or depot. Remembering that the programme is optimising both extraction and road transport costs, the higher the quality of the road leading to the pixel the greater the speeds (and thus lower cost per m^3) travelled on the road, relative to the slower speed (and thus higher cost per m^3) of extraction. Thus the vehicle will travel further along the road, resulting in shorter extraction distances to roadside during primary transport. On poorer roads the travel speeds will be lower and thus in order to optimise the cost of both operations it is more beneficial to drive across (angle) the compartment towards the sink rather than drive straight out to the road, then down the road towards the sink. (i.e. drive along the hypotenuse). Thus, longer extraction distances result with poorer quality roads.

Information summary files (Table 10) and cost files are the output files from the wood flow analysis. The cost file (cost of moving wood from a forest pixel to plantation sink) is in the form of a pixel map, which will serve as an information layer in the later layer analysis.

Table 10: Example of transport times and volume assigned per road pixel as recorded in the assignment file

Sink road node number	Road node number (#)	Time to move from sink to node (#) and back (hours)	Volume assigned to node (m^3)	Road node coordinates
1058	1	0.9395920	0.000	001x090
1058	2	0.9508420	3.500	001x091
1058	2	0.9620920	3.500	001x092
1058	3	0.9620030	0.000	001x093
1058		0.9507503	0.000	001x094
"	"	"	"	"
"	"	"	"	"
1058	9	0.8852770	3.750	003x086
1058	10	0.8965270	1.500	003x087

The wood flow programme optimises the cost of timber transport from stump to or via the roadside landing; from there to either plantation depots or sink/exits, using network minimisation inputs from the network analysis procedure. The final output is the cost for road haul and extraction per m^3 for the volume assigned in the area. The sum of extraction and road haul cost is given as well. Additionally, the average straight-line extraction distance from forest pixel to roadside is given for later comparison.

Additional plantation data is tabulated on the wood flow analysis Visual Basic form (Figure 13) and comprises of the given MAI (average growth by species group in m^3/ha/yr) and the number of pixels per timber species.

2.2.3.7. Depot layer analysis and Dirichlet tessellations

This procedure analyses costs via the depots to plantation exit points, and builds tessellations of wood flow to depots. A brief discussion of Dirichlet tessellations follows.

Given a collection of points in the plane, one may draw a cell or polygon around each point in such a way that each point's cell or polygon is the portion of the plane consisting of all locations closer to that point than to any of the other points. The resultant geometric Figure is called a Dirichlet tessellation (Byers 1996 and Schoenberg *et al.* 2001). Dirichlet tessellations have been used to define amongst others, colonisation of territories of bark beetles (Byers 1992 and 1996).

Dirichlet pavements are polygons, which intersect each other at their edges, and adjacent Dirichlet pavements are called Dirichlet neighbours (Pulkki 1984). According to Pulkki (1984) they can be derived through mathematical programming and can be used in investigations such as:

- Determining interface/fringe areas where detailed attention can be directed.
- Determine theoretical sphere of influence.
- Demarcation of areas.

The formation of Dirichlet pavements employing grid referenced spatial data is as follows. First, the coordinates of the focal points are specified. Straight-line distances or minimum cost of moving are then calculated between each grid cell and all focal points, and the grid cell is assigned the code of the "closest" focal point. Once all the cells have been assigned to a focal point we have a Dirichlet tessellation (Pulkki 1984).

2.2.3.8. Layer analysis

With timber being hauled to depots by extended primary transport three problems were encountered that needed solutions:

- What volume was being hauled to these depots individually?
- What was the cost of moving this volume to the depots?
- What was the cost of moving the volume away from these depots?

The layer analysis or Dirichlet tessellations provide the solutions required. The procedure involves the analysis of a variety of data, already produced in the previous analyses, which are placed in layers in order to interpret data in a zone or pixel common to all the layers. All pixel maps (information files) of individual areas, are compatible due to uniform size spatial data bases, thus data placed in layers concerning a certain pixel all have the same addresses and can be compared or used to facilitate analysis of the pixel's information. This is similar to work done by Pulkki (1987) in providing practical solutions to forest product exports from Finland and in Pulkki (1984).

By placing the following information in layers a layer analysis can be produced:

- Forest information (species per pixel).
- Data regarding forest pixel information (species and m^3/pixel).
- The road node map.
- The output file generated during the network analysis procedure.
- The cost file generated during the wood flow procedure.

With the above data available, a volume is assigned to every pixel depending on the species present in that pixel. If a volume has been assigned, then the layer analysis programme will find a depot giving the minimum cost of getting that volume to a depot and minimum cost of transporting the wood from that particular depot to the plantation exit or sink.

The volumes and costs to the particular depots are added and a depot number is assigned to that data. The depot number will coincide with the depot number and node numbers originally assigned (refer to Figure 15). The tessellation maps are now built and the data saved in a tessellation map file for that particular situation (Figure 15).

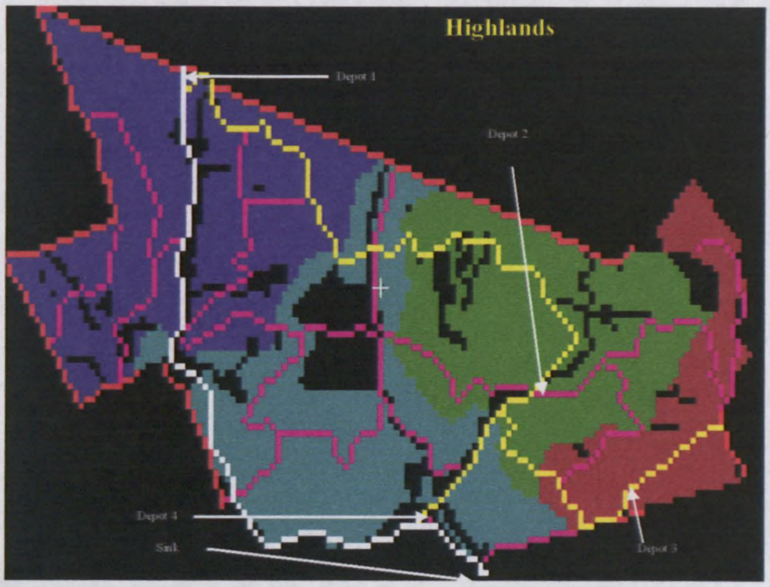

Figure 15: Example of Dirichlet tessellation showing wood flow to the four depots in colour code on Highlands plantation

The layer analysis programme in addition to producing the tessellation map calculates individual and global costs for timber transport to and from individual depots and totals the volumes allocated to each depot, which is the backbone to the economic analysis.

2.2.4. Manipulation of spatial database

2.2.4.1. Road density reductions

Manipulations of the database were restricted to the roads database matrices. As in most plantations there was an over abundance of roads. Two road reduction exercises were undertaken for each area. The general recipe in the first reduction was to reduce the number of road pixels on all plantations by approximately 50 %. The second procedure reduced the number of road pixels to 30% of the original number. This last reduction, however, had to be approached differently to the first road reduction process.

The reason for reducing the road network density and subsequent road upgrading was to allow the rigid truck and drawbar trailer vehicles to enter the plantation right to the compartment level. The three study areas with the original road network do not allow these vehicles to reach the compartment roadside. Only with reduced densities, could the available road maintenance and upgrade budget be effectively implemented to allow further travel into the plantation by these larger vehicles.

The initial reduction was an attempt to achieve some semblance of order in the road network. The standard applied in reducing the total number of road pixels by 50% for the first reduction was the following:

- Attempt to maintain an average primary transport distance in the region of 50 metres (maximum distance of 200 metres between roads) throughout the areas.
- Eliminate all roads with grades of 12% and greater, except for short pitches if identifiable from the contours, and adhere to harvesting codes of practices or best operating practice codes (Dykstra and Heinrich 1995, Anon 1995 and Anon 1999 a).
- Eliminate all unnecessary class three roads.
- The class three roads that are necessary to remain in order to maintain a logical network, were upgraded to class two roads.

The reason for the initial elimination of class 3 routes was that they were not suitable for travel by the high payload highway vehicles due to poor horizontal and vertical alignment. These routes are, when considering the initial network the most prevalent in comparison to other roads in the network. Because there are so many of them, they are generally in poor condition due to non-maintenance.

The standard applied in the second reduction was the following:

- Adjust the existing remaining road system to accommodate an average primary transport distance of 150 metres (road spacing of 600m).
- Where possible straighten out roads (take out unnecessary corners), which complicate the network, and often are sources for errors in the network.

The result of this road reduction process was that each plantation now has three road density scenarios, which can be compared during the economic analysis. Each area had more or less the same percentage road reduction namely from 100% down to 50% on the first reduction and then down to 30% of the original density. The road density scenarios will in future be referenced by the codes (100%), (50%) and (30%), respectively.

2.2.4.2. Road density determination and calculations

Accurate road density determination is not crucial to the outcome of this study. However the process of two progressive road length reductions with associated relative economic outcomes does give value to the eventual results of the study. The observations of tendencies as related to road densities are important.

Road density can be calculated as follows. From the wood flow analysis the programme calculates an average primary transport straight-line distance. Average road spacing is determined by multiplying the average straight-line distance by four. By dividing the average road spacing into 10 000, a road density in m/ha is calculated. Wood is however only being extracted to roads giving the lowest combined cost of extraction and hauling to sink. As seen from road pixel data, (Appendix E) only between 50 and 80% of the total road pixels are being utilised thus underestimating road density. Using this method in association with the following gives a realistic road density result.

Using the weighted average number of road pixels utilised per road density scenario, and taking into consideration the total volume extracted per plantation and the volumes assigned to each depot per plantation, a conservative but realistic road density can be calculated. A result is achieved by dividing the weighted numbers of road pixels used by the total number of road pixels per area, the result is in turn multiplied by the road density calculation result based on average extraction distance.

2.2.5. Travel times and equipment costing

The empty and loaded driving speeds on the road classes as specified in Table 3 are presented in Table 11. The costs to operate the timber transport equipment and vehicles, and load sizes, are given in Table 12. In order to estimate driving times over different road standards, average loaded and unloaded travel speed of the various vehicles were determined. Table 11 below summarises the basic data (Larcombe 1999, Shuttleworth 1999 and 2000 and Van Daele 1999).

Table 11: Travel speeds for applied equipment over different road classes

Road Class	Travel speeds in km/hour					
	Agricultural tractor and (bundle) semi-trailer		Agricultural tractor and semi-trailer		Rigid truck and drawbar trailer	
	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded
1	13.0	14.0	28.0	30.0	35.0	40.0
2	8.0	8.0	10.0	25.0	25.0	30.0
3	8.0	8.0	10.0	22.0	23.0	28.0
4	5.0	5.0	8.0	10.0	17.0	20.0
5	5.0	5.	8.0	10.0	17.0	20.0
In-field	2.2	2.5	3.0	4.0		

The costs per hour for each of the vehicles were calculated using a machine and vehicle costing model in Excel. A number of publications and models were used in order to derive a model that was suitable for the study. The models consulted were, Sessions and Sessions (1986), Hoffman (1991), (Anon 1992 a), Riddle (1994), Warkotsch (1994), Franklin (1997), and Grobbelaar (2000). In particular the vehicle-costing model was sourced from Lowe (1989) and Road Freight Costing Schedules (Anon 1999 b).

Table 12: Vehicle costs and load volumes

Vehicle type	Cost per hour (R/hour)	Load volume (m^3)
Agricultural (bundle) and semi trailer	103.45	7.6
Agricultural (bundle) and semi trailer	154.98	19.7
Rigid truck and drawbar trailer	316.56	45.0

2.2.6. Scenario runs using the combined network model

To apply the combined network model to the data, scenario runs had to be designed. That is, which systems, apart from the existing transport system, will be applied to the model? In line with the objective of the study, the potential phasing out of SIT and extended primary transport, it was decided to apply the following scenarios to the data.

Figures 16, 17 and 18 are matrices showing the three different transport systems. Figure 16 (system 1) is the existing transport system used. Extended primary transport to depot, SIT to plantation sink where the timber is reloaded for potential STT to processing plant. Figure 17 (system 2) represents a transport system of extended primary transport to depot and STT to plantation sink/exit. Figure 18 (system 3) represents the system, primary transport to roadside and STT to plantation sink. In all cases the analysis terminates with a loaded truck ready to leave the sink.

Each of these transport systems will be applied to each of the road reduction scenarios (100%, 50% and 30%), except for system 3, which will only be applied to road reduction scenarios reduced to (30%) of the original. The systems will be identified as indicated in Table 13.

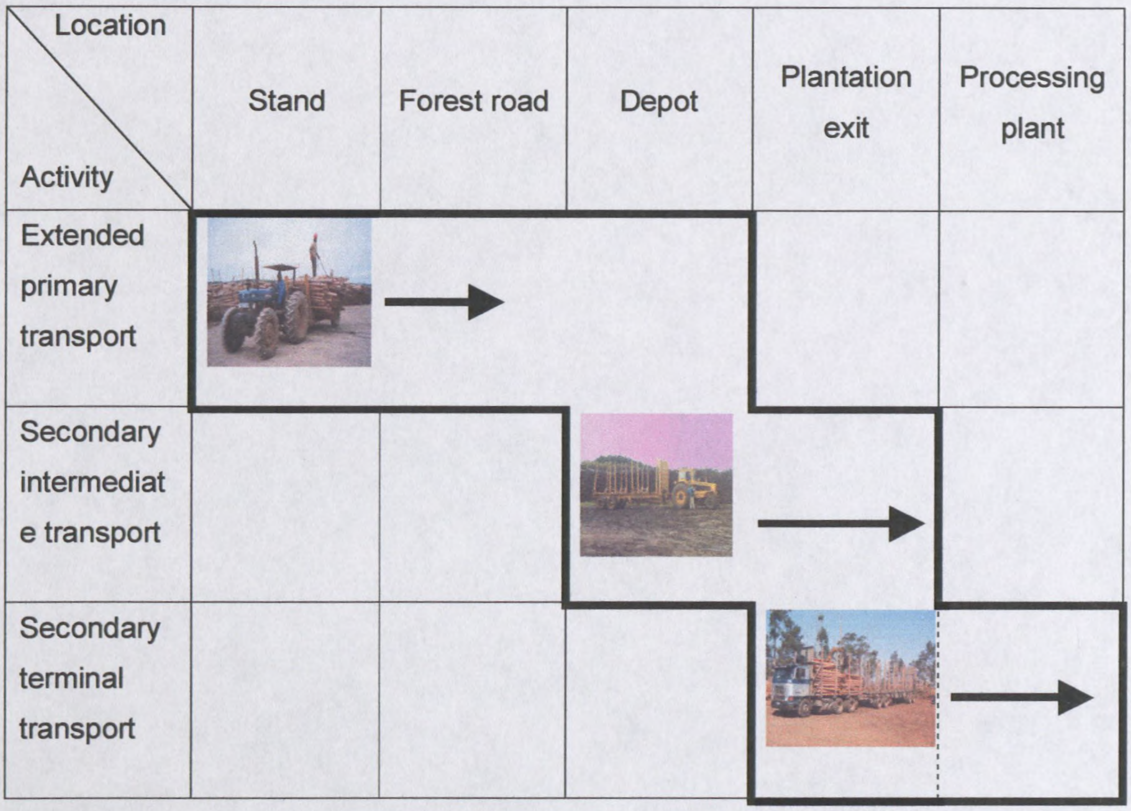

Figure 16: Transport matrix system 1

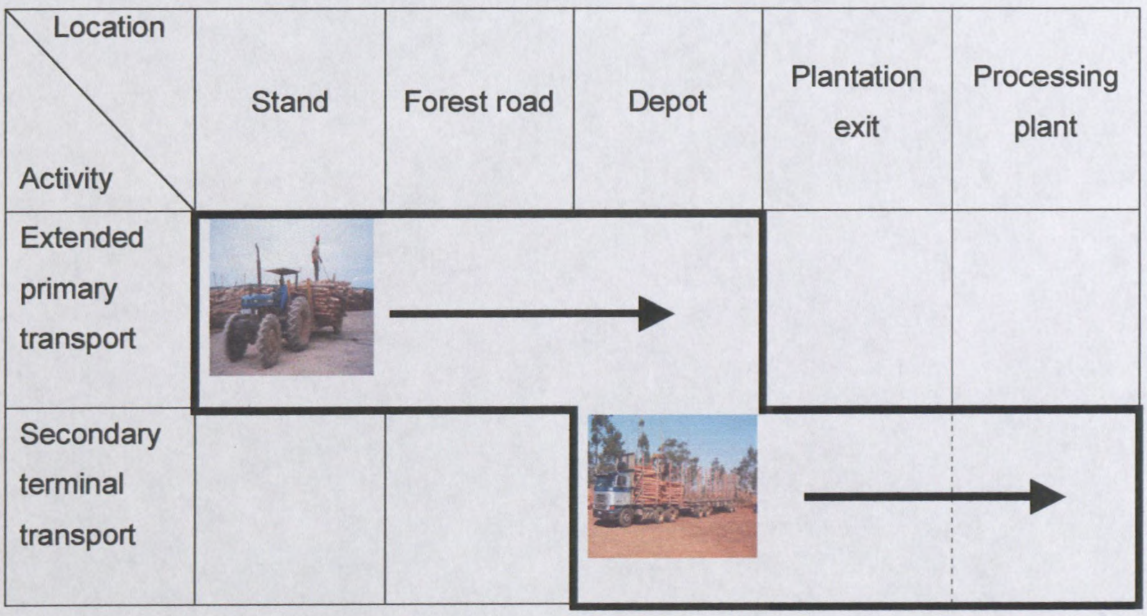

Figure 17: Transport matrix system 2

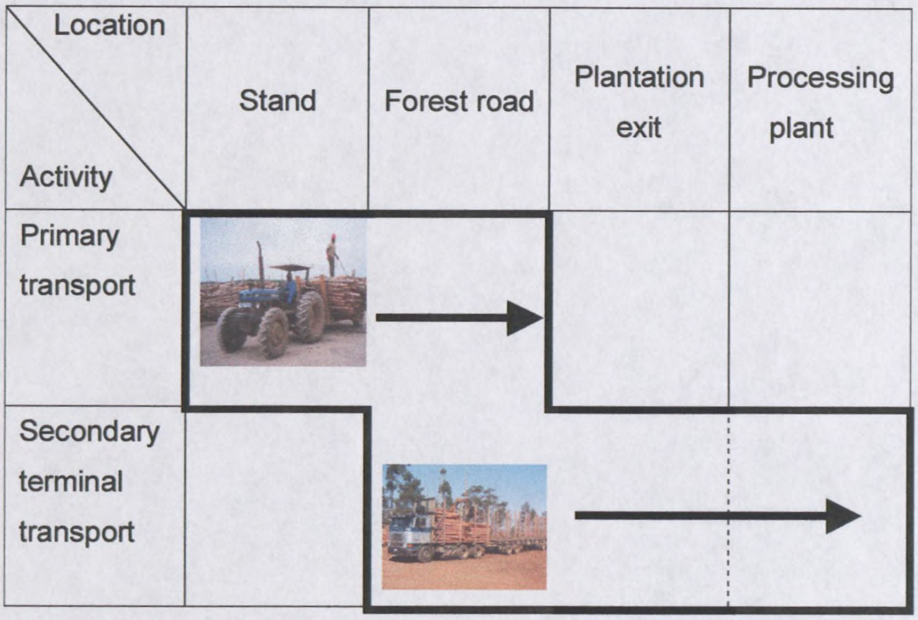

Figure 18: Transport matrix system 3

2.2.7. Depot locations

The depot locations for each estate were identified on the plantation stock maps in consultation with the area-harvesting manager. From the grid square system the coordinates of each depot were established for fixed reference.

A particular road node number for each depot, within each road density scenario, had to be established. Because road nodes were allocated unique sequential numbers by the programme in the matrix, from upper left to lower right, and would therefore change with every road node reduction as the numbers of pixels are reduced, it is important to establish each depot road node number per road scenario. The following three Tables show particulars regarding depot location for each plantation. Uplands, Highlands and Greenhill have five, four and nine depots each, respectively (Tables 14, 15 and 16). For the positioning on the matrix maps of these depots refer to the Appendix F.

Table 13: System matrix identification

Uplands	**Road density scenarios** Identification labelling for each situation		
	100%	**50%**	**30%**
System 1	1(100%)	1(50%)	1(30%)
System 2	2(100%)	2(50%)	2(30%)
System 3			3(30%)
Highlands			
System 1	1(100%)	1(50%)	1(30%)
System 2	2(100%)	2(50%)	2(30%)
System 3			3(30%)
Greenhill			
System 1	1(100%)	1(50%)	1(30%)
System 2	2(100%)	2(50%)	2(30%)
System 3			3(30%)

Table 14: Coordinates and road node numbers for depot sites on Uplands

Uplands depot location			Road density scenario and road node number for each depot		
Depot number	Row coordinate	Column coordinate	100%	50%	30%
1	16	10	0164	0114	0084
2	19	55	0248	0149	0123
3	37	664	0829	0360	0274
4	54	104	1468	0643	0499
5	59	78	1602	0691	0535
Sink	22	05	0307	0165	0132

Table 15: Coordinates and road node numbers for depot sites on Highlands

Highlands depot location			Road density scenario and road node number for each depot		
Depot number	Row coordinate	Column coordinate	100%	50%	30%
1	11	33	0078	0046	0040
2	59	96	1633	0914	0634
3	73	113	2146	1208	0820
4	78	77	2291	1283	0851
Sink	86	87	2402	1375	0922

Table 16: Coordinates and road node numbers for depot sites on Greenhill

Greenhill depot location			Road density scenarios and road node number for each depot		
Depot number	Row coordinate	Column coordinate	100%	50%	30%
1	5	83	0026	0021	0021
2	30	90	0413	0249	0157
3	53	65	1099	0630	0426
4	62	32	1368	0786	0523
5	65	49	1501	0880	0604
6	78	57	1885	1095	0764
7	81	93	1949	1160	0820
8	97	69	2475	1377	0966
9	105	108	2661	1477	1031
Sink	108	043	2728	1518	1058

2.2.8. Loading operations

Only three wheel log loaders are used to load timber within the study area. These loading operations occur at roadside, depot and/or at the plantation exit point/sinks. Because loading at stump is common to all systems it is not included in the study.

Unloading is accomplished by tipping the load from the trailer, and therefore minimal cost is attached. For systems 1 and 2, loading does occur at the depot site for transport to the plantation sink. System 1, however, has to be reloaded onto highway vehicles at the plantation exit point for transport to the processing plant. System three has one loading operation at roadside after the primary transport operation.

The inclusion of this second loading cost for system 1 is necessary to bring the operation in line with system 2 and 3, where timber has already been loaded onto highway vehicles at the depot and roadside, respectively. The highway vehicles thus arrive at the plantation exit/sink (the point at which the study ends) ready to move on to the processing plants. Thus the stages of the operations are all similar at the plantation exit. The cost of loading has been set at R4.45/m^3. This was determined from the weighted averages for five costing periods as calculated by Crickmay and Burne (2000) and Shuttleworth (2000).

3. Results

3.1. Part one: The survey

3.1.1. The sample

An analysis of the representation is as follows:

- Of the 9.40 million tonnes (11.6654 million m^3) roundwood intake by the mills during 1998, which had undergone primary transport, the survey covered 5.176 million tonnes (6.423 million m^3) of these activities. This is a percentage of 55%.
- Of the 3.991 million tonnes (4.953 million m^3), which arrived by rail at the mills, the survey covered 2.235 million tonnes (2.774 million m^3). This is a percentage of 56%.
- Of the 3.7 million tonnes (4.592 million m^3) transported by road to the different mills, which underwent intermediate secondary transport, the survey covered 3.049 million (3.784 million m^3) tonnes. This is a percentage of 82%.
- Of the 112 contractor and own-operations to which questionnaires were sent, 82 were returned and the data incorporated into the database. This is a percentage return of 73.2%. The database consisted of 25 and 43 contractors who contracted only for Sappi and Mondi respectively, and five who contracted for both parties. Surveys from nine own-operations were returned.
- The expenditure on road upgrades and maintenance by the two different companies can be considered as exact replication of reality. The company representatives supplied all this data.

In view of the good response rate to the questionnaire and the coverage of it to the total industry situation, the analysis and results of the survey are considered representative and valid. The complete survey results are in appendix D.

3.1.2. Spending on road maintenance and upgrading

There was a doubling of expenditure for 1998 as compared to 1997 on road upgrades and maintenance for the total industry (Figure 19). However, the upward trend declined drastically during 1999. The budgets for 1999 show a definite downswing in the region of R10 million or a 32 percent decrease over 1998. The downswing was not sustained and a general upwards tendency is observed up to the current budget year, 2001. What is of interest is the division of expenditure between the companies during this period (Table 17).

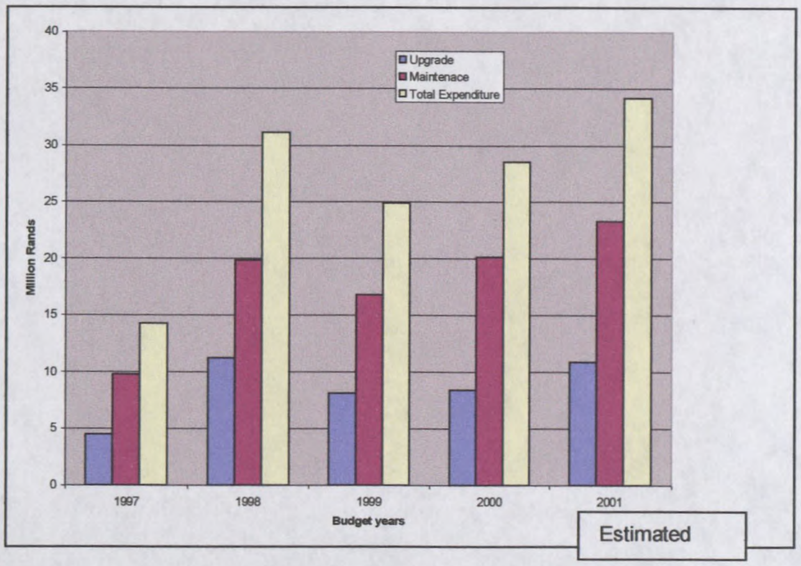

Figure 19: Expenditure (nominal) on road upgrades and maintenance from 1997 to 2001

Table 17: Nominal expenditure on roads per company for upgrades and maintenance and expenditure per hectare

Sappi	Road upgrade and maintenance annual budgets									
	1997		1998		1999		2000		2001	
	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha
Upgrade	0.97	2.59	1.00	2.67	0.86	2.30	4.30	11.49	6.80	18.17
Maintenance	3.04	8.13	5.12	13.68	6.23	16.65	8.93	23.87	10.50	28.06
Total	4.01	10.72	6.12	16.36	7.09	18.95	13.23	35.36	17.30	46.24

Mondi	Road upgrade and maintenance annual budgets									
	1997		1998		1999		2000		2001	
	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha
Upgrade	3.51	8.34	10.23	24.30	7.31	17.36	4.10	9.74	3.90	9.26
Maintenance	3.04	7.21	14.74	35.01	10.58	25.13	11.20	26.60	12.80	30.40
Total	10.20	24.22	24.97	59.30	17.90	42.52	15.30	36.34	16.70	39.67
					Summary data					
Upgrade	4.48	6.01	11.23	15.07	8.17	10.96	8.40	11.27	10.70	14.36
Maintenance	6.08	8.16	19.86	26.65	16.81	9.14	20.13	27.01	23.30	31.27
Grand total	14.21	19.07	31.09	41.72	24.99	33.54	28.53	38.29	34.00	45.63

3.1.3. Perceptions as to actual road repairs

The questionnaire requested the contractors to respond to the following:

- If roads required repairs in the areas they are expected to work, did the companies carry out these repairs?
- If repairs were needed and done, who did this work (Table 18)?

Only 73 contractors were expected to respond, and no own-operations, as these answers would be biased (Table 18). It is interesting to note that four contractors said that in desperation they undertook to repair the roads themselves, to a standard just high enough to get by with for the period that they were working in an area.

Table 18: Numbers and percentages of who undertakes road repair

Activity	Number of cases	Percentage of total
Company Repairs	22	30
Contractor Repairs	8	11
No Repair Done	43	59
Total	73	100

3.1.4. Perceived causes for the presence of SIT

3.1.4.1. Roads

Of the 62 contractors who responded to the question of what, in their opinion, was the major contributing factor to the presence of SIT or why SIT was being maintained as a transport method, 53 or 85%, said that the poor and declining condition of the roads in the plantations was the major cause. The remaining 11 contractors or 12.5% did not offer an opinion.

Of 62 contractors who did respond, 47 or 75% were of the opinion that road conditions had declined over the last three years (survey year 1998) and longer, as was not a phenomenon that had suddenly appeared. The remaining respondents responses varied.

3.1.4.2. Yield, inventories, security and supply chain concepts

Low yield per hectare was given as a reason by 12 contractors: i.e., it would be uneconomical to use large, high payload combined or articulated vehicles, but that intermediate secondary transport was more applicable.

Four contractors saw the need to have buffers of timber stored at depots for periods of inclement weather. This would of necessity create the need for SIT, as a storage site implies, intermediate transport according to the definitions of SIT.

One contractor, who has been the victim of timber theft, felt that if his timber had been transported to a depot, the responsibility of theft was passed onto the company. The matter of security did not appear at all with any of the other respondents.

Four contractors felt there were too many contractors in the supply chain (flow of timber from stump to mill); one doing the preparation, one involved with the extraction and one each doing SIT or STT, respectively. This promoted short-term gains or minimizing costs on individual activities instead of concentrating on total costs.

3.1.4.3. Contract periods

Contract periods allocated by the companies to contractors varied considerably. Table 19 shows a breakdown of the allocated periods per contract. Seventy-three contractors responded.

Table 19: Contract periods

Contract period	Number of contracts
No contract (ad hoc basis)	2
< Year	3
1 Year	33
1 – 3 Years	32
>3 Years	3
Total	73

3.1.5. Transport origins

In order to establish from and to where timber is being transported during the intermediate secondary transport phase, contractors were asked to indicate volumes that were transported from either stump or landing to depots or sidings, respectively (Figure 20):

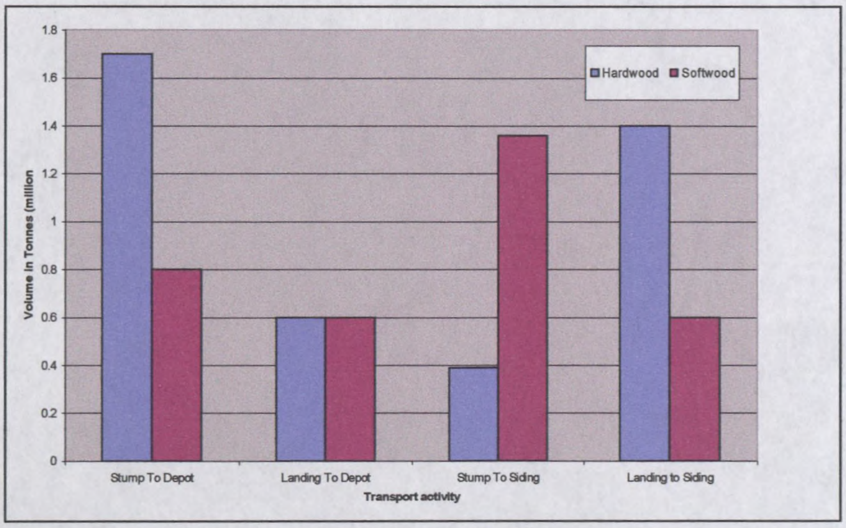

Figure 20: Transport origins and destinations comparisons

3.1.6. Loading methods

Loading methods, for transport from stump to depots or siding, or landing to depot or sidings, do not differ greatly. There is however a departure from manual loading to loading by three-wheel log loaders as one moves from the stump area to landings at roadside.

Figures 21 and 22 indicate this shift in loading methods from stump to the landing area. The dominance of three-wheeler log loaders for loading, be it at stump or on landing, is clearly indicated. Percentages for both series of data add to 100% of the volume allocated to each transport phase for both Figures 21 and 22.

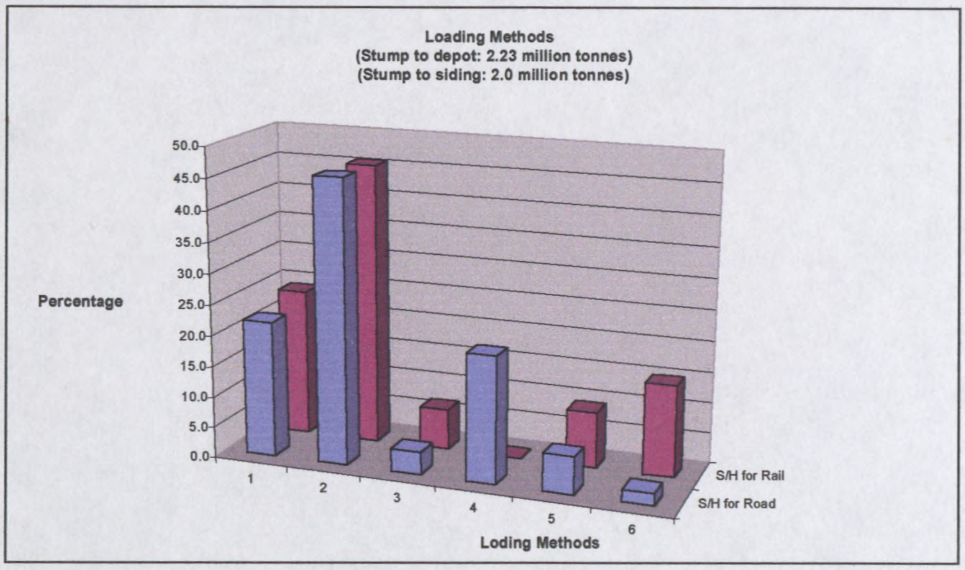

Figure 21: Loading methods from stump to depot and siding: (1. Manual loading; 2. Three-wheel log loaders; 3. Front-end loaders; 4. Vehicle mounted cranes (mounted on the vehicle which is transporting timber); 5. Independent loader (normally mobile); and 6. Other). (S/H is equivalent to shorthaul)

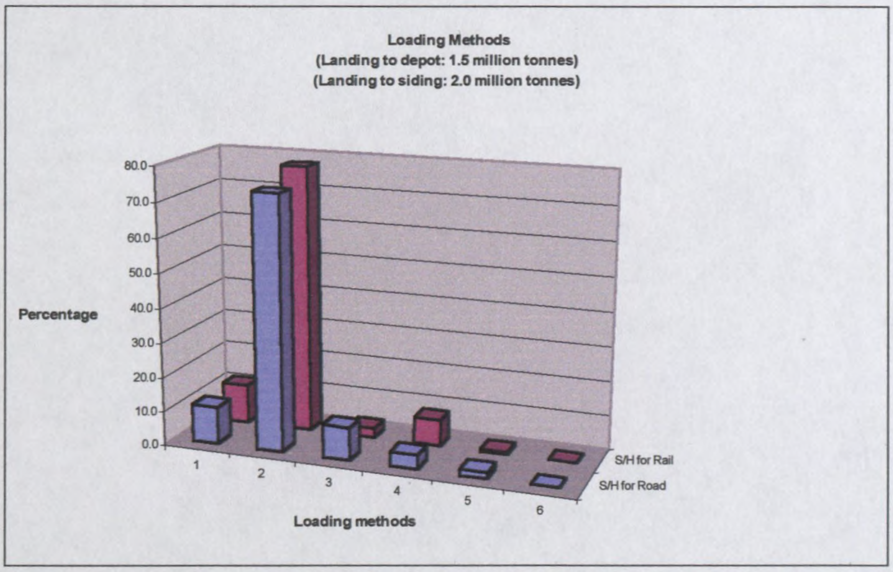

Figure 22: Loading methods from landing to depot and siding. 1. Manual loading; 2. Three-wheel log loaders; 3. Front-end loaders; 4. Vehicle mounted cranes (mounted on the vehicle which is transporting timber); 5. Independent loader (normally mobile); and 6. Other). (S/H is equivalent to shorthaul)

3.1.7. Lead distances

Extended primary and intermediate secondary transport lead distances vary considerably throughout the country (Figure 23). The greatest average lead distances are found to be associated with the Highveld and Mpumalanga geographical areas as opposed to Natal and Zululand.

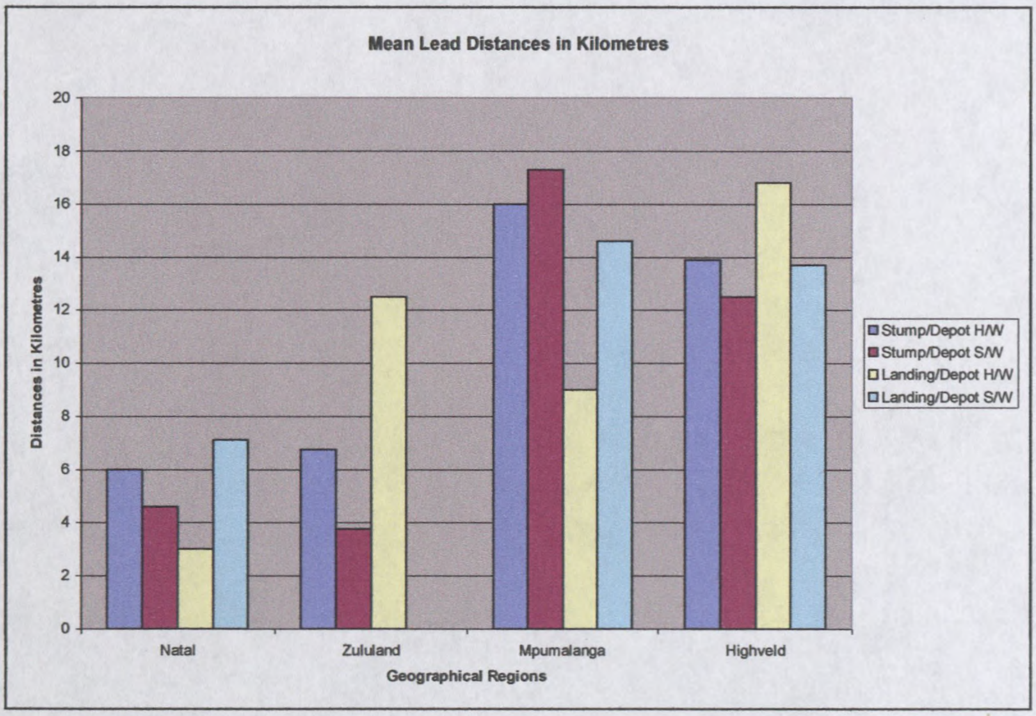

Figure 23: Extended primary and secondary intermediate transport lead distances (weighted by volume transported)

An analysis of mean, minimum and maximum lead distances per region per timber type, origin and destination vary greatly as illustrated in Table 20.

Table 20: Lead distance statistics per region, species and transport phase

	Natal				Zululand				Mpumalanga				Highveld			
	Stump to depot (km)		Land to depot (km)		Stump to depot (km)		Land to depot (km)		Stump to depot (km)		Land to depot (km)		Stump to depot (km)		Land to depot (km)	
	hw	sw	hw	sw	hw	sw	hw	sw	hw	sw	hw	sw	hw	sw	hw	sw
Mean	3	4.6	3	7.1	6.7	3.7	12	0	16	17	9	14	14	13	16	14
Min	3	2	3	2	1	3	5	0	16	12	5	4	1	1	3	6
Max	5	10	30	15	17	5	20	0	16	24	19	32	34	25	34	25

Statistical analysis						
	Stump to depot	Landing to depot	Stump to depot		Stump to landing	
df	83		H/w	S/w	H/w	S/w
			47		34	
Std dev	8.46		8.47		9.18	
T value	0.850*		0.27 (n/s)		0.066 (n/s)	

(* significant at 0.05 probability level)

3.1.8. Vehicle type

Timber transport from stump and or landing to depots, and to processing plants, is accomplished with eight basic types of vehicle types (Figure 24).

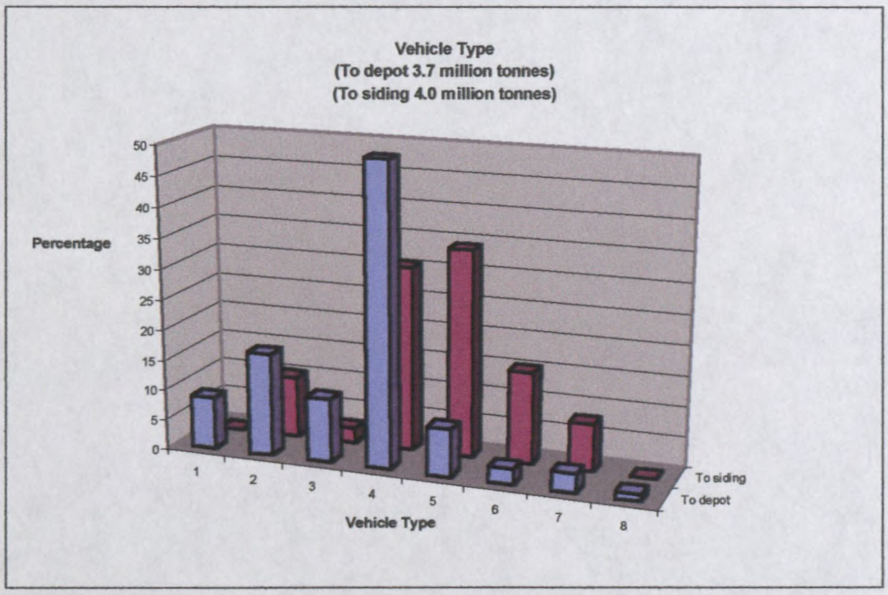

Figure 24 shows the use of SIT vehicles countrywide for both transport to depots and transport to sidings for rail transport from either stump or landing. (1. Forwarders; 2.

Timber haulers (e.g., Bell T25); 3. Agricultural tractor and semi-trailers with mounted cranes; 4. Agricultural tractor and semi-trailers with no crane (manual loading) ; 5. Rigid vehicles (with single or dual rear axles; 6. Rigid vehicles with drawbar trailers; 7. Articulated vehicles (prime mover and semi-trailer); and 8. Other).

3.2. Part two: The economic analysis

Figures 25 – 27 and Table 21, refer to the results of the scenarios run through the combined network analysis procedure.

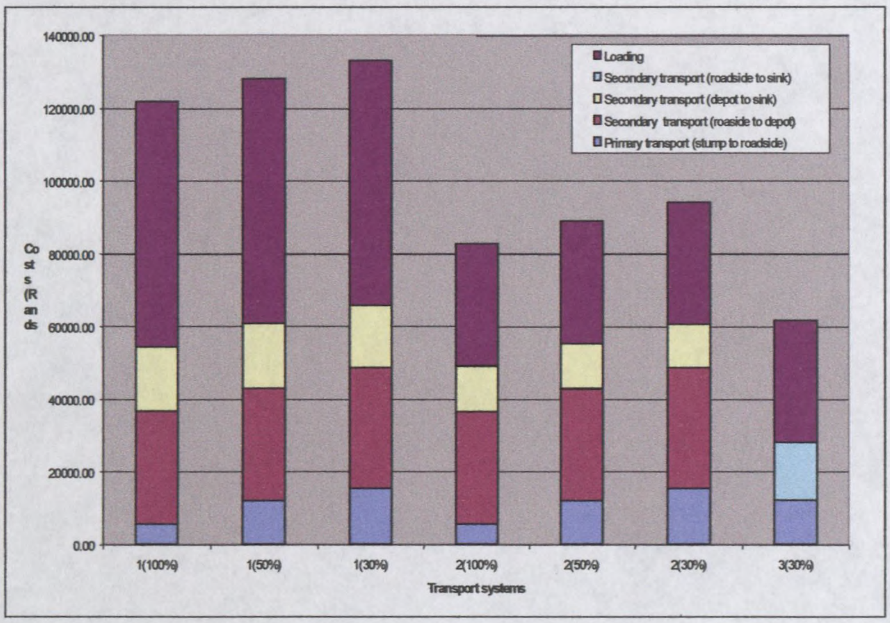

Figure 25: Uplands. Annual average cost comparisons between three timber transport systems and three road densities

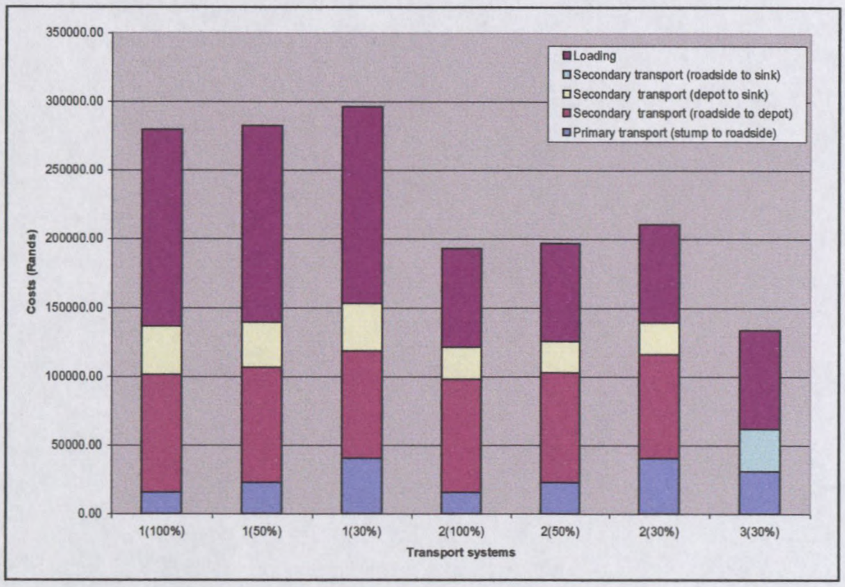

Figure 26: Highlands. Annual average cost comparisons between three timber transport systems and three road densities

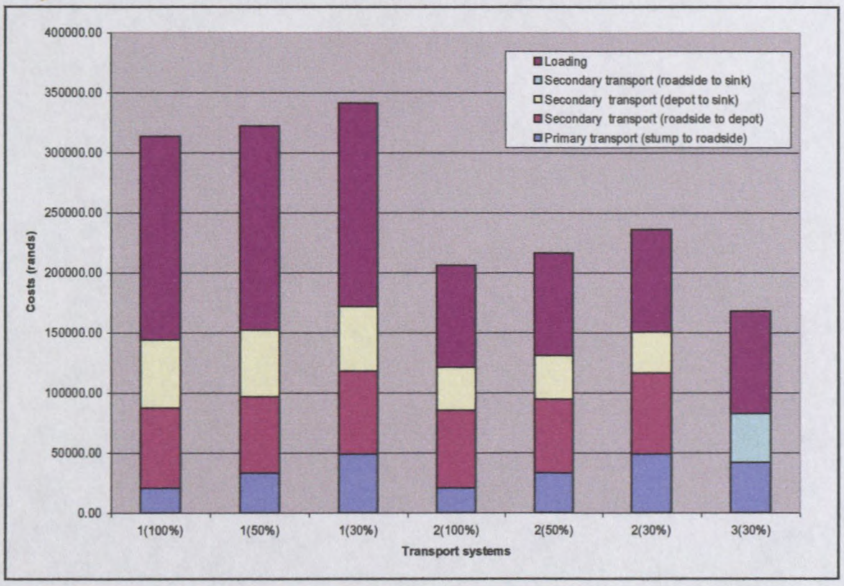

Figure 27: Greenhill. Annual average cost comparisons between three timber transport systems and three road densities

Table 21: Cost comparisons between the three timber transport systems for all three areas (average annual costs of timber removal in Rands if not otherwise indicated)

Uplands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Primary transport (stump to road side)	5626.50	11926.31	15386.39	5626.50	11926.31	15386.39	12195.30
Extended primary transport (road side to depot	30940.38	30913.67	33308.02	30891.28	30812.77	33233.88	
Secondary transport (depot to sink)	17806.03	17951.22	16974.33	12480.67	12536.47	12004.16	
Secondary transport (roadside to sink)							15786.30
Loading	67426.40	67426.40	67426.40	33713.20	33713.20	33713.20	33713.20
Total (rands)	121799.31	128217.60	133095.14	82711.65	88988.75	94337.63	61694.80
Average annual cost/m^3	16.08	16.92	17.57	10.92	11.75	12.45	8.14
Average straight line extraction distance	47.48	97.83	128.59	47.48	97.83	128.59	99.24
Road density (m/ha)	94.66	43.40	30.50	94.66	43.40	30.50	30.50

Highlands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Primary transport (stump to road side)	15807.28	22876.54	40319.37	15807.28	22876.54	40319.37	31263.21
Extended primary transport (road side to depot	85323.25	83618.56	77905.75	82172.74	79905.23	75994.47	
Secondary transport (depot to sink)	35473.81	32894.78	34987.43	23619.47	22724.98	22834.50	
Secondary transport (roadside to sink)							30770.76
Loading	143180.98	143180.98	143180.98	71590.49	71590.49	71590.49	71590.49
Total (rands)	279785.32	282570.86	296393.53	193189.98	197097.24	210738.83	133624.46
Average annual cost/m^3	17.39	17.56	18.42	12.01	12.25	13.10	8.31
Average straight line extraction distance	61.38	88.29	153.43	61.38	88.29	153.43	119.33
Road density (m/ha)	50.70	33.50	20.80	50.70	33.50	20.80	20.80

Greenhill

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Primary transport (stump to road side)	20714.10	33489.10	49418.60	20714.10	33489.10	49418.60	41628.94
Extended primary transport (road side to depot	66901.22	63097.34	68559.83	64598.66	61154.11	66683.27	
Secondary transport (depot to sink)	56505.21	55806.13	53963.20	36096.25	36709.74	34742.17	
Secondary transport (roadside to sink)							41303.00
Loading	169745.25	169745.25	169745.25	84872.25	84872.25	84872.25	84872.25
Total (rands)	313865.78	322137.82	341686.88	206281.26	216225.20	235716.29	167804.19
Average annual cost/m^3	16.46	16.89	17.92	10.82	11.34	12.36	8.80
Average straight line extraction distance	68.55	107.48	160.73	68.55	107.48	160.73	134.03
Road density (m/ha)	52.16	30.76	19.86	52.16	30.76	19.86	19.86

For comparative purposes all average annual costs of timber transport are shown in Figure 25, 26 and 27 and Table 21. These costs include, where applicable:

- Extraction costs (stump to roadside).
- Extended primary transport costs (roadside to depot).
- Secondary intermediate/terminal transport costs (depot to sink).
- Secondary terminal transport costs (roadside to plantation exit/sink).
- Loading costs.

3.2.1. Straight-line extraction distances

Comparisons of straight-line extraction distances per road density scenario are illustrated in Table 22 below.

Table 22: Straight-line extraction distances per plantation, per transport system and road density scenario

Transport system and density scenario	Uplands		Highlands		Greenhill	
	Primary transport cost (Rands)	Straight-line extraction distance (metres)	Primary transport cost (Rands)	Straight-line extraction distances (metres)	Primary transport cost (Rands)	Straight-line extraction distance (metres)
1(100%)	5626.50	47.48	15087.28	61.38	20714.10	68.55
1(50%)	11926.31	97.83	22876.54	88.29	33489.10	107.48
1(30%)	15386.39	128.59	40319.37	153.43	49418.60	160.73
2(100%)	5626.50	47.48	15807.28	61.38	20714.10	68.55
2(50%)	11926.31	97.83	22876.54	88.29	33489.10	107.48
2(30%)	15386.39	128.59	40319.37	153.43	49418.60	160.73
3(30%)	12195.30	99.24	31263.21	119.33	41628.94	134.03

3.2.2. Road network

Current road densities are relatively high, but on a *par* with what is found in South Africa at present. The following Table depicts the *status quo* (Table 23).

Table 23: Calculated current road densities per area

Estate/Plantation	Road densities
Uplands	94.66 m/ha
Highlands	50.70 m/ha
Greenhill	52.16 m/ha

Table 24 shows comparative road densities between forested and non-forested areas.

Table 24: Road density calculations comparisons between forest and non-forest areas

Ground cover	Uplands density (m/ha)	Highlands density (m/ha)	Greenhill density (m/ha)
Forest areas	79.0	46.0	44.9
Non-forest areas	120.5	78.2	71.3

The following Table (Table 25) gives an estimate of the distance in kilometres of roads per road class for the different plantation before density reductions

Table 25: Original distance per road class per estate

Study road class	Company class	Uplands (km)	Highlands (Km)	Greenhill (Km)	Totals (km)
1	P (prov)	6.6	3.7	9.3	19.6
2	A	4.6	5.8	10.2	20.6
3	B	41.7	24.4	40.2	106.3
4	Boundary	11.6	8.2	11.0	30.8
5	C	42.1	37.4	48.4	127.9
Total		106.6	79.5	119.1	305.2

Table 26 reflects potential cost benefits associated with road density reduction per plantation expressed in kilometres and m/ha of road. For visual representation of the different plantation's road density scenarios refer to plantation matrix road maps in Appendix F.

Table 26: Reduction in road density per plantation at 30% of original road density

Plantation	Density scenarios density and actual distance		Reduction %	Kilometres reduced
Uplands	100%	30%	67.7 % (64.11 m/ha)	72.22 km
	94.66 m/ha	30.55 m/ha		
	106.5 km	34.3 km		
Highlands	100%	30%	59.0% (29.9 m/ha)	46.90 km
	50.70 m/ha	20.80 m/ha		
	79.47 km	32.60 km		
Greenhill	100%	30%	62.0% (32.3 m/ha)	73.70km
	52.16 m/ha	19.86 m/ha		
	119.1 km	45.3 km		

3.2.3. Wood flow to plantation exit/sink via depots

The wood flows to the four depots on Highlands, at the three road densities, are indicated by colour codes (Figures 28 – 30). The road system is also available to aid the perspective of the wood allocation to the different areas. In contrast to Table 7, A-class roads are indicated in yellow.

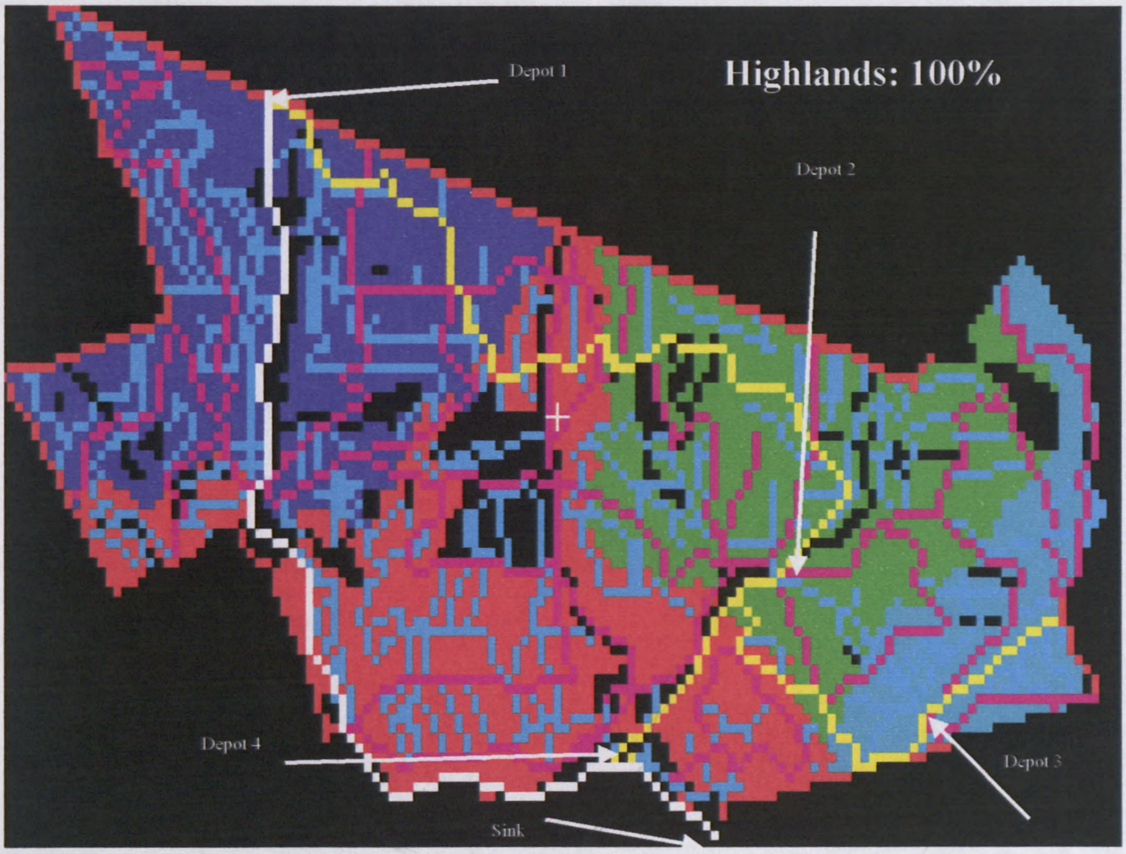

Figure 28: Tessellation maps: Highlands road density 100%

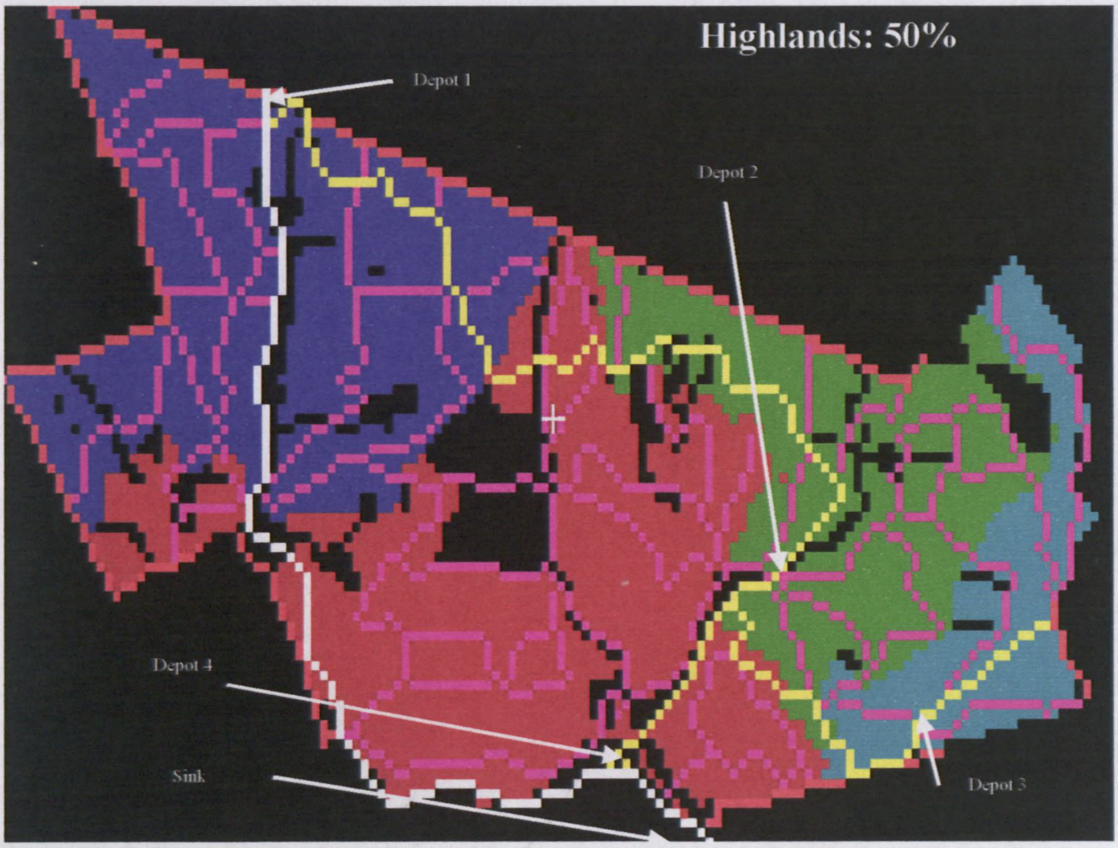

Figure 29: Tessellation map Highlands road density 50%

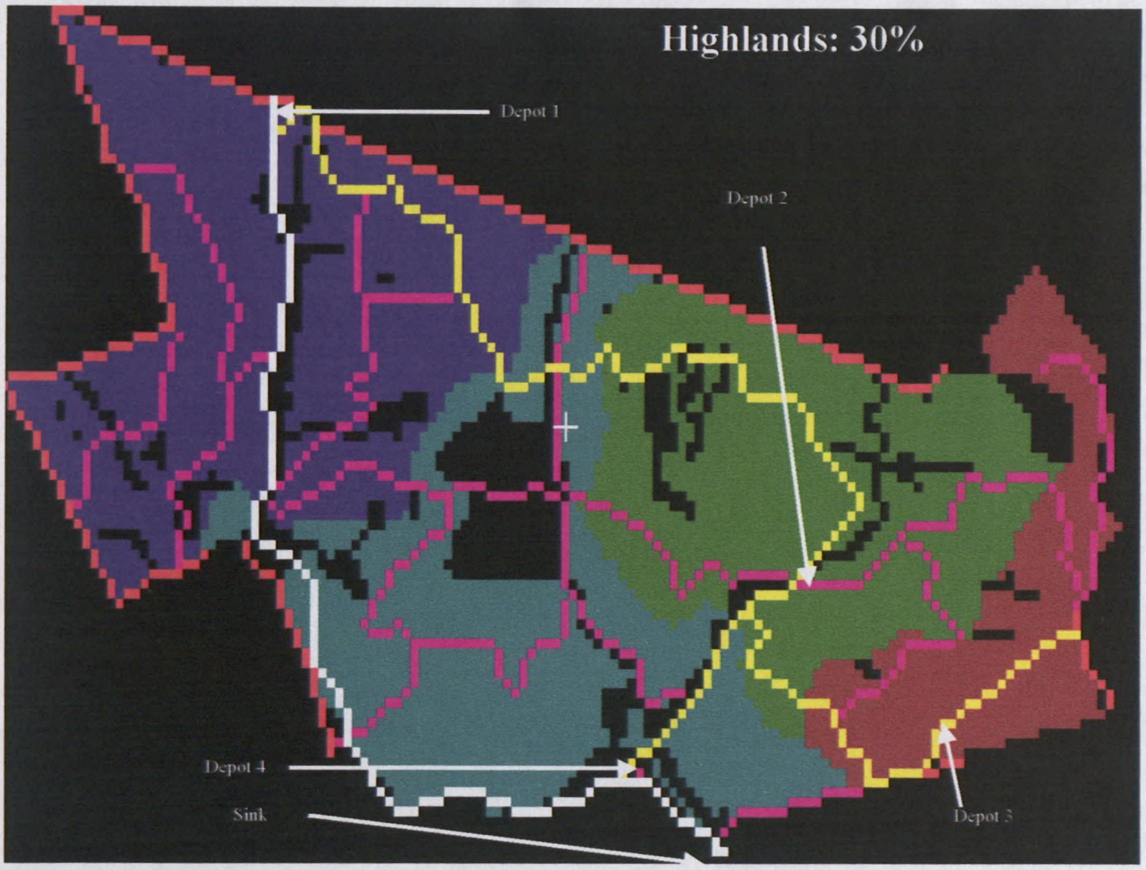

Figure 30: Tessellation map Highlands road density 30%

Tables 27 and 28 illustrate the movement of volume to individual depot sites for Highlands, from where the wood will in turn be transported to plantation sink for transport systems 1 and 2. There is no result for transport system 3 because transport is direct from roadside to plantation sink.

Depots 3 and 4 seem inappropriately located since the volume assigned is much less than depots 1 and 2, and decreases when the road density is decreased (with the exception of road density (30%). For detailed data on volume and cost of volume flow to and from each depot for each area refer to Appendix G and for visual representation of tessellations for each road density scenario refer to Appendix F.

Table 27: Highlands layer analysis, transport system 1

Layer analysis: Highlands, transport system 1.								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0078	5203.50	1	0046	5285.50	1	0040	5451.00
2	1633	4453.00	2	0914	3558.25	2	0634	4580.75
3	2146	1948.75	3	1208	1811.25	3	0851	3980.25
4	2291	4446.50	4	1283	5432.75	4	0820	2075.75
	Total	16087.75		Total	16087.75		Total	16087.75

Table 28: Highlands layer analysis, transport system 2

Layer analysis: Highlands, transport system 2								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0078	5857.50	1	0046	5882.00	1	0040	5717.50
2	1633	5306.75	2	0914	4943.25	2	0634	5469.75
3	2146	2129.00	3	1208	1917.25	3	0851	2824.25
4	2291	2794.50	4	1283	3345.25	4	0820	2076.25
	Total	16087.75		Total	16087.75		Total	16087.75

Tables 29 and 30 illustrate the movement of volume to individual depots for Uplands, from where the wood will in turn be transported to plantation sink for transport systems 1 and 2. Depot 4 seems inappropriately located since the volume assigned is much less than the other depots and decreases when the road density is decreased.

Table 29: Uplands layer analysis, transport system 1

Layer analysis: Uplands, transport system 1								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0164	1150.00	1	0114	1002.75	1	0084	1072.25
2	0248	837.00	2	0149	958.75	2	0123	1480.25
3	0829	2258.00	3	0360	2190.75	3	0274	1576.50
4	1468	749.00	4	0643	675.50	4	0499	405.00
5	1602	2552.00	5	0691	2718.25	5	0535	3012.00
	Total	7546.00		Total	7546.00		Total	7546.00

Table 30: Uplands layer analysis, transport system 2

Layer analysis: Uplands, transport system 2								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0164	1110.75	1	0114	973.75	1	0084	1037.75
2	0248	846.25	2	0149	943.75	2	0123	1486.75
3	0829	2205.75	3	0360	2197.25	3	0274	1577.75
4	1468	801.50	4	0643	700.00	4	0499	405.25
5	1602	2581.75	5	0691	2731.25	5	0535	3038.50
	Total	7546.00		Total	7546.00		Total	7546.00

Tables 31 and 32 illustrate the movement of volume to individual depots sites for Greenhill, from where the wood will in turn be transported to plantation sink for transport systems 1 and 2. Depot 5 seems inappropriately located since the volume assigned is much less than the other depots and decreases when the road density is decreased.

Table 31: Greenhill layer analysis, transport system 1

Layer analysis: Greenhill, transport system 1								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0026	744.00	1	0021	798.75	1	0021	946.75
2	0413	2080.75	2	0249	1681.25	2	0157	1644.25
3	1099	4226.25	3	0630	4254.75	3	0426	4782.75
4	1368	2131.50	4	0786	2107.00	4	0523	1324.75
5	1501	735.00	5	0880	1064.00	5	0604	602.00
6	1885	1442.00	6	1095	1260.00	6	0764	1384.25
7	1999	2431.75	7	1160	2102.00	7	0820	2498.00
8	2475	2076.00	8	1377	2433.50	8	0966	2589.50
9	2661	3205.25	9	1477	3371.25	9	1031	3300.25
	Total	19072.50		Total			Total	19072.50

Table 32: Greenhill layer analysis, transport system 2

Layer analysis: Greenhill, transport system 2								
Road scenario 100%			Road scenario 50%			Road scenario 30%		
Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)	Depot	Node No.	Volume (m^3)
1	0026	806.00	1	0021	937.00	1	0021	1092.25
2	0413	2517.75	2	0249	2115.25	2	0157	2070.00
3	1099	3613.75	3	0630	3778.00	3	0426	4480.00
4	1368	2625.00	4	0786	2336.25	4	0523	1554.00
5	1501	808.50	5	0880	1034.50	5	0604	679.00
6	1885	1424.50	6	1095	1324.75	6	0764	1286.25
7	1999	2197.25	7	1160	1871.50	7	0820	2165.75
8	2475	1842.50	8	1377	2273.50	8	0966	2461.00
9	2661	3237.25	9	1477	3401.75	9	1031	3345.25
	Total	19072.50		Total	19072.50		Total	19072.50

4. Discussion

4.1. Part one: Survey

4.1.1. Spending on road maintenance and upgrading

Expenditure on road upgrading and maintenance, by the pulpwood companies, shows an increasing tendency from 1997 to 2001 (Figure 19 and Table 17). The reason for the specific increase in the spending on road maintenance and upgrades, during 1998, can mostly be attributed to the Forest Certification drive throughout the country. Particularly Mondi Forests, who contributed mostly to the increase in expenditure, as they were the first to achieve FSC certification of the two.

It is well known that most major corrective action requirements (CAR's) in the forest certification processes are forest roads related; their placement and alignment being the most contentious issues, with the siltation of watercourses also of concern (inadequate and ineffective drainage). In order for Mondi and Sappi to achieve and maintain certification, additional funds had to be made available to react on these CAR's in a required and suitable manner.

During 1998 and 1999 Mondi spent in the region of ten times more than Sappi on road upgrades, and two to three times more on road maintenance during 1997 to 1999. However Sappi has shown a steady increase in both upgrading and maintenance since 1997.

Expenditure per hectare shows that Sappi has made the greatest advance in increasing funding for maintenance and upgrading (Table 17 and Figure 19). However, to make true comparisons, values of the expenditures adjusted to a common year (Table 33) should be evaluated over the period (Uys 1995).

Sappi increased their budgets from R11.12/ha in 1997 to R35.36/ha in 2000. Mondi on the other hand has increased their budget from R25.16/ha to R36.34/ha. From a R6.43 million difference between the two companies during 1997, Sappi has increased its share to only a R2.07 million deficit as compared to Mondi in 2000, or R35.36/ha as opposed to R36.34/ha. In nominal terms Sappi has exceeded Mondi's expenditure by R0.6 million in 2001.

Table 33: Real total expenditure (upgrades and maintenance) roads expressed in the year 2000 values

Year	FPI*	Nominal value (R millions)	Real Value (R millions)	Upgrade and maintenance (R/ha)
1997	101.7	14.27	14.75	19.8
1998	103.8	31.09	31.48	42.2
1999	104.6	24.99	25.11	33.7
2000	105.1	28.53	28.53	38.3

Road upgrades and maintenance annual budgets (real values)

	1997		1998		1999		2000	
Sappi	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha	R (million)	R/ha
Upgrade	1.00	2.67	1.01	2.70	0.86	2.30	4.30	11.49
Maintenance	3.16	8.45	5.19	13.87	6.26	16.73	8.93	23.87
Total	4.16	11.12	6.20	16.57	7.12	19.03	13.23	35.36
Mondi								
Upgrade	3.64	8.65	10.36	24.61	7.35	17.46	4.10	9.74
Maintenance	6.95	16.51	14.92	25.44	10.64	25.27	11.20	26.60
Total	10.59	25.16	25.28	50.05	17.99	42.73	15.30	36.34
Summary								
Upgrade	4.64	6.17	11.37	15.26	8.21	11.12	8.40	11.27
Maintenance	10.11	13.57	20.11	26.99	16.90	22.68	20.13	27.01
Total	14.75	19.74	31.48	42.25	25.11	33.80	28.53	38.29

*base year (100) 1995

In both cases the increase in allocated funds to road upgrades have not been as great as with maintenance figures for the same period. For Sappi, however, an increase from R2.67/ha in 1997 to a budgeted amount for 2000 of R11.49/ha is greater than Mondi's R8.65/ha (1997) to R9.74/ha for 2000. Sappi showed a dramatic escalation in expenditure from 2000 to 2001 of R11.49/ha to R18.17/ha in nominal terms.

Maintenance expenditure has increased the most. Sappi and Mondi have shown increases for 2000 over 1997 of 430% and 267% respectively. During 1997 Mondi was spending double that of Sappi (R8.45/ha as opposed to R16.51/ha), however this difference has slowly been eroded with the figures for 2000 being R23.87 and R26.60 for Sappi and Mondi respectively. Interestingly enough, although Mondi's expenditure on both upgrades and maintenance were consistently greater in 1999 than in 1997, there was a general decline in expenditure from 1998 to 1999.

What has been established so far is that there is some change in expenditure (positive and negative) amongst the companies. This has also illustrated some perceived awareness by the companies of the need to maintain infrastructure. The question remains why upgrading remains subservient to maintenance? Having insight into the condition of the forest road network, the upgrading of the network, would seem a priority at this stage, firstly to rehabilitate a severely damaged forest road network and secondly to improve access for larger vehicles closer to the compartment roadside and yet maintenance of the network (seemingly) remains a priority to the companies. However, the network road density is too high for the amount allocated to maintenance to actually make a sustained impression on the condition of the roads. The exercise remains one of crisis management and the efficient use of funding, marginal. Surveys done bear out the fact that road conditions are still no better than they were during 1998 or 1999 (Crickmay and Burne 2000) despite increased money allocations to road maintenance.

The most appropriate levels of spending on road maintenance and upgrades are unknown. The Global Forest Products (ex Mondi North) technical manager feels spending should be in the region of R86/ha (1998 costs), (Lawrie 1999). This equates to an allocation, for Mondi alone, of R36.2 million annually if R86/ha is to be achieved.

One factor that is not brought into account by managers are the existing road densities. Road densities in South Africa are unacceptably high and figures of 80 to 120 m/ha and higher are not uncommon (Strydom 1998). This has an impact on the funding required for the maintenance of the road network. Lawrie (1999), in arriving at R86/ha, based his calculation on a road density for Mondi of 80m/ha. If road density can be reduced to 20m/ha, expenditure per metre of road for maintenance will increase from R1.07/m to R4.30/m without any additional funds. This factor has implications of more efficient maintenance on plantations with lean road density figures. Additionally the opportunity of having more land under timber should not be overlooked (less road). Improvements to the road network might now become visible and sustained, with tangible benefits to timber transport operations. Road reduction planning is important for the future maintenance of the remaining forest roads.

For comparison, a Southern Natal Safcol operation is currently allocating R57/ha, for road maintenance on their stump to mill operations in pine sawtimber. This is based on a planted area of 24 000 ha and a road density of 60 m/ha (Kotze 2000). Safcol, Mpumalanga region, budgets in the region of R5.0 million for an afforested area of 62 000 ha. According to (Krieg 2000) this R81/ha is invariably cut to between R50/ha and R60/ha as the budget year progresses.

By restricting expenditure on road maintenance, companies have forced greater volumes of wood to be transported to depots, as more and more roads have become inaccessible to highway vehicles. As less money is spent the greater the deterioration, and the more inaccessible the roads become. This in turn necessitates SIT vehicles with greater off-road capabilities, which have to be used in on-road situations. These vehicles further damage the roads. Eventually eight wheel drive vehicles will replace vehicles with four or six wheel drives. These vehicles further damage the roads, travel greater distances at a greater cost, in an ever-continuing deteriorating cycle.

The 3.7 million tonnes transported by SIT is estimated to cost the industry R37.0 million annually purely because forest roads are no longer capable of allowing large highway type vehicles to travel to the compartment roadside. This amount was in excess of what was spent annually on roads, with the exception of 1998. However, the industry continually allocates insufficient funds for upgrades and maintenance of roads.

4.1.2. Perceptions as to actual road repairs

Table 18 shows that 65% of the respondents did not have roads repaired or maintained for them during their operations. Only in 26% of the cases did the companies actually pay attention to the roads that affected the operations.

To reinforce this perception, the results of two consecutive countrywide surveys, by Crickmay and Burne (2000), showed that contractors perceived that roads were one of the major constraints to both logging and transport. In addition, road condition deteriorated from the first to the second survey. The surveys were conducted over two back-to-back quarters of 2000.

4.1.3. Reasons for SIT: a contractor perspective

The majority of the contractors identified the reason for the presence and steady increase of SIT to the declining state of forest roads. In most cases the state of decline started more than three years ago. The reasons, for this steady decline, they felt were many and the following are a selection of some of the contractors thoughts.

- Company road upgrade and repair budget cuts, which were already thought to be inadequate, are attributed to:
  - Lack of commitment of companies to the maintenance and support of contractors.
  - Lack of vision for the industry in South Africa.
  - Due to the companies not transporting timber themselves, they do not feel the impact of poor roads on their transport costs.
  - Companies have not, to date, been held responsible for the negative impact their roads have on the environment. Thus roads have lost their importance over time and contractors have to bear the burden.
- Road geometry was also identified as a contributing factor. Larger, high payload vehicles are unable to negotiate tight corners and roads with adverse longitudinal and vertical alignments. When these roads were constructed years back, they were adequate for the transport systems used then. There is, however, new transport vehicle technology available and these vehicles cannot get to desired areas in the forests due to the road impediments mentioned above and road network upgrade work is required.

To reinforce the views of the contractors the following are additional reasons for the occurrence and retention of SIT.

4.1.4. Roads

The primary reason for the existence of SIT is the condition of the roads and the subsequent inability of the larger, high payload vehicles from reaching the individual compartments. Taylor (1979), Edwards (1986), Warkotsch (1988) and Morkel (1999a) commented on high road densities and low road standards as far back as 1979 and

1986. They added that presently road network planning, road drainage and maintenance are all but non-existent.

A survey (Morkel 1994) of the major users of the forest road network (pulpwood transport contractors) revealed that 80% perceived the conditions of the forest roads to be fair to poor. Respondents to the current survey endorse this fact, and also indicate that current road conditions increase fleet maintenance costs and reduce productivity.

The reasons for the deterioration of road standards and infrastructure are the following.

4.1.5. Limited expertise

In an industry-wide survey conducted by Morkel (1994) it was found that those largely responsible for managing forest roads were foresters who lacked a basic understanding of fundamental civil engineering principles and sound construction practices. In addition to this it is evident that many sectors of the industry fail to appreciate the skills and expertise required by staff given the responsibility for the supervision of road construction and maintenance works (Kennedy 1985).

4.1.6. Timber transport focus

Morkel (2000) makes mention of industry attention to the long distance transport phase of pulpwood transport and the effect it had on the continued use of SIT by the industry. The result was that forest companies, transport contractors and vehicle and trailer manufacturers have been successful in significantly reducing timber transport cost, but have in the process placed so much emphasis on STT that SIT has inadvertently been entrenched as a transport method.

As a result, depots became the link between SIT and STT. The harvesting forester became responsible for delivering pulpwood to depots and a separate transport function became responsible, for the loading and STT. The transport chain was broken into two separate, distinct phases with little focus on total cost.

As larger depots are built, further and further from the stump, haulers, trailer builders and loaders benefit, and STT and loading costs are reduced drastically. However, as larger volumes were now being transported over greater distances, SIT costs increased. With the deterioration of forest roads, there was a need for SIT vehicles with more off-road capabilities, which cost more to own and operate. This further increased SIT rates, adding to the contractor costs.

4.1.7. Primary road users

Roads are constructed, upgraded and maintained from the road builder's perspective, often ignoring the needs of the road user. The landowner has effectively distanced himself from the transport function and as the quality of the road infrastructure declines, the implications of the road condition on transport cost are not directly apparent. Climbing contract rates reflect the hidden road condition cost resulting from increased repairs and maintenance, increased fuel consumption, reduced travel speeds, lower productivity and reduced reliability of access (Morkel 1994).

4.1.8. Lack of stump to mill contractors

Four contractors felt there were too many contractors in the supply chain (flow of timber from stump to mill). Few stump-to-mill contractors are in existence today in South Africa. Transport contractors operate independently from the harvesting contractor and in many cases loading is also by a separate contractor. By having control and ownership over all the elements from stump-to-mill, the contractor can determine, for each compartment, what the optimum meeting point would be for the STT vehicle and his timber. Each contractor will strive for minimum costs within his own segment. The companies have also contributed to this phenomenon by allowing fragmented operations and by negotiating prices for operations with individual contractors.

4.1.9. Yield per unit area

This is a subjective point of view, brought up by 12 contractors, and could well be the case in isolated areas of poor growth or perhaps where the forested area under timber is small. The contractors volunteered no quantitative facts, but a person could realistically envisage areas such as these, yet they should however be more the exception than the rule.

4.1.10. Inventories

Four contractors felt that in order to maintain optimum inventory levels at the depot sites SIT is a necessity. Optimum inventory levels are difficult to determine. Pulkki (1990, 1991 and 1992) details the dangers of excessive inventories. However inventory has no bearing on the maintenance of SIT. With improved roads closer to the compartments, fresher timber of higher quality is available with clear benefits for the final product.

4.1.11. Security

In most cases contractors are paid for timber over the weighbridge at the processing plant. If the risk of theft is a reality, there is no benefit of having timber on roadside or at a central depot. Unless the contractor can prove negligence on the part of the company he will be at the losing end regardless.

4.1.12. Contract periods

The majority of contracts are between one and three years in length (65 out of 73 respondents). Contractors maintain that due to the lack of an extended contract period (>3 years) they have difficulty in justifying major equipment purchases to extend and improve their efficiencies in operations.

The general view, however, is that the stop/start phenomena by the companies towards their contractors has more of a debilitating effect than contract terms. If contractors are assured that their operations will not be shut down and started up at random due to mill erratic requirements, contractors would commit themselves to a greater extent. In very few cases does the company actually guarantee the covering of fixed costs in case of a shutdown. However, this has no direct bearing on the maintenance of SIT.

4.1.13. Transport origins

Of the total annual pulpwood intake of 9.39 million tonnes for 1998, 3.99 million tonnes arrived at processing plants by rail, 3.7 million tonnes were transported by means of SIT and 1.7 million tonnes were transported directly from stump or landing to processing site. Through extrapolation of the survey results the following were determined: there are 3.45 million tonnes of extended primary transport from stump to depot or siding, of which 2.5 million tonnes are transported to depots. An additional 3.2 million tonnes are transport from landing to either depot or siding (Figure 20), of which 1.2 million tonnes are transported to depots.

Thus the 3.7 million tonnes of SIT for STT estimated by Morkel (2000) is made up of both extended primary transport and SIT. Extended primary transport has historically been classified by the industry as *"shorthaul"* and recognised as a mode of transport contributing to the use of depot systems and an overall higher cost transport phase. Extended primary transport appeared on the scene as the only means of transporting timber over poor roads and due to the lack of terminology was lumped together with *"shorthaul"*. The volume moved from depots to plantation exits by agricultural tractors and semi trailers is unknown. However, it is occurring in the study area and therefore must be occurring elsewhere.

The definition for extended primary transport was only developed during the period of this study because of the radical difference between SIT and extended primary transport. In seeking a solution to SIT, it is evident that extended primary transport plays a major role and cannot be dealt with in isolation. As will be seen in the economic analysis this aspect is dealt with in proposing solutions to the 3.7 million tonnes that are transported to depots awaiting further transport.

Of the 1.7 million tonnes of STT mentioned above, the majority occurs in the Zululand (Pulp mills at Richards Bay and Tugela and to a certain extent SilvaCel) and Piet Retief areas (Piet Retief Pulp Mill and PG Bison, Piet Retief) with Mpumalanga contributing to a lesser extent.

Considering transport to depots (Figure 20), the noticeable factor is that more hardwood (1.6 million tonnes of hardwood as compared to 0.8 million tonnes of softwood) is removed from stump to depot than softwood. This is attributable to timber from the Highveld and Zululand areas, which are flat and conducive to vehicle movement to and from the stump.

The 1.4 million tonnes of hardwood moving from landing to siding indicates rail transport to Saiccor on the Natal South Coast and Mondi Richards Bay. Large volumes of hardwoods are railed from Southern Natal and Zululand to Sappi Saiccor in order to fulfill its requirements of 1.9 million tonnes of hardwood roundwood per annum for its dissolving pulp process.

4.1.14. Loading methods

The relatively low cost of labour and the flexibility of labour are factors, which contribute to more manual loading done at the stump (Figures 21 and 22). Site degradation, compaction and rutting are reduced and so is the percentage of site trafficked by wheels, when labour is used. Using three-wheel log loaders in field causes the most site degradation. If, however, a forwarder with its own knuckle boom crane is used, there is no more traffic than with an agricultural tractor with semi-trailer that is manually loaded. Huge reliance is being placed on the constant availability of suitable and enough labour to complete these tasks. This might not be the case in the near future, with the dramatic increase of HIV/Aids and the exploitation of labour in these situations. The question of the impact of this type of heavy manual work on the human body is a question that should earnestly be addressed. Issues of an ergonomic nature do not, unfortunately, have sufficient recognition in the production cycle at present.

Loading systems for SIT consist of mainly three wheel log loaders with approximately 2.1 million tonnes being loaded annually. Manual loading for SIT accommodates about 0.6 million tonnes annually. The two systems combined account for 2.7 million tonnes of the total 3.7 million tonnes being transport by SIT. As the wood moves closer to the road the more mechanical means are used to load vehicles. At the landing, roadside or depot, three-wheel log loaders predominate.

4.1.15. Transport lead distances

The reason for the longer lead distances in Mpumalanga is terrain related. Situated on and below the Drakensberg escarpment, suitable areas large enough for depot sites and close to main arterial routes are more difficult to locate. This translates to greater distances from compartments to depots. This tendency is the same for both softwood and hardwood. In areas such as Melmoth, Paulpietersburg, Louwsburg and possibly even Amsterdam, where planted areas are fairly scattered and railheads are distant, timber will be stored on depot sites for road transport to Richards Bay, Sappi Tugela and Merebank. These depot sites will then tend to be centralized to create increased inventories for greater efficiency for timber transport to the coastal areas.

In Table 20 the mean, minimum and maximum for each region are tabulated. A Student's t test was applied to test the similarity of the average lead distances. The results showed that there is a significant difference in lead distances between wood moving from stump to depots and landings to depots, but that there was no significant differences between softwood and hardwood within the two operations. This supports the preceding paragraphs that geographic location plays a relatively large roll in governing lead distances from stand to destination.

Maximum distances range between 1 and 34 km (Figure 23). Mpumalanga and the Highveld have the greatest mean lead distances and range between 16 and 34 km (Table 20).

4.1.16. Vehicle type

The agricultural tractor and semi-trailer, is the most favoured vehicle for SIT and extended primary transport (Figure 24) to depots. This configuration transports 60% of the 3.7 million tonnes (2.22 million tonnes). The timber hauler and forwarder, in turn transport 17% and 8.5% of the 3.7 million tonnes respectively. Perceptions from fieldwork by the surveyor are that the percentage use of the agricultural tractor and semi-trailer are higher. Problems are that contractors, for some reason, classify agricultural tractor and semi-trailer operations, as forwarder operations and that the timber hauler are also agricultural tractor and semi-trailer operations. This misinterpretation has possibly led to a slightly depressed percentage use of the agricultural tractor and semi-trailer as reflected in this survey.

The reasons for the preference of the agricultural tractor and semi-trailers are:

- It is the only configuration and vehicle type that can operate successfully all year round on debilitated forest roads with poor and declining conditions.

- Most contractors, being ex or current farmers already have the equipment available.
- Agricultural tractors are relatively inexpensive to purchase (relative to other transport equipment), even through the used vehicle market.
- Trailers are usually home built, rugged and very old and usually fully depreciated.
- Agricultural tractor and semi-trailers have capabilities of operating in rugged on- and off-road conditions.
- Low cost of licensing as compared to on-road vehicles.
- No roadworthy certificate requirements.
- Low ownership and operating costs due to factors already mentioned.
- Less stringent driver license requirements when considering the masses transported relative to highway trucks.

This transport system has however been operating illegally (Ramsden and Marchio undated) since the first timber was hauled from the compartments by these systems. There have been proposals submitted to the authorities to legalize the operation of these systems. These proposals do not however completely condone the use of agricultural tractors and semi-trailers in this application and a number of provisions are attached: e.g., increased license fees, annual road worthy testing, adequate braking systems, improved power to mass ratios and adequate drivers licenses (Van Zyl 2001).

4.1.17. Survey summary

The results of the survey were affected by the lack of understanding by the contractors of the definitions of primary, extended primary, secondary intermediate and secondary terminal transport. In many cases extended primary transport was classified, by contractors, as SIT and the transport of timber from depot to mill, if less than 50 km, as SIT as well. Distance being the deciding criteria. Fortunately most of these problems could be rectified by either a telephone call or in most cases by taking note of the region and area the work was being done in and making logical decisions. The main recourse was to contact the supervising area-harvesting manager.

In hindsight, technical detail and volumes would have been easier to obtain, and more accurate than what was experienced, if pertinent questions were posed to the specific contract managers from the various companies, instead of individual contractors *via* a postal survey as was done. These harvesting managers, additionally, have insight into longer-term work and volume allocations to each contractor. They are trained foresters with an understanding of harvesting and transport issues, and have all the relevant information available in a database. For other information such as for contractors' perception of road conditions and the attitude of the companies towards contractors, a selected sample from each region can be drawn and a telephone or face-to-face survey can be arranged for the sake of obtaining accurate information.

4.2. Part two: The economic analysis.

4.2.1. Total average annual transport costs

In all three case study areas, there is an increasing trend (for transport systems 1 and 2), in total average annual transport costs, as road densities decrease (Figures 25, 26 and 27 and Table 21). This is due to the longer off-road transport distances and thus higher cost of extraction and an additional loading phase in transport system 1. Transport system 3 delivers the lowest total average annual cost of timber transported.

The cost differences between transport system, 3(30%) and the currently employed system, 1(100%), are reflected in Table 34, indicating an approximate cost reduction, from 1(100%) to 3(30%), of 50%.

Table 34: Cost differences between systems 1(100%) and 3(30%)

Area	System 1(100%) R/m^3 (current system)	System 3(30%) R/m^3 (proposed system)	Average annual cost difference R/m^3	Average annual cost saving (Rands)
Uplands	16.08	8.14	7.94	60104.51
Highlands	17.39	8.31	9.08	146160.86
Greenhill	16.46	8.80	7.66	146061.59

The factors that contribute to these differences in cost are the following:

- Primary transport.
- Inclusion of extended primary transport.
- Inclusion of secondary intermediate transport.
- Secondary terminal transport.
- Timber loading at roadside, depot and plantation exit/sink.
- Road densities.

To be able to apply transport system 3 and allow the larger vehicles to reach the compartment roadside, as well as for transport system 2 (highway trucks reaching depots), roads to these locations have to be upgraded and maintained. Road upgrade and maintenance costs have not been included in the analysis due to it being out of the scope of this study to accurately determine these costs. However, provision for maintenance and upgrades of roads, to allow the selected transport systems from reaching intended locations, should be made from the potential savings in transport costs between transport systems which are calculated in this economic analysis.

4.2.2. Primary transport

Table 21 indicates that average annual primary transport costs increase dramatically as road densities decrease from 100% to 30% of the original road density in transport systems 1 and 2. Decreasing road densities have the effect of increasing extraction distances associated with more expensive primary transport costs. The effects of increased extraction distances are shown in an increase of the average straight-line extraction distances calculated by the network analysis programme. The narrower the road spacing, the shorter the average extraction distance from stump to roadside and *vice versa*.

Transport system 3 has a lower straight-line extraction distance than transport systems 1 and 2 on the same road density (30%) with the resultant lower primary transport cost. This is due to the wood flow procedure optimizing the combined cost of extraction and road haul of timber. The more improved the roads are as is the case with system 3(30%), (with resultant higher speeds and options of higher payload vehicles as opposed to the extraction phase) the further the programme will allow highway vehicles to travel toward the roadside area in order to optimize both cost components. The poorer the roads the further the programme will let timber be extracted, because of the "smaller" difference in payload and travel speeds between the primary and secondary transport vehicles.

4.2.3. Extended primary transport

In essence extended primary transport is not entirely taboo and depends on how it is applied in practice and how the complete transport system is built around it. Many instances of this transport phase are evident, particularly where decisions have to be made whether additional roads have to be constructed *versus* the risk of possible major environmental impacts, high costs of construction and safety of the harvesting crews (Adamson 1989, Plamondon and Favreau 1994, Jayne 1996 and Anon 1998).

A practice internationally, is to move timber from the stump, past the traditional landing site, past the accepted secondary transport pickup point in tree lengths or long lengths to merchandising areas, from which traditional activities will emanate. This is, however, contrary to what occurs in South Africa, where the final product is moved past the roadside area to a depot purely because the existing roads are impassable at that point to all but off-road vehicles (four to six wheel drive agricultural tractor and semi-trailer configurations and forwarders).

The cost of primary transport is inevitably higher with agricultural bundle tractor and semi-trailer units than with forwarder transport systems, which are specifically designed for off-road travel in forestry operations. This is due to low payloads, high *tare* masses and slower travel speeds. Because the primary transport phase with the agricultural tractor and bundle semi-trailer unit converts into extended primary transport to the depot with the same vehicle, these inherent inefficiencies are passed on to the section of transport from roadside to depot with the related higher cost.

As illustrated in Table 21, the roadside to depot cost portion of the extended primary transport phase contributes between 45 and 55% (no loading included) of the total transport account. This is due to the use of the existing system of agricultural tractor and bundle semi-trailer units from stump to depot on roads that should have higher payload vehicle hauling timber to the next destination, and in reality, originally designed for this. Timber forwarders can be used in an extended primary transport operation, but to run them down existing roads would not be a correct application physically and financially.

A typical example of a mid-range six-wheel drive forwarder, with a legal gross vehicle mass of 24 000 kg and a tare weight of 16 200 kg, can carry a public road legal payload of 7 800 kg (design operating payload of 12 000kg). Depending on age after felling and also depending on species, this mass may equate to in the region of 9.0 to 9.5 m^3 in *Eucalyptus* or as little as 7.0 m^3 in the case of pine logs. This is not a major increase in the volume carried by a bundle agricultural tractor and semi-trailer of 7.6 m^3. The design travel speeds of forwarders are higher than agricultural tractor and semi-trailer units for on road travel yet it is not sufficient to be comparable to a road transport vehicle transporting 45 m^3 payloads.

An example of these inefficiencies mentioned previously can be illustrated by the next transport phase – namely, secondary intermediate/terminal transport to plantation sink/exit from the depot. The programme was run using either an agricultural tractor and semi-trailer (current system) or rigid truck and drawbar trailer configuration. The latter, due to higher speeds and greater loads on better roads out-performed the former by an average of R0.70/m^3 on all three plantations.

To transport wood over roads with slow vehicles and high ratio between payload and tare (albeit low payload or high *tare* mass) is inherently expensive and the cost of road maintenance over transport costs must be evaluated in order to determine what the risks are. The question of additional funding on roads will be addressed later in this section.

A comparison of the average annual costs of the two elements in transport from roadside to plantation sink/exit (extended primary transport from roadside to depot and secondary transport from depot to plantation sink/exit) for the three areas, show relatively similar costs regardless of road density. The minor differences can be related to inherent road network efficiencies or inefficiencies. As the aim of this report was not to optimise the road network, but illustrate the potential benefits of reduced road densities as a part of the study, it is accepted that the road network is not optimally laid out.

The presence of a dense as opposed to a lean road network could carry some physical benefits for e.g. fire protection and cheaper primary transport, but no other monitory benefits are evident. In reality the added burden of maintaining the vast road network will marginalize the entire road network's efficiency. It is also for this reason that transport system 3 was only run on the 30% road network, since it would not be feasible, or possible, to run highway trucks on the very dense, poorly maintained road network.

4.2.4. Secondary intermediate/terminal transport

Of the individual transport costs incurred in the process of moving wood to plantation exits, this phase is the cheapest (Table 21). This stands to reason, as all the depot sites are on major class 1-road routes on which higher speeds can be sustained by the particular transport vehicle used. There are fewer road-based impediments to the vehicles, allowing for higher travel speeds in both in and outbound directions. It is no longer necessary to use off-road vehicles, to overcome the poor roads, found between roadside and depot sites. However, in this case study agricultural tractors and semi-trailers are still being used to transport timber from depots to sink.

The underlying reason for using a depot system (providing an accessible and stable loading platform for larger, high payload highway vehicles) has not been adhered to in the three study areas, and consequently system 1 is currently in use due to large vehicles not being able to reach these depot sites and these highway type vehicles are being loaded at plantation exits. Even with a system of depots there are benefits in using higher payload vehicles as opposed to off-road vehicles moving timber from depot to plantation sink. This is illustrated in Table 35.

Table 35: Average annual secondary transport costs, depot to sink

Uplands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Secondary transport (depot to sink)	17806.03	17951.22	16974.33	12480.67	12536.47	12004.16	
Secondary transport (roadside to sink)							15786.30

Highlands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Secondary transport (depot to sink)	35473.81	32894.78	34987.43	23619.47	22724.98	22834.50	
Secondary transport (roadside to sink)							30770.76

Greenhill

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Secondary transport (depot to sink)	56505.21	55806.13	53963.20	36096.25	36709.74	34742.17	
Secondary transport (roadside to sink)							41303.00

Of significance is the difference in cost between the two modes of transport moving wood from depot to plantation sink (agricultural tractor and semi-trailer and rigid truck and drawbar trailer vehicles, as applied in systems 1 and 2, respectively). This phase of transport serves as an example, as mentioned earlier, of the benefits of the type of transport vehicle used, provided the plantation infrastructure would allow it. It is evident that the greater the payload and the higher the loaded and unloaded speed of the vehicles, the greater the financial benefits. These cost benefits range between 30% and 36% of the rigid truck and drawbar trailer vehicle (system 2) over the agricultural tractor and semi-trailer unit (system 1) (Table 35). The rigid truck and drawbar trailer's configuration allows the maximum gross vehicle mass for South African roads, namely 56 000 kg (plus 10% for unintentional overload). This is then the largest possible vehicle that can legally travel on roads in South Africa. Payloads will be in the region of 45 m^3 depending on the truck/trailer tare masses as compared to an average of 19.7m^3 for the agricultural tractor and trailer unit.

4.2.5. Secondary terminal transport (roadside to plantation exit/sink)

There are clear indications that there are benefits to load at compartment roadside and deliver wood directly to the plantation sink/exit (Table 36), with rigid and drawbar trailer vehicles. As opposed to an extended primary transport phase from roadside to depot with an agricultural tractor and bundle semi-trailer and then to plantation sink with either an agricultural tractor and semi-trailer or a rigid truck and drawbar trailer vehicle. The underlying reasons are:

- Low payloads and high tare weights of the agricultural tractor and semi-trailers.
- Slow travel speeds of the agricultural tractor and semi-trailer on a poor dense forest road network.

Table 36: Secondary transport cost per transport system per plantation

Road scenario	Uplands			Highlands			Greenhill		
	Transport phases			Transport phases			Transport phases		
	R/Side to Depot (Rands)	Depot to Sink (Rands)	Total (Rands)	R/Side to Depot (Rands)	Depot to Sink (Rands)	Total (Rands)	R/Side to Depot (Rands)	Depot to Sink (Rands)	Total (Rands)
1(100%)	30940.38	17806.03	48746.41	85323.25	35473.81	120797.06	66901.22	56505.21	123406.43
1(50%)	30913.67	17951.22	48864.89	83618.56	32894.78	116513.34	63097.34	55806.13	118903.47
1(30%)	33308.02	16974.33	50282.35	77905.75	34987.43	112893.18	68559.83	53963.20	122523.03
2(100%)	30891.28	12480.67	43371.95	82172.74	23619.47	105792.21	64096.25	36096.25	100192.50
2(50%)	30812.77	12536.47	43349.24	79905.23	22724.98	102630.21	61154.11	36709.74	97863.85
2(30%)	33233.88	12004.16	45238.04	75994.47	22834.50	98828.97	66683.27	34742.17	101425.44
3(30%)	Roadside to sink		28194.98	Roadside to sink		62033.97	Roadside to sink		41303.00

The cost difference as indicted in Table 36 is to be expected purely due to the more efficient mode of transport being used: i.e., rigid truck and drawbar trailer vehicle versus the agricultural tractor and semi-trailer system.

The potential benefits of applying a different transport system from the depot to the plantation exit (rigid truck and drawbar trailer vehicle) as opposed to the current system (agricultural tractor and semi-trailer) are apparent from Table 37. Benefits range from a cost reduction of 11.0% for Uplands to 18.0% for Greenhill over the current system.

Table 37: Percentage cost reduction between transport systems

Scenario Differences	Uplands	Highlands	Greenhill
	% (Beneficial) Cost Reduction	%(Beneficial) Cost Reduction	%(Beneficial) Cost Reduction
1(100%) – 2(100%)	11.0	12.4	18.8
1(50%) – 2(50%)	11.3	11.5	17.6
1(30%) – 2(30%)	10.0	12.4	17.2

4.2.6. Loading through the different phases

As can be seen from Table 38, loading accounts for a considerable portion of the average annual total costs of the entire operation. By limiting loading to only one operation (loading at roadside) costs are reduced by 25% to 27%. By loading at roadside and transporting direct to processing plant considerable savings can be achieved. By using depot systems an additional loading operation is unavoidable and eventual fibre losses, due to multiple handling and ageing, are incurred. These losses can amount to 2% of the average annual volume for the three estates; around 850 m^3 can be lost annually. At a cost of R200/m^3, this equals R170 000/year in timber losses. Present value into perpetuity, this will equal R1.2 million of foregone income.

Table 38: Loading costs per system per plantation

Uplands

Cost in Rands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Loading	67426.40	67426.40	67426.40	33713.20	33713.20	33713.20	33713.20

Highlands

Cost in Rands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Loading	143180.98	143180.98	143180.98	71590.49	71590.49	71590.49	71590.49

Greenhill

Cost in Rands

Activity	1(100%)	1(50%)	1(30%)	2(100%)	2(50%)	2(30%)	3(30%)
Loading	169745.25	169745.25	169745.25	84872.25	84872.25	84872.25	84872.25

4.2.7. Summary of transport costs

Transport system 3 has the lowest total average annual cost due to four factors:

- The absence of extended primary transport from roadside to depot.
- A more efficient transport phase from landing to plantation exit/sink through the use of vehicles with high payloads and higher travel speeds over an improved, maintained and upgraded, low density forest road network.
- Reduced primary transport costs.
- Limited loading of timber (single operation).

4.2.8. Some deductions and applications

Currently road density scenario (100%) are not suitable for use by rigid truck and drawbar trailer vehicles, due to road surface, geometry and alignment limitation, and only transport system 1 can access this scenario. Access to rigid truck and drawbar trailer vehicles, as far as the depot, for road density scenarios (100%) and (50%), will only be possible if road network upgrading is undertaken up to that point. Transport systems 2(100%) and 2(50%) make provision for rigid truck and drawbar trailer vehicle access as far as depots in this study. Road scenario (30%) does in theory however, allow access to the compartment roadside by rigid and drawbar trailer vehicles because of road network density reductions coupled with upgrading and maintenance.
For comparative purposes, current road scenario and transport system 1(100%) will be used as a basis. System 3(30%) is the proposed transport system for the area, and the other intermediate scenarios are used to aid in the establishment of trends.

Total average annual transport costs for each system per plantation have been tabulated for comparison (Table 39). To get an impression what tangible cost savings are to be gained by applying the proposals of this study, comparisons between the most preferred transport system, 3(30%), and all other transport systems are done and tabulated (Table 40).

Table 39: Total average annual costs per plantation per transport system

Transport systems	Uplands (Rands)	Highlands (Rands)	Greenhill (Rands)
1(100%)	121799.31	279785.32	313865.78
1(50%)	128217.60	282570.86	322137.82
1(30%)	133095.14	296393.53	341686.88
2(100%)	82711.65	193189.98	206281.26
2(50%)	88988.75	197097.24	216225.20
2(30%)	94337.63	210738.83	235716.29
3(30%)	61694.80	133624.46	167804.19

Table 40: Average annual savings to be expected between most preferred transport system 3(30%) and all other transport systems

Transport systems	Savings Uplands (Rands and R/m^3)	Savings Highlands (Rands and R/m^3)	Savings Greenhill (Rands and R/m^3)	Volume weighted average saving (R/m^3)
1(100%) – 3(30%)	60104.51 7.94	146160.86 9.08	146061.59 7.66	<u>8.24</u>
2(100%) – 3(30%)	21016.84 2.77	59565.52 3.70	38477.07 2.02	2.79
1(50%) – 3(30%)	66522.80 8.78	148946.40 9.26	154333.63 8.09	8.65
2(50%) – 3(30%)	27293.95 3.60	63472.78 3.94	48421.01 2.54	3.26
1(30%) – 3(30%)	71400.34 9.42	162769.07 10.12	173882.69 9.12	9.55
2(30%) – 3(30%)	32642.83 4.31	77114.37 4.80	67912.10 3.56	4.16

The interpretation of Table 40 is that if the mean annual increment (MAI) produced, is moved off the plantation according to the planned transport system, the potential cost savings (Table 40), are realizable. The best potential saving, considering the present situation, is between current transport systems 1(100%) and proposed transport system 3(30%). Comparison of systems 1(50%) – 3(30%) and 1(30%) – 3(30%) do indicate greater savings but these are not valid due to systems 1(50%) and 1(30%) not being considered for current or potential logical use. These greater differences are entirely due to increased primary transport and loading costs as road densities are decreased.

In other words, funds (Table 40) can potentially become available for other purposes and operations on the plantation. The obvious choice, in line with the underlying thought behind this thesis is for these savings to be used on road deactivation, upgrading (where required) and road maintenance in order to implement a more efficient transport system, 3(30%).

Obviously immense sums of capital would be required to upgrade the road network, as implied in the study, from road density (100%) through to road density (30%), in order to make the roads of acceptable standard for selected vehicles to operate on. By concentrating on a road improvement plan of limited time length (pulpwood rotation length) the cost burden can be spread and a meaningful impression on road improvements made.

An interim solution, in order to spread the cost burden of the total forest road network upgrade, would be to (as intimated above) improve the network up to depots in order to apply transport system 2 on road density scenarios (100%) and (50%) instead of transport system 1. Once this has been satisfactorily completed the programme can be extended to further reduce the density and upgrade the network in line with road density scenario (30%). This upgrading can theoretically be undertaken with savings gained from applying system 2 instead of system 1 on road densities 100% and 50%. In order to evaluate this possibility, Table 41 contains the differences in transport cost between systems 2 and 1 and illustrates the potential savings by applying system 2. There are still obvious financial penalties in employing this approach due to the extended primary transport phase still being used to move timber to depot sites in the interim.

Table 41: Potential savings between transport systems 1 and 2(100%) and 1 and 2(50%)

Transport systems	Uplands (Rands and R/m³)	Highlands (Rands and R/m³)	Greenhill (Rands and R/m³)	Volume weighted average saving (R/m³)
1(100%)–2(100%)	39087.66 5.16	86595.34 5.38	107584.52 5.64	5.46
1(50%)–2(50%)	39228.85 5.17	85473.62 5.31	105912.62 5.55	5.39

The present value of these savings in perpetuity (assuming an interest rate of 14.5%) are represented in the following values (Table 42), and can potentially, as an interim measure, be used to upgrade roads to accommodate transport system 2 in the shorter term before undertaking the upgrading of the balance of the road network for the eventual implementation of transport system 3. This approach has the benefit of spreading the cost of roadwork over a period of time with its associated cash flow benefits.

Table 42: Present value of savings into perpetuity between transport systems 1 and 2 on road density scenarios (100%) and (50%)

Scenario comparisons	Uplands (Rands)	Highlands (Rands)	Greenhill (Rands)
1(100%)–2(100%)	269570.07	597209.24	741962.21
2(50%)–2(50%)	270543.79	589473.24	730431.86

Extended primary transport is an integral part of the current transport system as previously mentioned. Even if the secondary transport phase changes from SIT to STT by employing a rigid truck and drawbar trailer instead of the agricultural tractor and semi-trailer, the inefficiency of the extended primary transport along existing roads, remain. Thus in order to evaluate the systems, it is not sufficient to isolate only the SIT portion but to evaluate the system as a whole to determine the cost differences and the eventual cost of SIT within the system. This is something that may or may not be done, due to lack of precise definitions in the field, where extended primary transport is at times classed as extraction or primary transport.

The best potential weighted average cost saving per m^3 was established between system 1(100%) and 3(30%), (Table 40). This is then the cost of applying SIT, R8.24/m^3, under conditions of this study. To establish a per tonne cost, the conversion factors presented in section 2, with the total annual growth removed per species per plantation and the total cost of the removal (cost difference between transport systems 1(100%) and 3(30%)), a cost per tonne of R11.69 is derived. The result is comparable under the controlled conditions of the study. Accordingly, the total annual cost of applying SIT by the industry, is R43.25 million. This translates into an additional cost of R4.60 for every m^3 for the full annual volume of 9.4 million tonnes to the pulpwood industry.

The potential savings presented in Table 40, represent a first year average annual savings or a sum that can potentially be ploughed back into road upgrade and maintenance. If the changes are made to the road networks and transport system 3(30%) is applied, the present values of the potential savings into perpetuity are as in Table 43. The values of interest are once again 1(100%) – 3(30%) within the ramifications of the study and as indicated previously.

A further benefit of road density reduction adds to the impact of the present value of savings on transport into perpetuity (Table 43). Reductions in road density imply reduced spending per hectare for maintenance.

Road density reductions will have the benefit of real increased expenditure on road maintenance per m of road without any increase in the budgeted amount. The extent of such "increased" allocation per m of road depends entirely on what the road reduction is and the initial amount available. The fact that more Rands will be allocated to metre of road is a reality.

Table 43: Present values of savings into perpetuity per plantation between transport system 3(30%) and all other transport systems

Scenario comparisons	Uplands (Rands)	Highlands (Rands)	Greenhill (Rands)	Total (Rands)
1(100%) – 3(30%)	414 513.86	728 545.79	1 007 321.30	2 150 380.95
2(100%) – 3(30%)	144 943.72	410 796.69	265 359.10	810 995.51
1(50%) – 3(30%)	458 777.93	1 027 216.55	1 064 369.86	2 550 364.34
2(50%) – 3(30%)	188 234.14	437 742.76	333 938.00	959914.90
1(30%) – 3(30%)	492 416.14	1 122 545.31	1 199 190.97	2 814 152.42
2(30%) – 3(30%)	225 122.97	531 823.24	468 359.31	1 225 305.52

A further tangible benefit would be the addition to the planted area of land presently under roads. Additional area under trees of at least 58.0, 38.0 and 59.0 ha for Uplands, Highlands and Greenhill respectively are potentially possible. These values assume a conservative average road right-of-way width of 8 m. An area of 50 ha with an average MAI per estate of, conservatively, 10m^3/ha/yr, delivering pulpwood in successive rotations at a price of R200 per cubic metre (production costs not included), into perpetuity, has an approximate present value of R690 000.

Other opportunity costs which are difficult to quantify, but related to the reduction of exposed road surface area, is the reduction of erosion of these roads through water action and eventual siltation of steams and rivers, many of which have their sources in the tree growing areas of the country. There is overwhelming evidence (Egan 1999 a and 1999 b, Elliot *et al.* 1999, Elliot and Tysdal 1999 and Swift and Burns 1999) of the concern for road-associated erosion. The need for road network planning as an aid for road network length minimisation is all-important.

Hand in hand with road reduction mechanisms are the techniques required for road deactivation once roads have either served their immediate purpose or have been identified as superfluous within the road network (Swift and Burns 1999). These operations are new to the Southern African forester, as well as the understanding of water crossings (Taylor *et al.* 1999). This is once again borne out by the number of major corrective actions experienced during sustainability assessments for certification purposes.

4.2.9. Wood flow to plantation sink via depots

Separate Dirichlet tessellations were built for each depot site to which wood is transported for each road density scenario and each plantation. The prime purpose of these tessellations was to derive a final transport cost of timber flowing from stump via extended primary transport to the depots and from the depots to the plantation exit points. An analysis of volumes flowing through each depot for each plantation, unit and total cost is shown in appendix G.

A second purpose is that it can be used as a tool to derive the theoretical service areas for each depot site. A detailed analysis of depot location, costs and volumes assigned are presented in Table 27 to 32 and Figures 28 to 30. It is evident that as the road densities change so does the volume distributions to each depot.

5. Conclusions and recommendations

5.1. Conclusions

To haul timber, by means of secondary intermediate transport (SIT), from roadside to a depot for intermediate storage, before it is finally transported to processing plants via the plantation exit has been identified as an additional and unique transport phase in pulpwood transport in South Africa. This study calculated the cost of the inclusion of this phase of transport, to the pulpwood industry, to be R8.24/m^3 or R11.69/tonne. With the estimated volume of pulpwood subjected to SIT of 3.7 million tonnes, the total average annual cost of SIT, to the industry, is R43.25 million. By not employing SIT the industry will potentially save R4.60 for every tonne of the 9.4 millions tonnes consumed by pulpwood processing plants annually.

The underlying reason for SIT, as an accepted part of pulpwood transport in South Africa, has been confirmed to be poor and declining conditions of the forest road network and the lack of forest road network upgrading and maintenance due to insufficient funding. This perception is confirmed through a survey of harvesting and transport contractors. The literature also contains numerous references, by company foresters, academics and contractors, who have confirmed the progressive decline in forest road standards and the ultimate increase in the use of SIT.

The realignment, by the major companies, of long distance transport has also hastened the deterioration of forests roads, due to a shift in focus away from traditional forest operations in favour of reducing long distance transport costs (minimal off-highway travel). The eventual outcome was the establishment of a system of depots close to national roads to which the majority of timber is hauled (SIT) over continuously deteriorating roads.

Due to poor roads, conventional highway transport vehicles cannot reach compartments in order to haul timber, and more off-road type vehicles are employed to fulfill this task. In South Africa 86% of the 3.7 million tonnes of timber are transported by off-road vehicle to depots. Agricultural tractors and semi trailers are responsible for 60% of this volume with forwarders and timber haulers making up most of the balance. Of the 3.7 million tonnes, 2.2 million tonnes are transported from stump to depot and

1.5 million tonnes from landing to depot. Therefore SIT vehicles are being forced to move closer to the stump and further along the road. Low travel speeds and low payloads, over poor roads, results in high SIT transport costs. Annually manual loading and three wheel log loaders account for the loading of 0.6 and 2.1 million tonnes respectively of the 3.7 million tonnes subject to SIT.

To support the statement that there is a lack of upgrading and maintenance of forest roads due to insufficient funding, a survey of expenditure on road maintenance and upgrading by the two pulp companies indicated that in 2000 only R28.53 million in total were expended on these operations. This translates to an expenditure of R38.29/ha for maintenance and road network upgrading. This should be compared to a suggested South African benchmark of R86/ha. There is however an observed tendency of increased annual expenditure on the forest road network by the two major pulp companies, R14.75 million in 1997 to R28.53 million in 2000. However subsequent surveys have confirmed that despite this increase in funding, road conditions are still below standard and declining. If the amount of R43.25 million, expended on SIT, were added to the budgeted expenditure on roads for 2000, the unit cost for road maintenance and upgrading would be R71.78/ha. A figure closer to the benchmark suggested for road repairs and upgrades in SA.

Forest road network densities in South Africa are generally accepted to be too high when compared to international trends. The impact of high road densities and low rates of expenditure on road maintenance result in inefficient allocation of R/km and associated sub-optimal road maintenance levels and very little road upgrading.

A network analysis programme developed by Taha (1982) and Pulkki (1984), in conjunction with a fixed grid network and pixel based GIS was applied to three study areas in the Kwa-Zulu Natal Midlands in order to assess the economic impact and assist in the analysis of SIT and individual transport components in the transport chain from stump to plantation exit. The simple pixel based GIS was used to develop spatial databases of forest road network systems, surface cover and slope classification.

Three transport systems were identified and applied to three different road density scenarios on each of three estates. System 1, the transport system currently in use (extended primary transport to depot with agricultural tractor and bundle semi-trailer, and agricultural tractor and semi trailer to plantation exit/sink). System 2, similar to system 1, with the difference that transport from depot to plantation sink is by rigid truck and drawbar trailer vehicle. In the final system (system 3), primary transport to roadside occurs with bundle agricultural tractor and semi-trailer and a rigid truck and drawbar trailer vehicle is used to haul the timber direct to plantation exit.

Three road density scenarios applied to the study, were, the present situation (the original (100%), one with approximately half the roads removed (50%) and one with 30% of the road remaining (30%). Each of the transport systems were run over these three forest road systems except system 3 which was only applied to density scenario (30%).

System 3 showed the lowest average annual cost of transport, while system 1 was the most expensive operation. There was a general upward trend in costs for systems 1 and 2 with decreasing road density. This was expected due to increased extraction distances.

The reasons for system 3 having the lowest cost are:

- There is no extended primary transport to depot from compartment roadside.
- There is no additional transport phase to the plantation exit from the depot (single phase from compartment roadside to plantation sink).
- There is only one handling and loading operation (at plantation roadside).

Apart from a common primary transport phase to roadside, system 3 has only one other transport phase by high payload vehicle (STT) and this is direct to the processing plant via the plantation exit from compartment roadside, over a lean and improved road network.

System 2 is less expensive than system 1 due to the improved transport system from depot to plantation exit/sink. A rigid truck and drawbar trailer vehicle, with higher speeds and payloads, replaces the agricultural tractor and semi-trailer. There is also one less handling and loading phase associated to this transport system.

5.2. Recommendations

There are clear indications that SIT is not a financially viable operation within the pulpwood industry, and that it should be phased out of pulpwood transport systems. This can be accomplished by:

- Reducing road densities according to a planned strategic road deactivation programme, which is linked to a forest road management plan. This plan must indicate the densities required to match strategically planned harvesting and transport systems and the period over which it should be implemented (preferably short – one rotation). Road densities of 20 to 25 m/ha should be striven for.

- Increasing road upgrade and maintenance spending in order to improve the remaining road network. The gradual reduction of the road density will facilitate the more efficient allocation of funds over fewer roads (km). The increased allocation of finances can be "paid" for from potential saving on timber transport over fewer roads with associated cost benefits as indicated.

- Exclude extended primary transport as it is being applied (transporting over existing roads with off-road vehicles). Transport timber from stump to roadside as primary transport only.

- Allow the largest vehicle (payload) possible to load timber at roadside for direct STT to plantation exit and in turn to the processing plants. The advantage of higher speeds over improved roads and greater payloads over fewer roads are achieved. Once road densities start to decrease and more finances are available for road upgrades and maintenance this should become a reality.

- Eliminate the depot system. Multiple handling and associated fibre losses out-way the perceived benefits of accumulating buffers and reducing long distance transport costs.

- Consider the total supply chain from stump to customer. Total cost analysis should allow for this type of economic analysis before it reaches the proportion SIT has reached over the last ten years in South Africa.

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7. Appendices

Appendix A:

Detailed terminology and definitions

Terminology and definitions:

Introduction

The need to define the various facets of harvesting operations stems firstly, from the considerable misuse of terminology related to harvesting methods and systems. Secondly, the wide variety of systems and harvesting methods applied to the delivery of roundwood timber during stump to mill operations in South Africa. In particular, during pulpwood harvesting operations. The following are suggested terminology that will be used in the study. The terms proposed and used originate from international literature sources on logging terminology and from discussions with field personnel.

Logging (harvesting)

The terms logging or harvesting are used synonymously when referring to the felling, extraction and transport of trees or logs to a processing site. The individual components of harvesting or logging are, in broad terms, the following:

- Preparation
- Primary transport (extraction)
- Secondary transport

Preparation

Comparative terms would be, logging method, referring to the form in which wood is delivered to the stump area, roadside or even the processing site. Preparation refers to the felling of trees in combination with one or all of the following:

- Debranching
- Debarking
- Crosscutting or bucking, and if necessary;
- Stacking or bunching of timber at stump area.

The movement of timber is restricted to the gathering and stacking of the timber in predetermined bunch or stack sizes within the stump area. These stacks, if stacks are made, are now available for primary transport, or derivatives, phase of the operation. Stacking could be either a planned gathering or a precise stacking of logs. Precise stacking is neatly indexed stacks of exact volume to aid future operations, the primary transport phase of the operation.

Planned gathering of logs refers to the rough stacking of timber; possibly into different products when more than one product is being sourced from the tree or compartment. It could also serve the purpose of bringing the timber closer to an area, where manual loading onto trailer or vehicles are required (reduce walking time from pick-up to loading).

Primary and secondary transport

In theory the transport of wood from stump to mill can be divided into two distinct phases.
1. Primary transport
2. Secondary transport

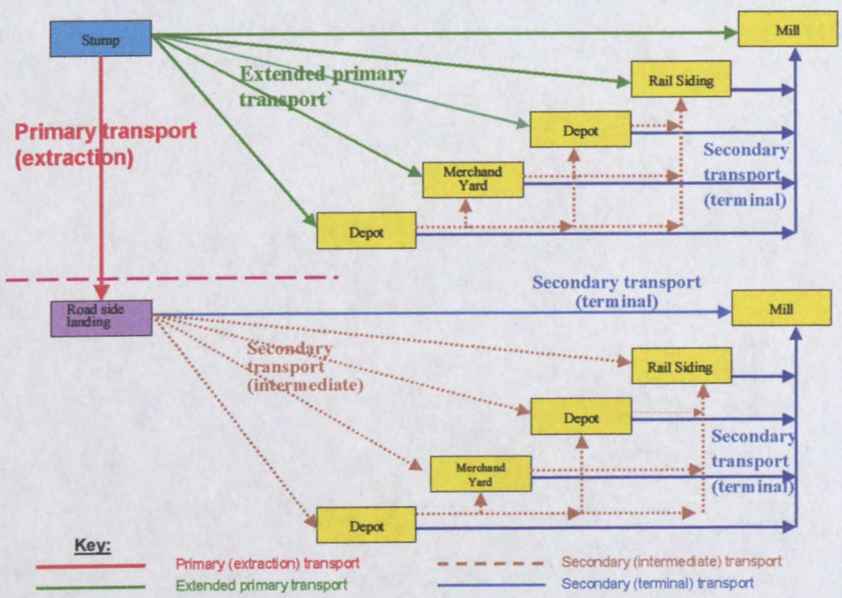

Figure 1: Schematic description of the phases of wood transport

Primary transport (extraction)

Primary transport is the movement of the felled tree from the stump to the landing and occurs off-road. Or, transport of the felled tree, from the stump area to beside a transport route, which is associated with the particular area that is receiving the harvesting treatment

Primary transport is accomplished in a number of ways and with a variety of harvesting systems. Typical Southern African operations are:

- Manual extraction to landing
- Animal extraction to landing
- Chute extraction to landing
- Ground skidding to landing (cable, grapple and bundle skidding)
- Agricultural tractor and trailer transport to the landing
- Forwarder extraction to landing
- Cable extraction (yarding) to landing
- Aerial extraction to landing (e.g. helicopter)

Within the above systems the following are applicable:

- Forest transport – refers to the area in which transport occurs (in stump area)
- Terrain transport – refers to transport along the ground in the cutting area.
- Skidding, forwarding, yarding – refers to the mode of primary transport.

It is important to note that the terminal point of primary transport is the landing.

Secondary transport

The final component in a logging or harvesting system is secondary transport. This includes all wood movement from the landing or transfer point to processing plants. Rail and water transport also forms part of secondary transport. Secondary transport by definition ends at the processing plant or mill yard. Primary and secondary transport meets at roadside landings, however origins such as depots, merchandising yards or rail sidings can also be starting points for this mode of transport.

Derivatives of primary and secondary transport

The following three terminologies are relevant:

- Extended primary transport
- Secondary intermediate transport
- Secondary terminal transport

Although extended primary transport is an accepted and known operation internationally, the other two terms are not used or documented in international literature. They only have application within South Africa. The terms secondary intermediate and secondary terminal transport became necessary in order to phase out existing terms such as shorthaul and longhaul, which were being used in a haphazard context within the pulpwood industry.

Extended primary transport

Extended primary transport, accordingly to starts in the stump area and is continued directly along a long distance transport route by the same transport vehicle to the point of utilization or to any intermediate depot, merchandising yard or rail siding along the way. For example forwarding continued along a road to mill or a rail siding. Typically this operation would be executed using agricultural tractor and trailer units, timber haulers and rigid vehicles with drawbar trailers.

Secondary intermediate or terminal transport

The pulpwood industry makes use of a number of intermediate sites between the landing and processing plants. These intermediate sites are:

- Depots in particular
- Merchandising yards/areas

- Railway sidings
- Ports

Secondary intermediate transport

This encompasses transport, as indicated above, from roadside landings to either of:

- depot or
- merchandising yard or
- railsiding

or:

- from depot to depot or
- from depot to merchandising yard or
- from merchandising yard to depot
- from depot to railsiding or
- any combination of the above **provided it does not reach the mill yard.**

All the above are examples of intermediate secondary transport of repeated handling without the wood reaching the mill site.

Secondary terminal transport

Wood, that has reached its final destination, the mill yard, after an uninterrupted flow from a roadside landing, depot, merchandising yard or rail siding.

Landing and depots

Landings, and in particular depots, are an integral part of the wood transport processes of pulpwood in Southern Africa, and are closely tied to primary and secondary transport and the derivative of the primary and secondary transport.

Landings

Landings are areas, contiguous to compartments being harvested, where wood is piled or stored directly after primary transport. Landings are either centralized or continuous

Centralized landings

Centralized landings are areas localized within fixed boundaries and of limited size. In most cases these landings are constructed and possibly hardened, depending on the season of operation. All extracted timber from the adjacent compartment or wood from designated sectors is stored at these sites, awaiting transport, be it either intermediate or terminal secondary transport. Merchandising can take place on the landing depending on the harvesting method employed.

Continuous landings

With continuous landings, the length of the roadside adjacent to the compartment being harvested is used as a storage area. As with centralised landings merchandising can take place on continuous landing, depending on the harvesting method employed.

Landings serve a limited area and volume and when the volumes have been depleted, are usually rehabilitated to the original state and incorporated into the adjacent planted area.

Depots

Depots are constructed areas at which wood is stored, after an extended primary transport phase or secondary intermediate transport phase. This wood is in turn waiting for another secondary intermediate phase or will undergo a terminal secondary transport phase.

Depots are either:

- Permanent depot sites: large wood storage sites with hardened surfaces to facilitate all weather access. They are usually near major national transport infrastructure to facilitate secondary terminal transport.

- Informal depots: used in dry periods, where a permanent surface is not required, and would typically be in open areas or at large intersections of plantation roads. In these cases no hardening is required. Normally of localised importance and therefore small in area (limited volumes due to nature and time of use).

Appendix B:

Name list and addresses of contractor information included in database

- Sappi list
- Mondi list

Sappi list

Name	Company	Address	
1. Blaine, W	Unitrans Lowveld	PO Box 6378	Nelspruit
2. Botha, Pieter	Bormat	PO Box 583	Barberton
3. Cele, James	Dumangese Timber	PO Box 215	Mtubatuba
4. Coertzen, Pieter	MRB Onderneming	PO Box 218	Barberton
5. Dada, Steiner	Dada Harvesting Systems	PO Box 1057	Richmond
6. Dlamini, Bush	Bush Dlamini Timbers	PO Box 14192	Merrivale
7. Du Randt, F	Umkomaas Forestry Co	PO Box 317	Highflats
8. Forsyth, D	DB Forest Harvesting	PO Box 59	Seven Oaks
9. Fourie, Theo	TIMCO	PO Box 126	Ixopo
10. Gebers, Rupert	Wartburg Timber Contr.	PO Box 1484	Greytown
11. Geyer, Herman	Forestry CC	PO Box 1497	Piet Retief
12. Griebenouw, E	Genric Trust	PO Box 21	Hazyview
13. Grover, Henry	Henry Grover Transport	PO B ox 1074	Lydenburg
14. Gumede, Herbert	Abenguni Timber Harvest	PO Box 938	Esikhawini
15. Hageman, Dave	Fell & Haul	PO Box 515	Mtubatuba
16. Howe, Derek	Derek Howe Logging	PO Box 2831	Pietermaritzburg
17. Howes, E	Assoc. Carriers	PO Box 2055	Empangeni
18. Johnson, P		PO Box 104	Piet Retief
19. Johnson, Roger	HTH Trust	PO Box 50	Weza
20. Kamhoot, F	FTH Harvesting	Klein Geluk Farm	PO Eastwolds
21. Kent, T	Unit	PO Box	Barberton
22. Kusel, E	Ihlati	PO Box 1006	Piet Retief
23. Maartens, Dewald	Mooiplaas Contractors	PO Box 212	Melmoth
24. Mackenzie, B	Woodcutters	PO Box 765	Greytown
25. Mackenzie, Ken	KD Logging	PO Box 46	Doonybrook
26. McCauly, Ian	M&H Mech Harv	PO Box 11338	Aston Manner
27. McColm, Mel	Melann Contractors	PO Box 155	Kwambonambi
28. Minisi, P		P Bag X04	Piet Retief

Sappi list

Name	Company	Address	
29. Nkozi, R		PO Box 963	Piet Retief
30. Ogram, Allan	Nordfor	PO Box 24	Harding
31. O'Sullivan, Sean	SOS Contractors	PO Box 1206	Howick
32. Pagel, Percy	Pagel's Contractors	PO Box 368	Winterton
33. 3Pottow, Garth	Dambuza Harvesting	PO B ox 64	Loins River
34. Rapson, Bryan	Zululand Forestry Services	PO Box 297	Kwambonambi
35. RobertsRobbie	Roberts Broers	PO Box 1020	Piet Retief
36. Roos, Francois	Bostek	PO Box 4038	Nelspruit
37. Sams, Gavin	Sable	PO Box 2553	WhiteRiver
38. Sawyer, B	BCL Transport	PO Box 23	Lows Creek
39. Scheepers, Koos	Bosbok Ontginning	PO Box 129	Graskop
40. Surendorff,S	Logtrans	PO Box 22122	Mayors Walk
41. Taylor, Niel	Stoneshack	PO Box 391	Nelspruit
42. Valentyne, Rob	Prolog	PO Box 2553	White River
43. Van der Merwe, F	Coastal Shorthaul	PO Box 814	Kwambonambi
44. Van Rensburg, M	MLJ Transport	PO Box 7	Dullstroom
45. Van Rooyen, A	Forest Service	PO Box 52	Piet Retief
46. Yengwa, M Mr	DY Timber Harvesting	PO Box 160	Donnybrook

Mondi list

Company	Name	Address	
1. Qala Forestry Contractors	LN Mitchell	P O Box 25500	Umtentweni
2. Forest Services	Des le Roux	P O Box 14	Creighton
3. V.R. Timbers	V Gerbers	P O Box 661	Melmoth
4. Van Eeden For. & Farming	T van Eeden	P O Box 166	Kwambonambi
5. MV Timber	M Ngubane	P O Box 530	Melmoth
6. Wattle Timber Harvesters	A French	P O Box 485	Melmoth
7. Green Zebra	P Ndlovu	P O Box 8	Melmoth
8. Forest Projects	P Walker	P O Box 553	Melmoth
9. Forest Care	Z Newland	P O Box 319	Melmoth
10. Vriendskap Boerdery	H Harris	P O Box 14	Melmoth
11. Nyamazane Forestry	T Schlanders	P O Box 80	Babanango
12. Eagle View Timbers	CJ Walberer	P O Box 163	Babanango
13. Agric Forest	Rob Edwards	P O Box 373	Hluhluwe
14. Logging Services	Ziggy Rudner	P O Box 1122	Mthubathuba
15. Gerry's Transport	JJ Gumede	P O Box 637	Mthubathuba
16. Hartley Harvesting CC	John Hartley	P O Box 7912	Empangeni
17. Bell Logging	Mike Campbell	P O Box 198	Empangeni
18. Sheshe Contractors	J Louw	P O Box 222	Mtunzini
19. Sinclair Estate	J Schutte	P O Box 242	Howick
20.	MD Chowles	P O Box 242	Howick
21. Birkenstock	T Birkenstock	P O Box 2267	Vryheid
22. Els Brothers	G Els	P O Box 666	Vryheid
23. Paul and Son	K Paul	P O Box 23	Iswepe
24.	H Filter	P O Box 75	Iswepe
25.	Nic Grobler	P O Box 1153	Piet Retief
26. Green Gold		P O Box 2439	Piet Retief
27. Karat Harvest. & Transport	M Johannes	P O Box 429	Piet Retief
28. H.A.T. Houtvervoer	T v.d. Walt	P O Box 633	Piet Retief

29. Creydt Contracting	C Creydt	P O Box 1064	Piet Retief
30. Steenkamp Vervoer	H Steenkamp	P O Box 587	Piet Retief
31. SUBB Family Trust	Selvyn Bohmer	P O Box 402	Piet Retief
32. H&K Forestry Contractors	H Marsland	P O Box 774	Piet Retief
33.	H Grobler	P O Box 881	Piet Retief
34.	H Ntshangase	P O Box 2086	Piet Retief
35. SPP Bosbou		P O Box 1389	Vryheid
36.	C Zulu	P O Box 10740	Vryheid
37. Nettsure	P Netterville	P O Box 582	Vryheid
38. Forest Pro		P O Box 276	P/pietersburg
39. Warburg Timber Contractors	Rupert Gebers	Woodrose Farm	Creighton,
40. Unitrans	C Martin	P O Box 44	Darnall
41. Spoornet		P O Box 177	Durban
42. Bainesfield Timber Contract	C Ivins	P O Box 45	Busby
43.	C van Dyk	P O Box 409	Richmond
44. CLC Contractors	Colin Luke	P O Box 452	Richmond
45. Richmond Forestry Service	R Gemmel	P O Box 985	Richmond
46.	M van der Merwe	P O Box 82	New Hanover
47. Van Rensburg Harvesting	L van Rensburg	P O Box 820	Greytown
48.	Stephan West	171 Loop Street	P/maritzburg
49. IntermanHarvesting	Donald McNair	P O Box 1923	White River
50. Hi-Lead	H Lubbe	P O Box 12380	Nelspruit
51. LT Plant CC	E Duvenhage	P O Box 1936	White River
52. Mining Industrial Dowel	W Serfontein	P O Box 6755	Nelspruit
53. Peoria Logging	Brian Willison	P O Box 12659	Nelspruit
54. P & P	I Patterson	P O Box 250	Graskop
55. Dacran Timbers CC	CFW Cooper	P O Box 298	White River
56. JW Forestry Services CC	W Whelshans	P O Box 675	Sabie
57. Phineas Theko Contractors		P O Box 39	Shathale
58.	J Msimango	P O Box 174	Graskop
59. Long Hauls	M Purvis	P O Box 5514	Horison
60. Arborcare	Harold Moffat	P O Box 22435	Glenashley

61. TJ Timbers	T Sclanders	P O Box 891	Vryheid
62. FFS	George Farmer	P O Box 1524	Piet Retief
63.	C Woest	P O Box 409	Piet Retief
64. I J Timbers		P O Box 891	Vryheid
65.	Peet Botes	P O Box 97	Sabie
66. JW Forestry Services	CCW Whelshans	P O Box 675	Sabie

Appendix C:

The countrywide survey document distributed and responded to.

Pulpwood Industry Survey

Shorthaul Transport

April 1998

Cover letter

2 April 1999

Address

Analysis of shorthaul transport in the pulpwood industry

Dear Sir

Throughout the pulpwood industry, a lack of information and knowledge regarding ***shorthaul transport of pulpwood to depots*** has been identified. It was therefore decided to launch a research project to investigate the situation. This project has been sanctioned as well as initiated by both MONDI and SAPPI.

This countrywide survey forms a major part of the research, which will be done on the analysis of shorthaul transport. Hence we require you to complete the attached questionnaire as thoroughly as possible. You, as harvesting and transport contractors and company foresters, are the only persons who can supply the correct and precise required information, aiding the researchers in attaining their goal.

Although I acknowledge that you are fully engaged, it would be appreciated if you return the attached and completed documents in the included prepaid and addressed envelope by 31 July 1999.

If you have any questions regarding the questionnaire please do not hesitate to contact:

Pierre Ackerman
Forest Engineering
University of Stellenbosch
Private Bag X1
Matieland
7602

Tel: 021-808-3300
Fax: 021-808-3603
E-mail: Packer@land.sun.ac.za

We thank you for your co-operation

Pierre Ackerman

Forest Engineering

Part One

General information

This section requires general information to identify who you are and whom you contract for. If you are an "own operations harvesting and transport forester" for Mondi please complete question one only.

Question 1.1: Company particulars

Your Company name:	**Company** you contract for (also own operations) and **district** you work in:

Question 1.2: Do you have a contract with the company/ies who employs your services? Indicate the length for which the contract is valid. (If "own operations", ignore this question.)

Contract term	Indicate (✓) which is applicable
< 1 year	
1 Year	
1 – 3 years	
>3 years or more	
None	

Part Two

Transporter survey: Shorthaul for the year 1998

If one of your activities involves the **shorthaul transport** of timber, then please complete this part of the questionnaire.

This activity involves the movement of timber once the **extraction** process has been completed. There are **only** two origins and **only** two destinations for shorthaul transported timber (refer to classification):

Origins:

1. From in-field
2. From a landing

Destinations:

1. To a depot
2. To a rail siding

Question 2.1: If you **shorthauled** timber from **in-field to depot** what tonnage did you transport?

Softwood (tonnes)	Hardwood (tonnes)	Total (tonnes)

Question 2.2: If you **shorthauled** timber from a **landing to depot** what tonnage did you transport?

Softwood (tonnes)	Hardwood (tonnes)	Total (tonnes)

Question 2.3: If you **shorthauled** timber to a **railway siding** what tonnage did you transport under the following headings?

Type of shorthaul	Softwood (tonnes)	Hardwood (tonnes)	Total tonnage
1. In-field to siding			
2. Landing to siding			

Question 2.4: Indicate the type of **shorthaul** and average lead distance (average distance from origin to destination) **shorthauled** during 1998. **Disregard transport to rail siding completely in this question.**

Type of shorthaul	Average lead distance (Kilometres)	
	For softwood	For hardwood
1. Infield to depot		
2. Landing to depot		

Question 2.5: What types of **shorthaul equipment** do you use for the shorthaul phase of your transport.

Type of vehicle	Volume transported per type of vehicle/year.
1. Forwarder with self loading crane	
2. Forwarder without mounted crane	
3. Agricultural tractor and semi-trailer with self loading crane	
4. Agricultural tractor and semi-trailer without crane	
5. Rigid vehicle	
6. Rigid truck and drawbar trailer	
7. Truck/tractor and semi-trailer	
8. Interlink	
Other: (specify)	
8.	
9.	

Part three

Loading of shorthaul transport equipment

The loading of a shorthaul vehicle can take place at the following places:

a) In-field once preparation has been completed
b) At a landing

The final destination **can only be a depot or siding.**

Question 3.1: If you transport from ***in field to either depot or siding*** how do you load your shorthaul vehicles? What are the percentages of total pulpwood volumes that are loaded by the following methods?

Loading method or loader type	Volume of pulpwood per method (%)
1. By manual loading	
2. By three wheeler	
3. By front-end loader	
4. By crane mounted on shorthaul vehicle	
5. By independently mounted heel-boom or knuckle-boom crane	
By other methods (specify) : 6.	

Question 3.2: If you shorthaul transports from roadside landing to either depot or siding how do you load your shorthaul vehicles? What are the percentages of total pulpwood volumes that are loaded by the following methods?

Loading method or loader type	Volume of pulpwood per method (%)
1. Manual loading	
2. Three wheeler	
3. Front-end loader	
4. Crane mounted on shorthaul vehicle	
5. Independently mounted heel-boom or knuckle-boom crane	
6. Other methods not specified	

Part four

Road conditions

Please answer the questions below as objectively as possible.

Question 4.1: In your opinion and experience why has shorthaul transport of timber become increasingly necessary in the pulpwood industry?

1.
2.
3.

Question 4.2: Have the quality/condition of the **forest roads**, you are expected to use, declined over the periods indicated in the Table below?

1. Have not deteriorated	
2. Last year?	
3. Last two years?	
4. Last three or more years?	

If your answer to question 4.2 was [1: have not declined] then skip the rest of part four.

Question 4.3: Based on your experience as a harvesting and/or transport contractor why has shorthaul transport become necessary in the transport of pulpwood out of the plantations?

1. Declining road quality preventing the entry of large vehicles.	
2. Insufficient volumes available per areas to	

warrant the entrance of large vehicles.	
3. Any other reasons	

Any comments you would consider relevant as to the condition of roads within your sphere of influence:

……………………………………………………………………………………………………
……………………………………………………………………………………………………
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Appendix D

Detailed survey results:

- General details of each contractor
- Timber transport origins and destinations
- Types of SIT vehicles used to depots
- Types of shorthaul vehicles to rail siding
- Loading methods: stump to depot and siding
- Loading methods: landing to depot and siding

Harvesting and transport contractors survey results

General detail of each contractor

Contractor	Company contracting to:			Contact period					Road repairs done by:	
	Sappi	Mondi	Both	None	< 1 year	I year	1 to 3 years	>3 years	Company	Contractor
Timbco			x		x				x	
Umkamaas FC	x				x					
Coastal Short Haul	x							x		
MRB Ondernemers	x						x		x	x
DB Forest Harvesting			x				x			
Ihlati	x					x				
DY timber Harvesting	x						x			
SOS contractors	x			x					x	
THT Forests	x						x			
Bostek	x						x			
Sable	x					x			x	
Henry Grover Transport	x					x				
Stoneshack	x						x			
Melann Contractors	x							x		
Ass Carriers	x						x			
Derek Howe			x				x		x	
M&H Mechnised Harvesting	x						x		x	
Log Trans	x						x			x
Bomat	x						x		x	
Dambuza	x					x			x	
Fell & Haul	x						x			
Nordfor	x						x			x
Prolog	x			x	x					
FTH	x						x			
Genric Trust	x					x				x
Bosbok Ontginning	x						x			
Zululand Foretsry Services	x						x			
Gerrys		x					x			
Sheshe		x				x				
HAT		x				x			x	
Filter		x				x				
Qala Forestry		x				x				
Hartley Harvesting		x				x				
Agric Forests		x				x				
CLC Contractors		x					x		x	
MV Timbers		x				x			x	
Green Gold		x				x				
Interman		x				x				
Logging Services		x				x			x	
Nyamazane Forestry		x				x				
SPP Bosbou		x					x			
Karat H &T		x				x			x	
Hi-Lead		x				x				
Steenkamp Vervoer		x				x			x	
Forest services		x				x				
Greeb Zebra		x					x			
Unitrans (1)	x							x		
Long Haul			x				x		x	
Forest Pro		x				x				x
SUBB Family		x				x			x	
v Rensburg Harvesting		x				x				
VriendskapBoerdery		x					x			
Forest Care		x					x			
Msimango		x					x			x
JW Forestry		x				x				
Arbor Care		x				x			x	
Phineas Theko		x				x				
Bainesfield T C		x				x				x
Richmond FS		x					x		x	
Farmer FS		x				x			x	
Mining Indusrial		x					x			
Forest Projects		x				x				
van Rensburg T		x				x				
Wartburg T			x			x				
Woest veroer		x					x		x	
Wattle & Timber		x					x			
H Grobelaar		x					x			
Peet Botes		x				x				x
C Zulu		x					x		x	
Ntshangase		x				x				
Spoornet		x					x		x	
unitrans (2)		x					x			
N Grobler		x								
longridge (own ops)		x								
Rhenoster (own ops)		x								
Swaziland (own ops)		x								
Kwambo (own ops)		x								
Melmoth (own ops)		x								
Richmond (own ops)		x								
Warburton (own ops)		x								
Graskop (own ops)		x								
Howick (own ops)		x								
Totals	25	43	5	2	3	33	32	3	23	8

Harvesting and transport contractors survey results

Timber transport origins and destinations

Contractor	S/H stump to depot (tonnes)		S/H landing to depot (tonnes)		S/H stump to siding (tonnes)		S/H landing to siding (tonnes)		Lead stump to depot (km)		Lead landing to depot (km)	
	Hard wood	Soft wood	Hard wood	Soft wood	Hard wood	Soft wood	Hard wood	Soft wood	Hard wood	Soft wood	Hard wood	Soft wood
Timbco			200000					83000			3	3
Umkamaas FC				86000				40000				3
Coastal Short Haul					180000				9			
MRB Ondernemers			60000					100000				32
DB Forest Harvesting	45000								2			
Ihlati					147000				24			
DY timber Harvesting								72000				13
SOS contractors	20000	20000	5000							2		2
THT Forests								18000				5
Bostek				28000								10
Sable												
Henry Grover Transport		100000				50000				12		
Stoneshack												
Melann Contractors					50000				8			
Ass Carriers	30000	120000							4	4		
Derek Howe		50000						150000	15			15
M&H Mechnised Harvesting												
Log Trans				150000				89000				14
Bomat												
Dambuza	43000			17000					3			3
Fell & Haul	54000	72000			80000				5	5	5	
Nordfor			2000		17000					6		10
Prolog				30000								8
FTH	60000		60000						3		3	3
Genric Trust	38000	94000			48000	110000			16	16	19	19
Bosbok Ontginning			50000								7	
Zululand Foretsry Services					80000				10			
Gerrys					10000				10			
Sheshe	60000								3	3		
HAT					18000	15000			7			10
Filter			10000	28000	60000	10000			6	6	6	6
Qala Forestry												
Hartley Harvesting												
Agric Forests					24000				9			
CLC Contractors												
MV Timbers												
Green Gold	6000		4000						17		20	
Interman					130000				20			
Logging Services	20000				32000				1			
Nyamazane Forestry	36000	2000							25	25		
SPP Bosbou												
Karat H &T	30000	7500			30000	7500			18	18		
Hi-Lead												
Steenkamp Vervoer	75000		24000		38000		12000		20		20	
Forest services		57500								2		
Greeb Zebra							133000					4
Unitrans (1)					10000	70000	10000	70000			5	5
Long Haul							76000	220000			5	
Forest Pro	45000				45000				1	1		
SUBB Family	150000										5	
v Rensburg Harvesting	25000	40000							3	3		
VriendskapBoerdery	25000								3			
Forest Care	32000								2			
Msimango												
JW Forestry												
Arbor Care												
Phineas Theko												
Bainesfield T C				82000								3
Richmond FS					64000				6			
Farmer FS	36000								18			
Mining Indusrial	39000						98000			24		24
Forest Projects	60000	15000							3	3		
van Rensburg T	50000		50000						3		3	
Wartburg T												
Woest veroer				18000								19
Wattle & Timber												
H Grobelaar												
Peet Botes												
C Zulu	56000								34		34	
Ntshangase												
Spoornet					10000		60000	50000			18	25
unitrans (2)							12300	67000				
N Grobler												
longridge (own ops)												
Rhenoster (own ops)												
Swaziland (own ops)												
Kwambo (own ops)	120000								2			
Melmoth (own ops)	60000								2			
Richmond (own ops)												
Warburton (own ops)												
Graskop (own ops)												
Howick (own ops)		50000								10		
Totals	1215000	628000	465000	439000	1073000	262500	401300	959000				

Harvesting and transport contractors survey results

Contractor	Types of SIT vehicles used to depot (Tonnes)							
	Forwarder	Timber hauler	Agricultural tractor and semi trailer with mounted crane	Agricultural tractor and semi trailer	Rigid truck	Rigid truck with drawbar trailer	Prime mover and semi trailer	others
Timbco				200000				
Umkamaas FC				86000				
Coastal Short Haul								
MRB Ondernemers								
DB Forest Harvesting		25000		20000				
Ihlati								
DY timber Harvesting								
SOS contractors	5000			40000				
THT Forests								
Bostek				11000	17000			
Sable								
Henry Grover Transport		100000						
Stoneshack								
Melann Contractors								
Ass Carriers		150000						
Derek Howe				50000				
M&H Mechnised Harvesting								
Log Trans		71700					78300	
Bomat								
Dambuza	43000			17000				
Fell & Haul				126000				
Nordfor				2000				
Prolog	30000							
FTH				120000				
Genric Trust					132000			
Bosbok Ontginning					50000			
Zululand Foretsry Services								
Gerrys								
Sheshe			60000					
HAT								
Filter			24000	14000				
Qala Forestry								
Hartley Harvesting								
Agric Forests								
CLC Contractors								
MV Timbers								
Green Gold						10000		
Interman								
Logging Services	20000							
Nyamazane Forestry				38000				
SPP Bosbou								
Karat H &T			15000	22500				
Hi-Lead								
Steenkamp Vervoer				62000		37000		
Forest services				57500				
Greeb Zebra								
Unitrans (1)								
Long Haul								
Forest Pro				45000				
SUBB Family								
v Rensburg Harvesting			25000	40000				
VriendskapBoerdery			25000					
Forest Care			32000					
Msimango								
JW Forestry								
Arbor Care								
Phineas Theko								
Bainesfield T C		82000						
Richmond FS								
Farmer FS				36000				
Mining Indusrial				39000				
Forest Projects			24000	24000				27000
van Rensburg T				100000				
Wartburg T								
Woest veroer						18000		
Wattle & Timber								
H Grobelaar								
Peet Botes								
C Zulu				56000				
Ntshangase								
Spoornet								
unitrans (2)								
N Grobler								
longridge (own ops)								
Rhenoster (own ops)								
Swaziland (own ops)								
Kwambo (own ops)	120000							
Melmoth (own ops)			60000					
Richmond (own ops)								
Warburton (own ops)								
Graskop (own ops)								
Howick (own ops)				50000				
Totals	218000	428700	265000	1256000	199000	65000	78300	27000

Harvesting and transport contractors survey results

Contrator	Types of shorthaul vehicle used to rail siding (Tonnes)							
	Forwarder	Timber hauler	Agricultural tractor and semi-trailer with mounted crane	Agricultural tractor and semi trailer	Rigid truck	Rigid truck with drawbar trailer	Prime mover and semi trailer	others
Timbco				83000				
Umkamaas FC				40000				
Coastal Short Haul					180000			
MRB Ondernemers					100000			
DB Forest Harvesting								
Ihlati				90000	15000	42000		
DY timber Harvesting				72000				
SOS contractors								
THT Forests					18000			
Bostek								
Sable								
Henry Grover Transport		50000						
Stoneshack								
Melann Contractors				50000				
Ass Carriers								
Derek Howe		15000						
M&H Mechnised Harvesting								
Log Trans							89000	
Bomat								
Dambuza								
Fell & Haul				80000				
Nordfor				17000				
Prolog								
FTH								
Genric Trust					158000			
Bosbok Ontginning								
Zululand Foretsry Services				80000				
Gerrys				10000				
Sheshe								
HAT				11000	11000	11000		
Filter			30000	40000				
Qala Forestry								
Hartley Harvesting								
Agric Forests				24000				
CLC Contractors								
MV Timbers								
Green Gold								
Interman								
Logging Services		130000						
Nyamazane Forestry			32000					
SPP Bosbou								
Karat H &T				37500				
Hi-Lead								
Steenkamp Vervoer				38000		12000		
Forest services								
Greeb Zebra					133000			
Unitrans (1)					160000			
Long Haul					98000	198000		
Forest Pro						45000		
SUBB Family								
v Rensburg Harvesting								
VriendskapBoerdery								
Forest Care								
Msimango								
JW Forestry								
Arbor Care								
Phineas Theko								
Bainesfield T C								
Richmond FS		64000						
Farmer FS								
Mining Indusrial				98000				
Forest Projects								
van Rensburg T								
Wartburg T								
Woest veroer								
Wattle & Timber								
H Grobelaar								
Peet Botes								
C Zulu								
Ntshangase								
Spoornet				10000			110000	
unitrans (2)						79000		
N Grobler								
longridge (own ops)								
Rhenoster (own ops)								
Swaziland (own ops)								
Kwambo (own ops)								
Melmoth (own ops)								
Richmond (own ops)								
Warburton (own ops)								
Graskop (own ops)								
Howick (own ops)								
Totals	0	259000	62000	780500	873000	387000	199000	0

Harvesting and transport contractors survey results

Contractor	Loading methods: Stump to depot and siding (Tonnes)											
	To depot						To siding					
	Manual loading	Three wheel log loaders	Front end loaders	Vehicle mounted crane	Independent loader	Other	Manual loading	Three wheel log loaders	Front end loaders	Vehicle mounted crane	Independent loader	Other
Timbco												
Umkamaas FC												
Coastal Short Haul												180000
MRB Ondernemers												
DB Forest Harvesting		45000										
Ihlati								147000				
DY timber Harvesting												
SOS contractors	5000	35000										
THT Forests												
Bostek												
Sable												
Henry Grover Transport		100000						50000				
Stoneshack												
Melann Contractors											50000	
Ass Carriers		150000										
Derek Howe		40000			5000	5000						
M&H Mechnised Harvesting												
Log Trans												
Bomat												
Dambuza				43000								
Fell & Haul		31000			95000			20000			60000	
Nordfor							17000					
Prolog												
FTH	30000	30000										
Genric Trust		84000						110000				
Bosbok Ontginning												
Zululand Foretsry Services							80000					
Gerrys							10000					
Sheshe				60000								
HAT							20000					
Filter		10000						10000				
Qala Forestry												
Hartley Harvesting												
Agric Forests							24000					
CLC Contractors												
MV Timbers												
Green Gold	6000											
Interman												
Logging Services				20000				50000	80000			
Nyamazane Forestry	38000							32000				
SPP Bosbou												
Karat H &T	22500			15000			37500					
Hi-Lead												
Steenkamp Vervoer	75000						38000					
Forest services	57500											
Greeb Zebra												
Unitrans (1)								80000				
Long Haul												
Forest Pro		45000						45000				
SUBB Family												
v Rensburg Harvesting		65000										
VriendskapBoerdery				25000								
Forest Care				32000								
Msimango												
JW Forestry												
Arbor Care												
Phineas Theko												
Bainesfield T C												
Richmond FS							64000					
Farmer FS	36000											
Mining Indusrial	39000											
Forest Projects		24000		24000		27000						
van Rensburg T		50000										
Wartburg T												
Woest veroer												
Wattle & Timber												
H Grobelaar												
Peet Botes												
C Zulu	56000											
Ntshangase												
Spoornet								10000				
unitrans (2)												
N Grobler												
longridge (own ops)												
Rhenoster (own ops)												
Swaziland (own ops)												
Kwambo (own ops)				120000								
Melmoth (own ops)			60000									
Richmond (own ops)												
Warburton (own ops)												
Graskop (own ops)												
Howick (own ops)		50000										
Totals	365000	759000	60000	339000	100000	32000	290500	554000	80000	0	110000	180000

Harvesting and transport contractors survey results

Contractor	Loading methods: Landing to depot and siding (Tonnes)											
	To depot						To siding					
	Manual loading	Three wheel log loaders	Front end loaders	Vehicle mounted crane	Independent loader	Other	Manual loading	Three wheel log loaders	Front end loaders	Vehicle mounted crane	Independent loader	Other
Timbco		200000						83000				
Umkamaas FC			86000						40000			
Coastal Short Haul												
MRB Ondernemers		44000			16000			100000				
DB Forest Harvesting												
Ihlati												
DY timber Harvesting								72000				
SOS contractors	5000											
THT Forests								9000			9000	
Bostek		24000	4000									
Sable												
Henry Grover Transport												
Stoneshack												
Melann Contractors												
Ass Carriers												
Derek Howe								105000				
M&H Mechnised Harvesting												
Log Trans		150000						89000				
Bomat												
Dambuza		17000										
Fell & Haul												
Nordfor	2000											
Prolog				30000								
FTH	30000	30000										
Genric Trust		48000						48000				
Bosbok Ontginning	20000	30000										
Zululand Foretsry Services												
Gerrys												
Sheshe												
HAT							12000					
Filter		19000		9000				30000		30000		
Qala Forestry												
Hartley Harvesting												
Agric Forests												
CLC Contractors												
MV Timbers												
Green Gold	4000											
Interman												
Logging Services												
Nyamazane Forestry												
SPP Bosbou												
Karat H &T												
Hi-Lead												
Steenkamp Vervoer	24000						12000					
Forest services												
Greeb Zebra								133000				
Unitrans (1)								80000				
Long Haul								296000				
Forest Pro												
SUBB Family												
v Rensburg Harvesting												
VriendskapBoerdery												
Forest Care												
Msimango												
JW Forestry												
Arbor Care												
Phineas Theko												
Bainesfield T C		82000										
Richmond FS												
Farmer FS												
Mining Indusrial							28000	70000				
Forest Projects												
van Rensburg T		50000										
Wartburg T												
Woest veroer	18000											
Wattle & Timber												
H Grobelaar												
Peet Botes												
C Zulu												
Ntshangase												
Spoornet							110000					
unitrans (2)										79300		
N Grobler												
longridge (own ops)												
Rhenoster (own ops)												
Swaziland (own ops)												
Kwambo (own ops)												
Melmoth (own ops)												
Richmond (own ops)												
Warburton (own ops)												
Graskop (own ops)												
Howick (own ops)												
Totals	103000	694000	90000	39000	16000	0	162000	1115000	40000	109300	9000	0

Appendix E:

Road pixel utilization data.

Actual number of pixels used per plantation per transport system.

- Uplands
- Highlands
- Greenhill

Uplands 1(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	19	119	138	1	1250	56.05
2	49	46	95	2	1234	55.34
3	520	350	870	3	1237	55.47
4	76	170	246	4	1242	55.7
5	503	378	881	5	1234	55.34
Total	1167	1063	2230			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	19	4	23			
2	48	0	48			
3	516	73	589			
4	76	24	100			
5	462	32	494			
Total	1121	133	1254			

Uplands 2(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	19	119	138	1	1242	55.7
2	49	46	95	2	1227	55.02
3	520	350	870	3	1225	54.93
4	76	170	246	4	1228	55.07
5	503	378	881	5	1224	54.89
Total	1167	1063	2230			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	19	4	23			
2	48	0	48			
3	516	74	590			
4	74	13	87			
5	465	33	498			
Total	1122	124	1246			

Uplands 1(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	18	118	136	1	597	59.23
2	46	44	90	2	597	59.23
3	342	198	540	3	603	59.82
4	73	169	242	4	578	57.34
5	0	0	0	5	589	58.43
Total	479	529	1008			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	18	40	58			
2	46	6	52			
3	324	99	423			
4	44	25	69			
5	0	0	0			
Total	432	170	602			

Uplands 3(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	18	117	135			
2	45	44	89		Road Pixels	769
3	238	118	356		used	541
4	63	126	189		%	70.35
5	0	0	0			
Total	364	405	769			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	18	35	53			
2	45	6	51			
3	234	83	317			
4	63	57	120			

Uplands 2(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	18	118	136	1	597	59.23
2	46	44	90	2	597	59.23
3	342	198	540	3	603	59.82
4	73	169	242	4	578	57.34
5	0	0	0	5	589	58.43
Total	479	529	1008			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	18	39	57			
2	46	6	52			
3	324	98	422			
4	44	25	69			
5	0	0	0			
Total	432	168	600			

Uplands 1(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	18	117	135	1	498	64.68
2	45	44	89	2	500	64.94
3	239	118	357	3	494	64.16
4	63	126	189	4	476	61.82
5	0	0	0	5	484	62.86
Total	365	405	770			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	18	42	60	12.0		
2	45	6	51	10.2		
3	235	88	323	64.6		
4	35	31	66	13.2		
5	0	0	0			
Total	333	167	500	100.0		

Uplands 2(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	18	117	135	1	498	64.76
2	45	44	89	2	500	65.02
3	238	118	356	3	494	64.24
4	63	126	189	4	476	61.9
5	0	0	0	5	484	62.94
Total	364	405	769			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	16	49	65			
2	30	6	36			
3	213	91	304			
4	49	47	96			
5	0	0	0			
Total	308	193	501			

Highlands 1(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	66	114	1	1926	80.18
2	153	22	175	2	1952	81.27
3	644	92	736	3	1941	80.81
4	3	244	247	4	1899	79.06
5	1012	118	1130			
Total	1860	542	2402			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	35	83			
2	153	15	168			
3	612	46	658			
4	3	79	82			
5	877	26	903			
Total	1693	201	1894			

Highlands 2(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	66	114	1	1926	80.18
2	153	22	175	2	1952	81.27
3	644	92	736	3	1941	80.81
4	3	244	247	4	1899	79.06
5	1012	118	1130			
Total	1860	542	2402			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	34	82			
2	153	15	168			
3	614	46	660			
4	3	79	84			
5	881	27	908			
Total	1699	203	1902			

Highlands 1(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	66	114	1	1193	86.76
2	150	22	172	2	1134	82.47
3	752	89	841	3	1155	84
4	5	243	248	4	1153	83.85
5	0	0	0			
Total	955	420	1375			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	43	91			
2	150	15	165			
3	715	56	771			
4	5	126	131			
5	0	0	0			
Total	918	240	1158			

Highlands 3(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	67	115			
2	151	21	172			
3	341	67	408			
4	4	223	227			
5	0	0	0		Total	922
Total	544	378	922		used	805
					%	87.31
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	46	94			
2	151	16	167			
3	341	50	391			
4	4	149	153			
5	0	0	0			

Highlands 2(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	66	114	1	1193	86.76
2	150	22	172	2	1134	82.47
3	752	89	841	3	1155	84
4	5	243	248	4	1153	83.85
5	0	0	0			
Total	955	420	1375			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	43	91			
2	150	15	165			
3	713	57	770			
4	5	129	134			
5	0	0	0			
Total	916	244	1160			

Highlands 1(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	67	115	1	742	80.48
2	151	21	172	2	701	76.03
3	341	67	408	3	722	78.31
4	4	223	227	4	713	77.33
5	0	0	0			
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	46	94			
2	151	15	166			
3	326	50	376			
4	2	88	90			
5	0	0	0			
Total	527	199	726			

Highlands 2(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	48	67	115	1	742	80.48
2	151	21	172	2	701	76.03
3	341	67	408	3	722	78.31
4	4	223	227	4	713	77.33
5	0	0	0			
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	48	46	94			
2	151	15	166			
3	326	49	375			
4	2	87	89			
5	0	0	0			
Total	527	197	724			

Greenhil 1(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	96	144	240	1	2170	70.32
2	188	77	265	2	2134	69.15
3	713	328	1041	3	2160	69.99
4	21	265	286	4	2140	69.35
5	906	348	1254	5	2163	70.09
	1924	1162	3086	6	2168	70.25
				7	2163	70.09
				8	2174	70.45
				9	2168	70.25
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	96	87	183			
2	187	39	226			
3	690	113	803			
4	20	79	99			
5	802	72	874			
Total	1795	390	2185			

Greenhil 1(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	95	142	237	1	1272	76.21
2	179	85	264	2	1236	74.06
3	624	270	894	3	1266	75.85
4	21	253	274	4	1237	74.12
5	0	0	0	5	1255	75.19
	919	750	1669	6	1256	75.25
				7	1279	76.63
				8	1269	76.03
				9	1284	76.93
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	95	92	187			
2	177	48	225			
3	578	142	720			
4	19	115	134			
5	0	0	0			
Total	869	397	1266			

Greenhil 2(100%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	96	144	240	1	2170	70.32
2	188	77	265	2	2134	69.15
3	713	328	1041	3	2160	69.99
4	21	265	286	4	2140	69.35
5	906	348	1254	5	2163	70.09
	1924	1162	3086	6	2168	70.25
				7	2163	70.09
				8	2174	70.45
				9	2168	70.25
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	96	83	179			
2	187	38	225			
3	690	112	802			
4	20	83	103			
5	796	73	869			
Total	1789	389	2178			

Greenhil 2(50%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	95	142	237	1	1272	76.21
2	179	85	264	2	1236	74.06
3	624	270	894	3	1266	75.85
4	21	253	274	4	1237	74.12
5	0	0	0	5	1255	75.19
	919	750	1669	6	1256	75.25
				7	1279	76.63
				8	1269	76.03
				9	1284	76.93
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	95	91	186			
2	176	47	223			
3	571	134	705			
4	19	114	133			
5	0	0	0			
Total	861	386	1247			

Greenhil 1(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	92	141	233	1	927	79.1
2	179	84	263	2	877	74.83
3	288	99	387	3	917	78.24
4	24	265	289	4	859	73.29
5	0	0	0	5	877	74.83
	583	589	1172	6	917	78.24
				7	951	81.14
				8	946	80.72
				9	938	80.03
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	92	96	188			
2	164	50	214			
3	268	79	347			
4	19	141	160			
5	0	0	0			
Total	543	366	909			

Greenhil 3(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	92	141	233	Total	1172	
2	179	84	263	used	969	
3	288	99	387	%	82.68	
4	24	265	289			
5	0	0	0			
	583	589	1172			
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	92	97	189			
2	179	49	228			
3	288	80	368			
4	24	160	184			
5	0	0	0			
Total	583	386	969			

Greenhil 2(30%)						
Road pixels by class in forest and non-fo				Depot no	Road pixels	%used
class	forest	non forest	total			
1	92	141	233	1	927	79.1
2	179	84	263	2	877	74.83
3	266	99	387	3	917	78.24
4	24	265	289	4	859	73.29
5	0	0	0	5	877	74.83
	583	589	1172	6	917	78.24
				7	951	81.14
				8	946	80.72
				9	938	80.03
Total	544	378	922			
Road pixels with volume asg in final tess						
class	forest	non-forest	total			
1	92	95	187			
2	157	48	205			
3	266	78	344			
4	19	141	160			
5	0	0	0			
Total	534	362	896			

Appendix F

Pixel maps

Uplands

- Uplands forest cover
- Uplands roads map (100%)
- Uplands tessellation map with roads (100%)
- Uplands tessellation map (100%)
- Uplands tessellation map with roads (50%)
- Uplands roads map (50%)
- Uplands tessellation map (50%)
- Uplands roads map (30%)
- Uplands tessellation map with roads (30%)
- Uplands tessellation map (30%)

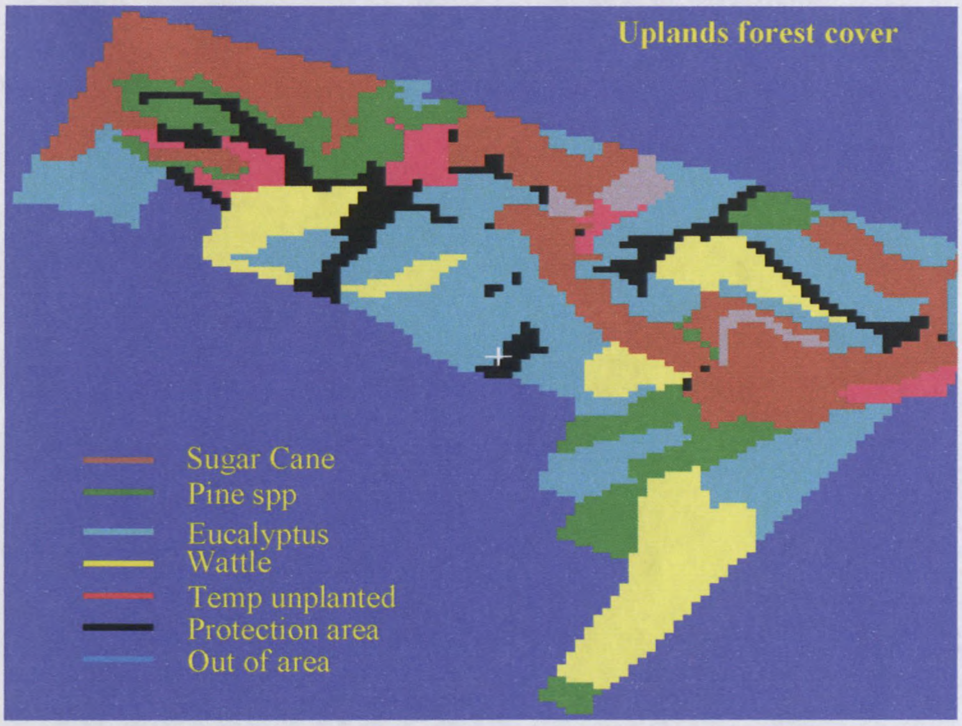
Highlands

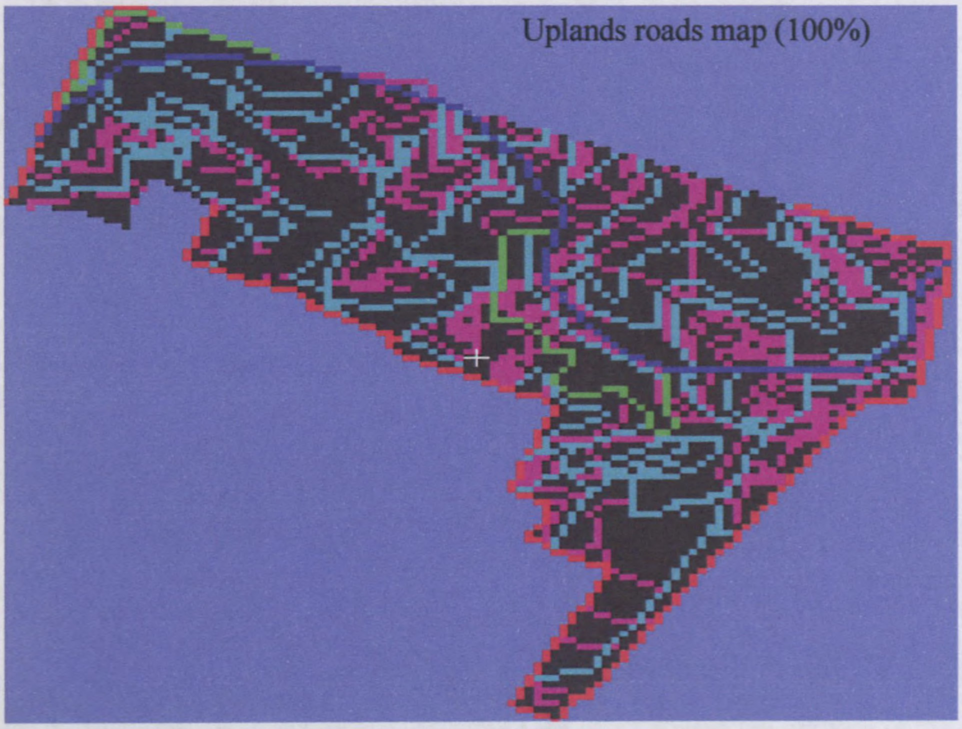
- Highlands forest cover
- Highlands roads map (100%)
- Highlands tessellation map with roads (100%)
- Highlands tessellation map (100%)
- Highlands tessellation map with roads (50%)
- Highlands roads map (50%)
- Highlands tessellation map (50%)
- Highlands roads map (30%)
- Highlands tessellation map with roads (30%)
- Highlands tessellation map (30%)

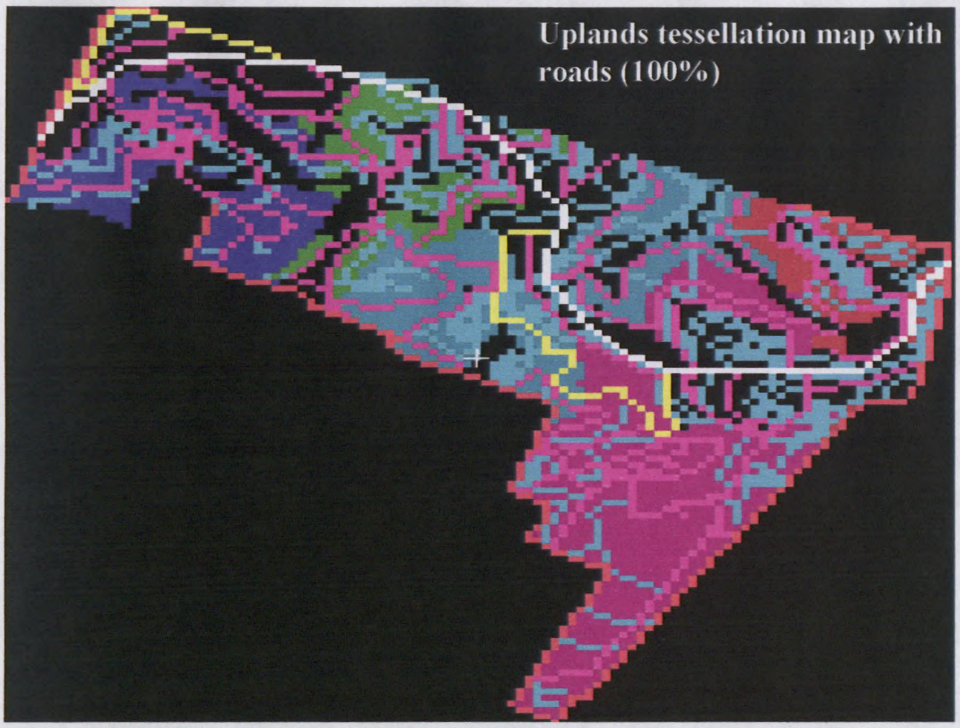
Greenhill

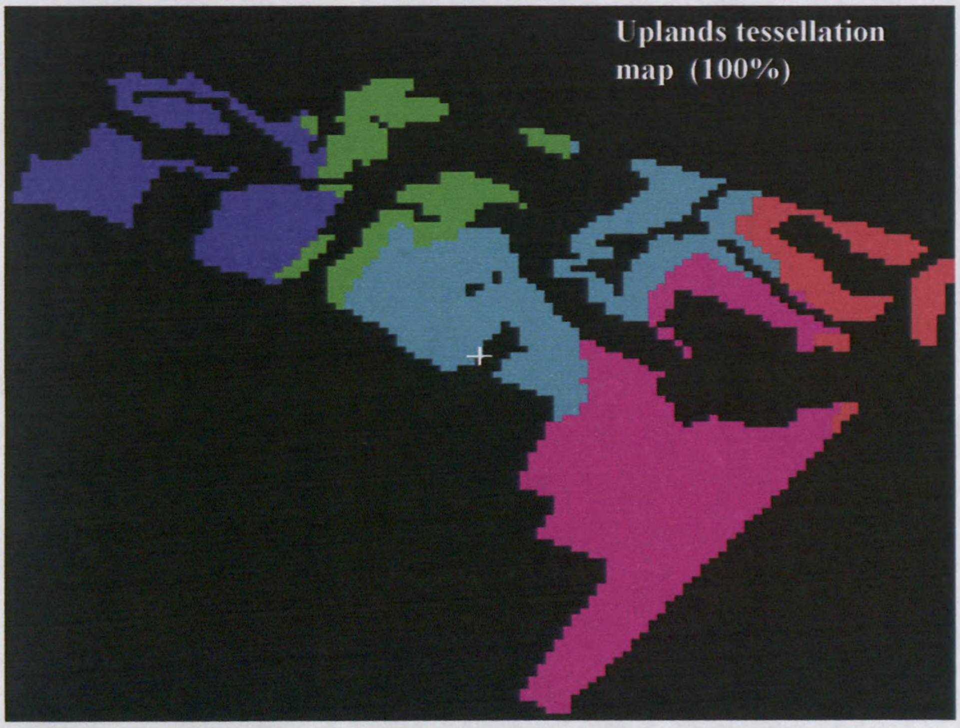
- Greenhill forest cover
- Greenhill roads map (100%)
- Greenhill tessellation map with roads (100%)
- Greenhill tessellation map (100%)

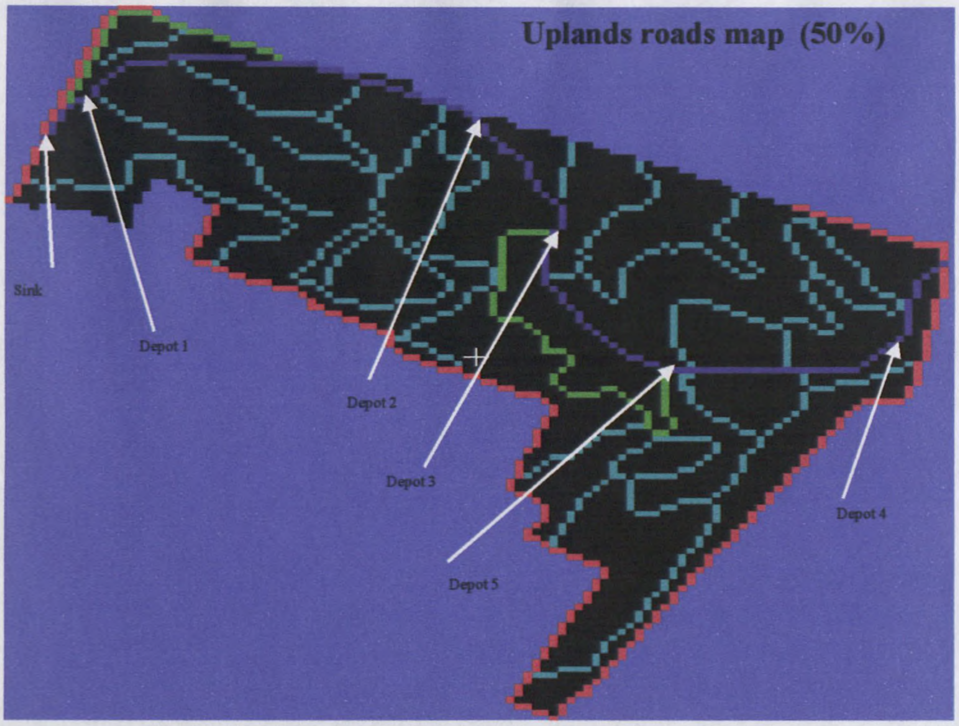
- Greenhill tessellation map with roads (50%)
- Greenhill roads map (50%)
- Greenhill tessellation map (50%)
- Greenhill roads map (30%)
- Greenhill tessellation map with roads (30%)
- Greenhill tessellation map (30%)

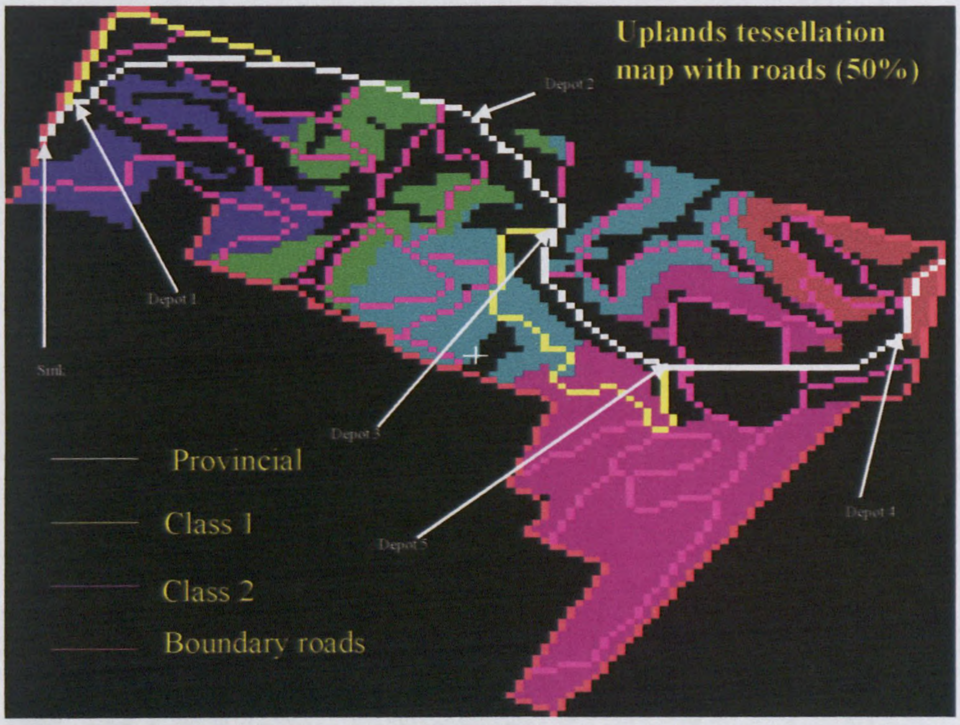

Uplands forest cover
Sugar Cane
Pine spp
Eucalyptus
Wattle
Temp unplanted
Protection area
Out of area

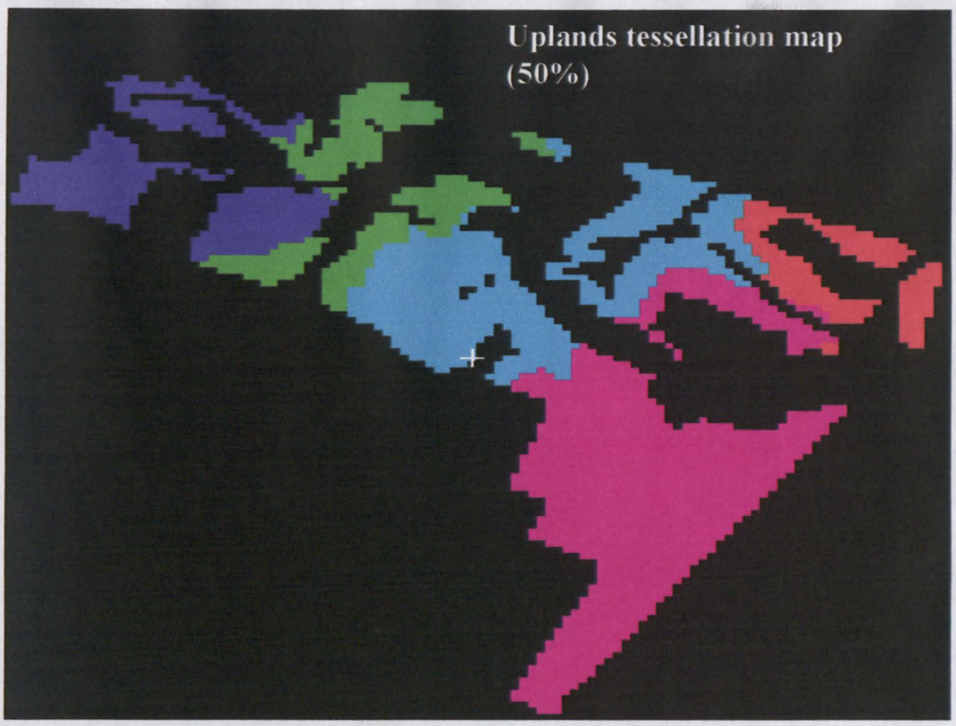

Uplands roads map (100%)

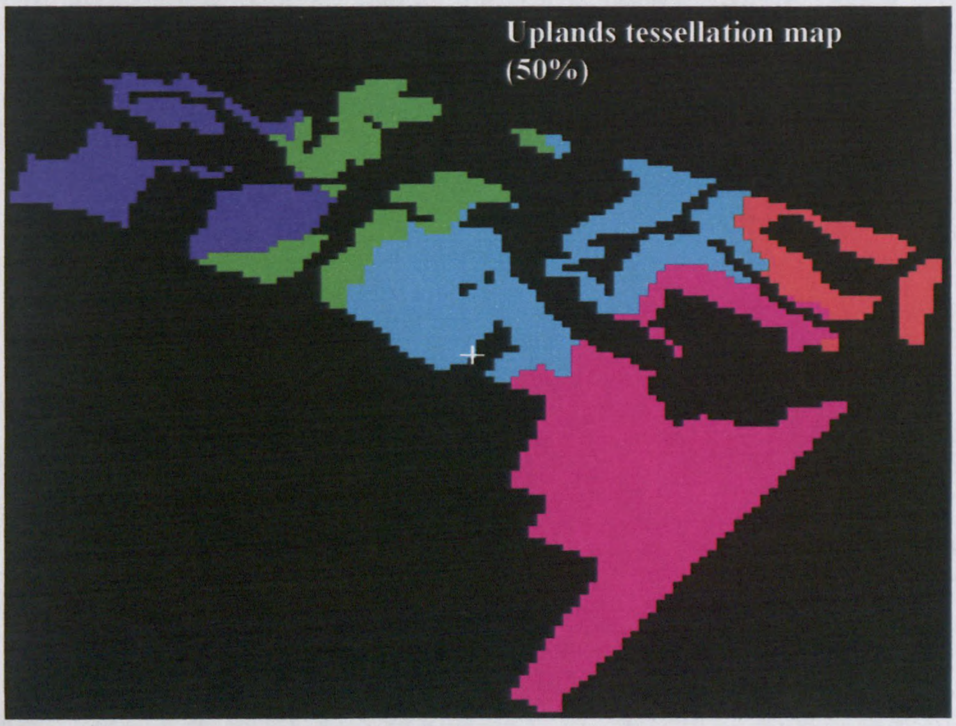

Uplands tessellation map with roads (100%)

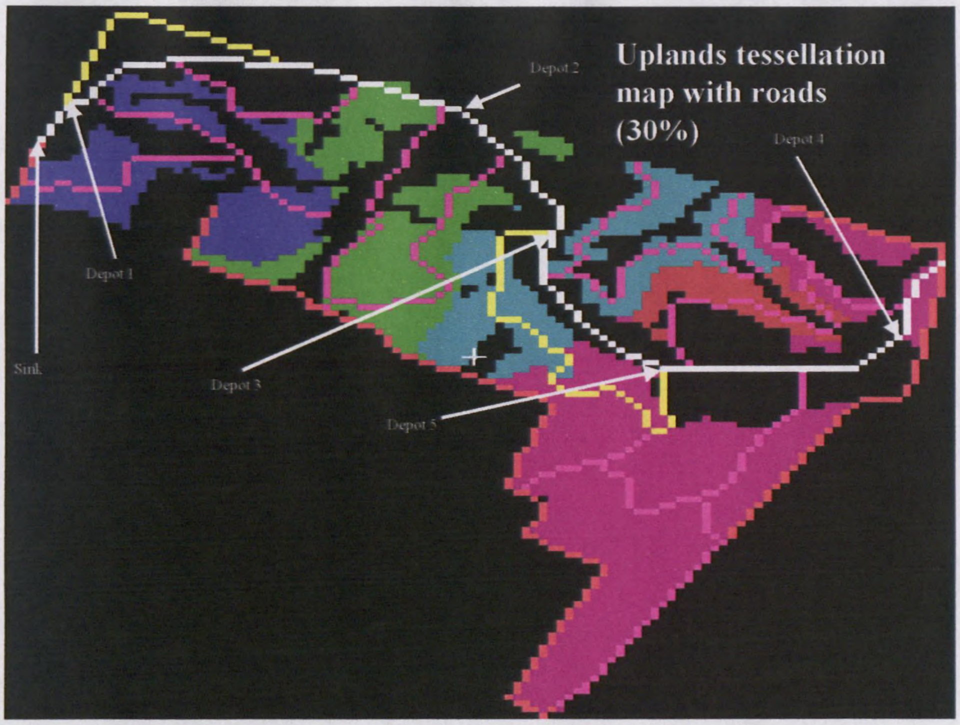

Uplands tessellation map (100%)

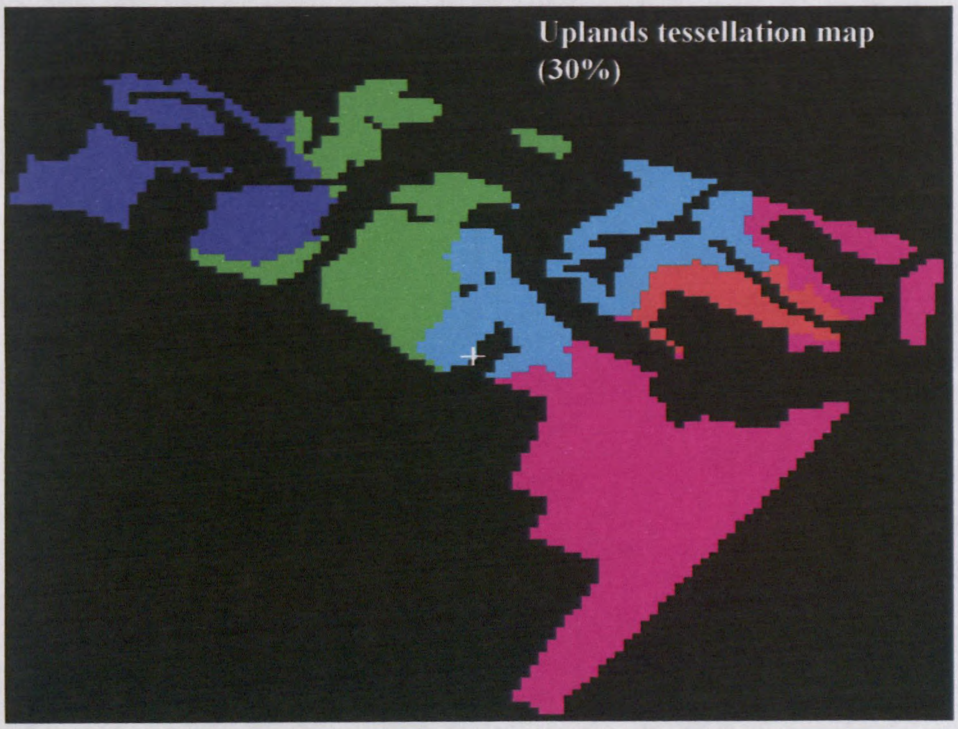

Uplands roads map (50%)
Sink
Depot 1
Depot 2
Depot 3
Depot 4
Depot 5

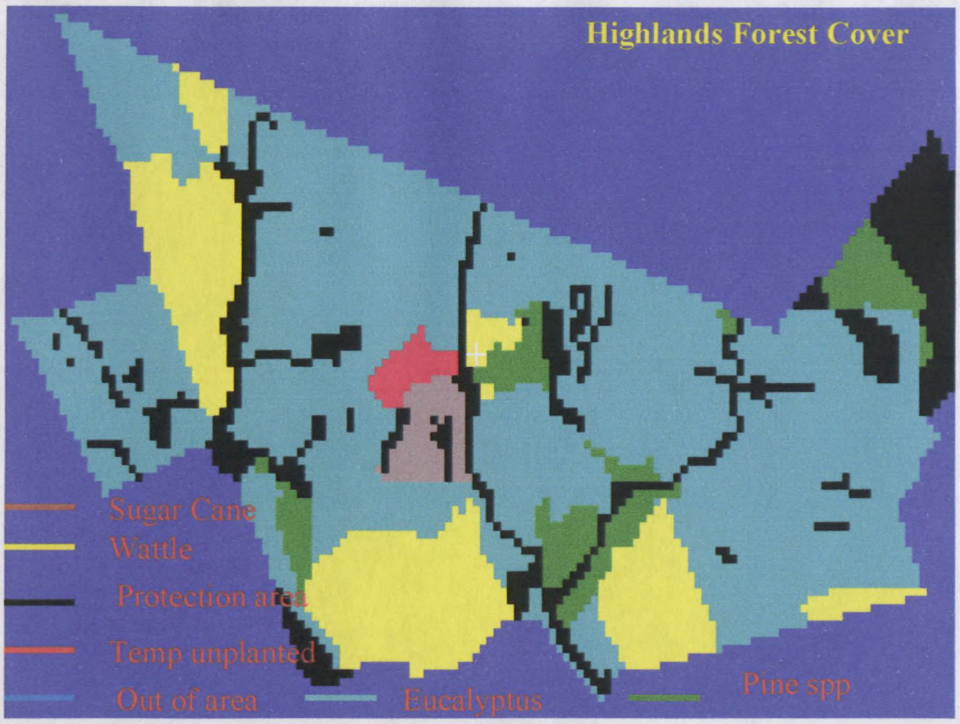

Uplands tessellation map with roads (50%)
Depot 2
Depot 1
Depot 4
Depot 5
Provincial
Class 1
Class 2
Boundary roads

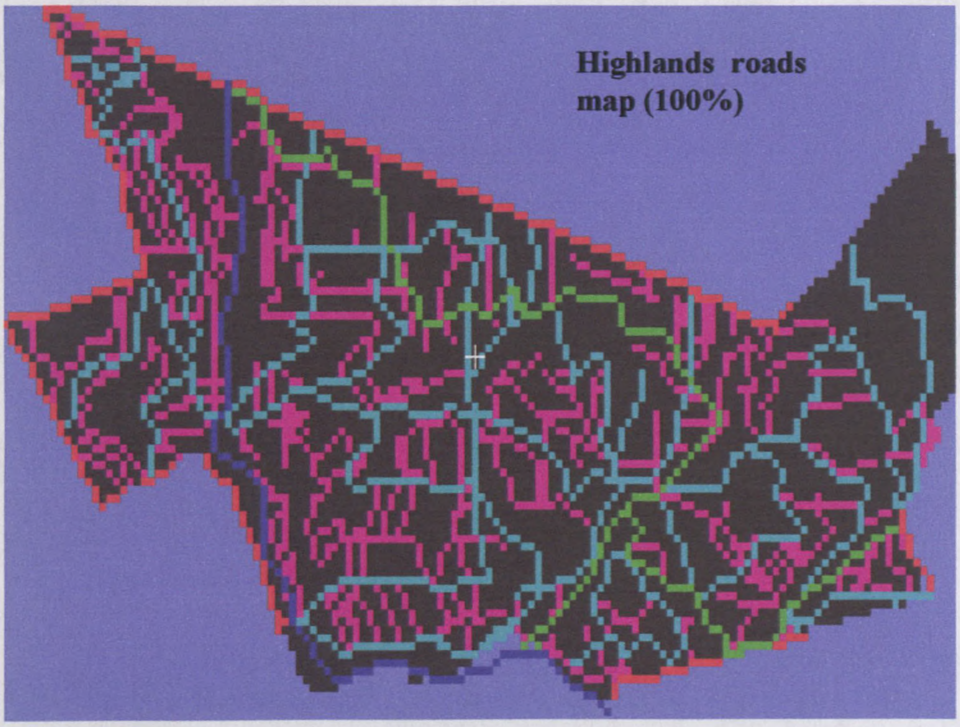

Uplands tessellation map
(50%)

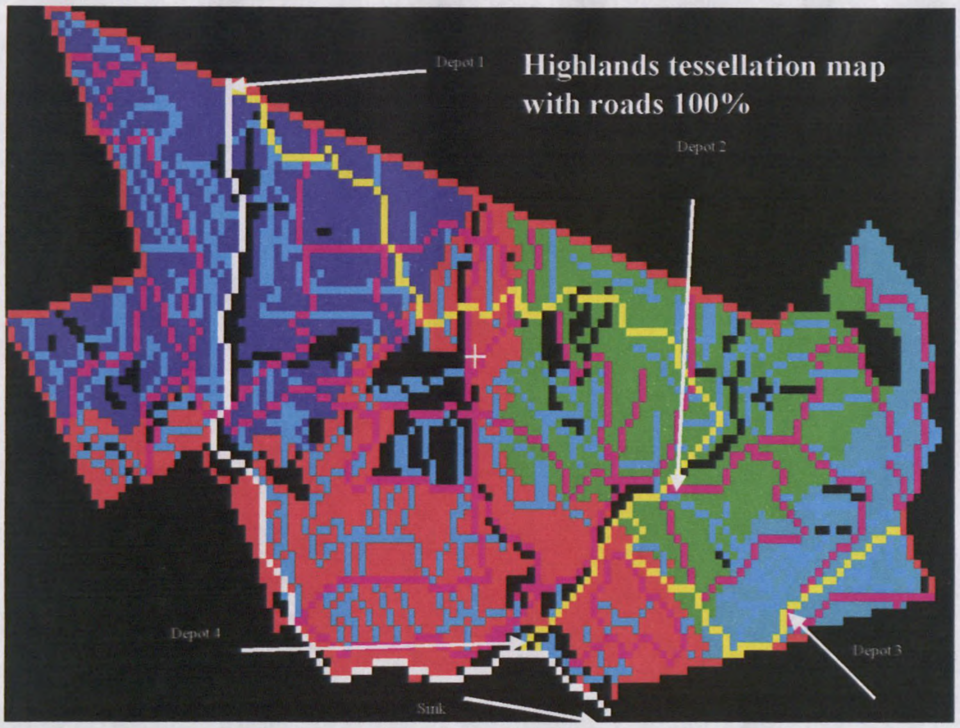

Uplands tessellation map
(50%)

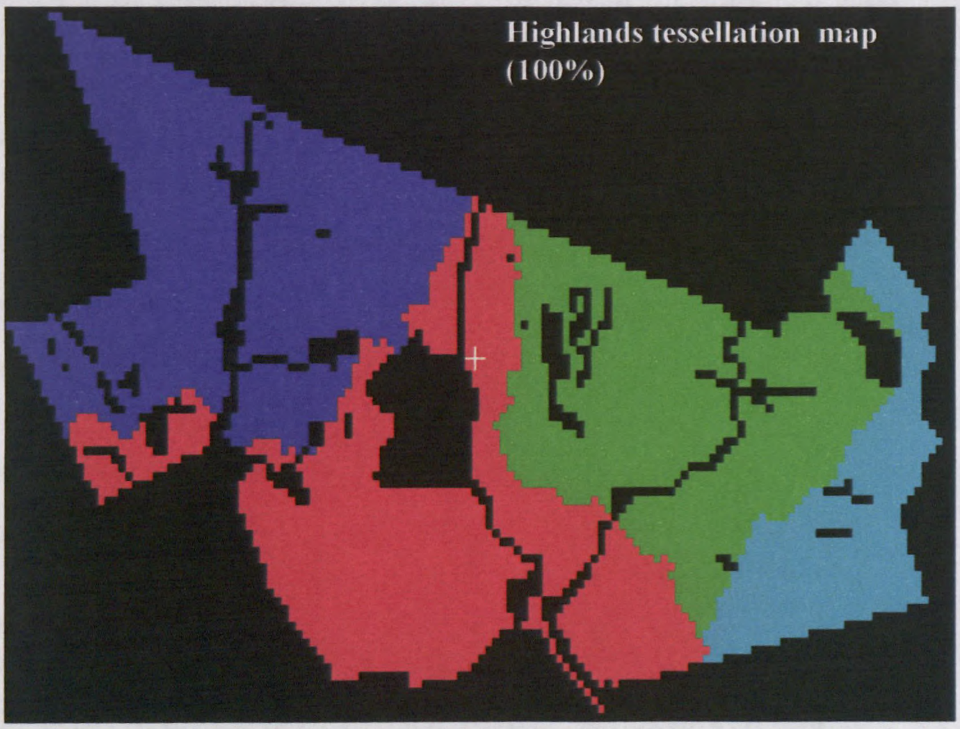

Uplands tessellation map with roads (30%)
Depot 2
Depot 4
Depot 1
Sink
Depot 3
Depot 5

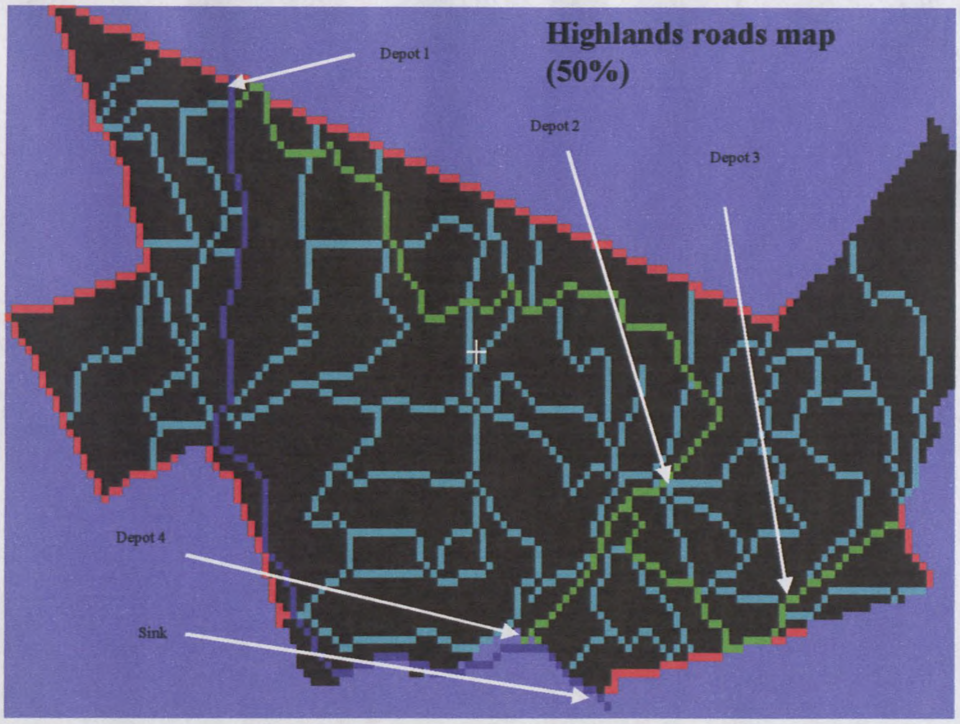

Uplands tessellation map (30%)

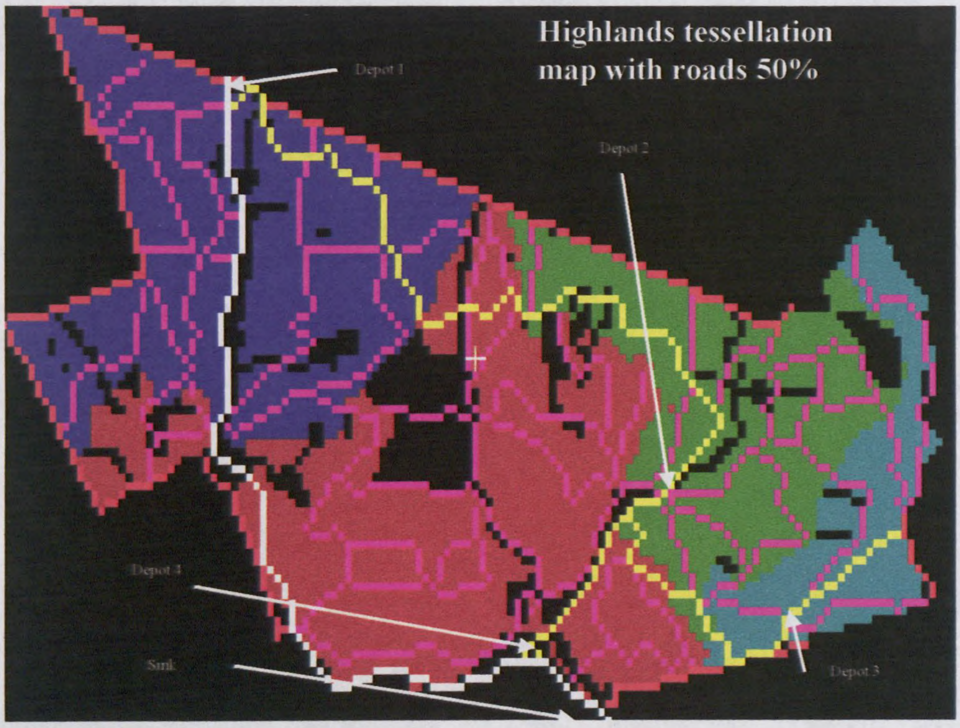

Highlands Forest Cover
Sugar Cane
Wattle
Protection area
Temp unplanted
Out of area
Eucalyptus
Pine spp

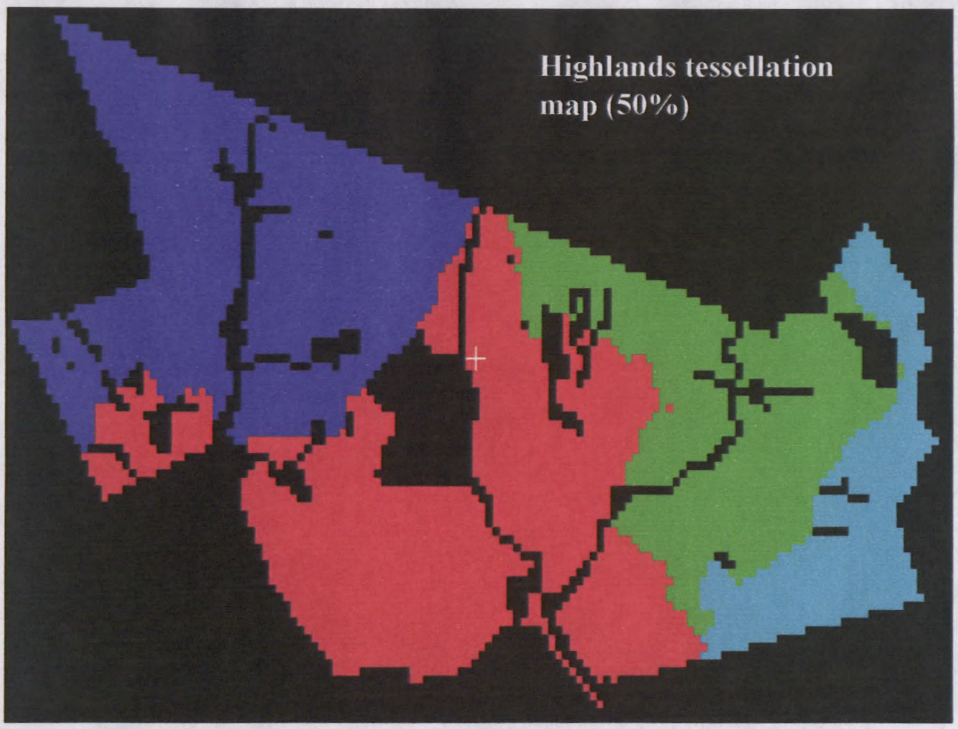

Highlands roads map (100%)

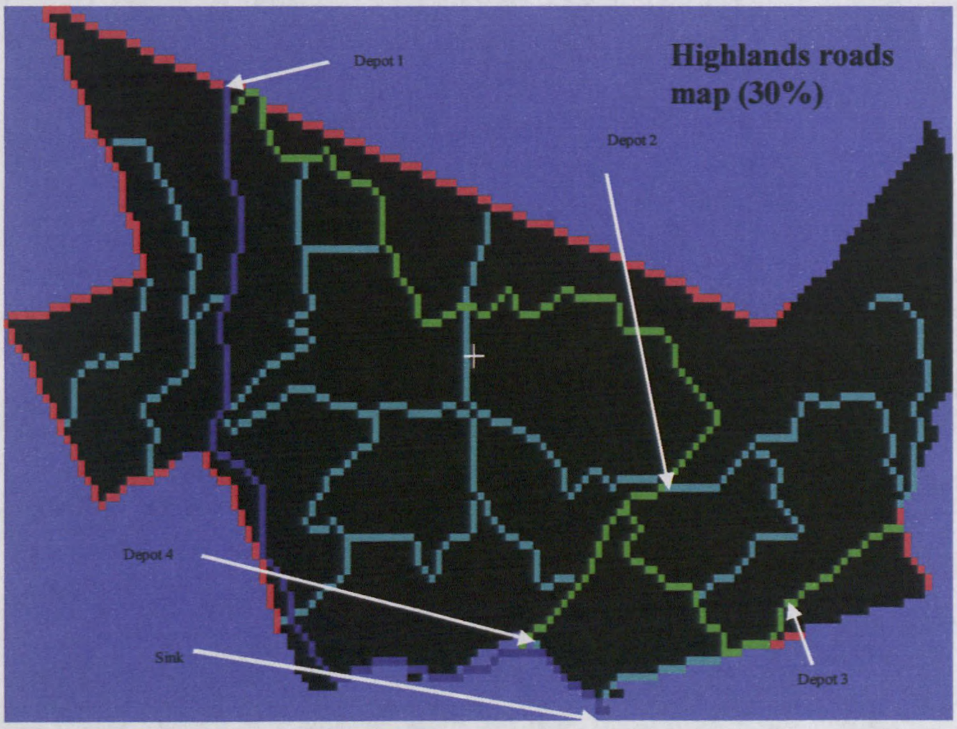

Highlands tessellation map with roads 100%
Depot 1
Depot 2
Depot 3
Depot 4
Sink

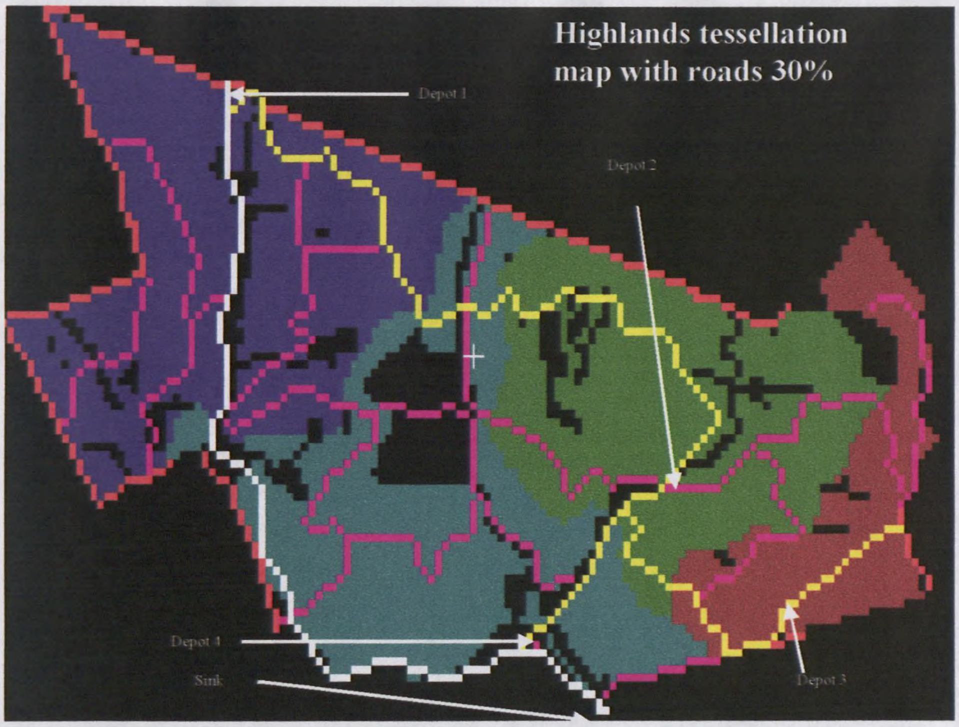

Highlands tessellation map (100%)

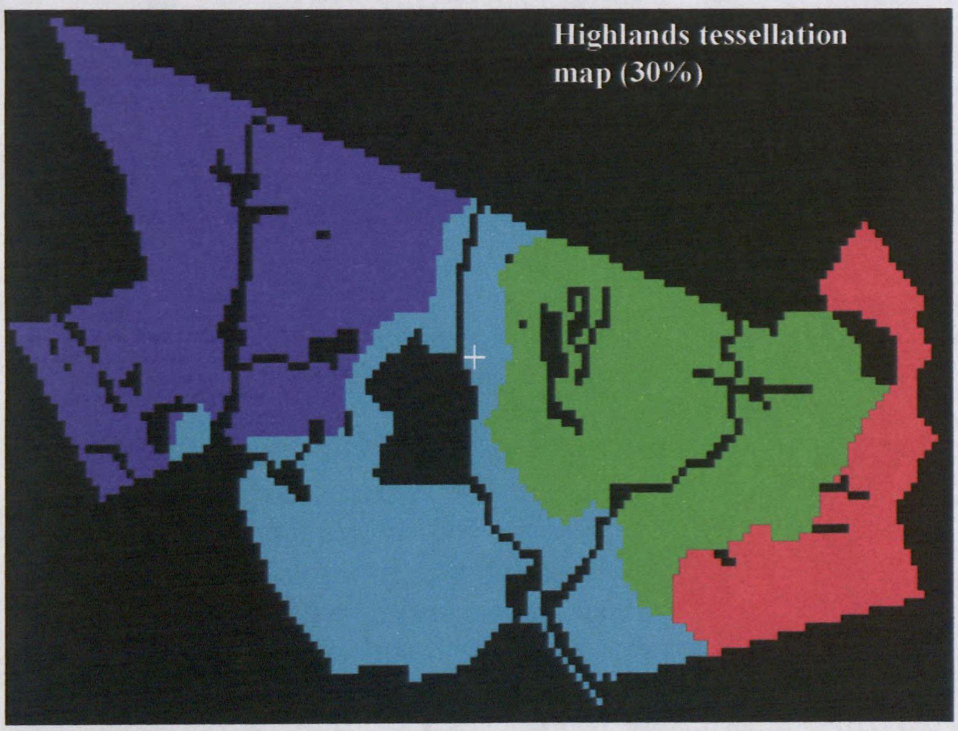

Highlands roads map
(50%)
Depot 1
Depot 2
Depot 3
Depot 4
Sink

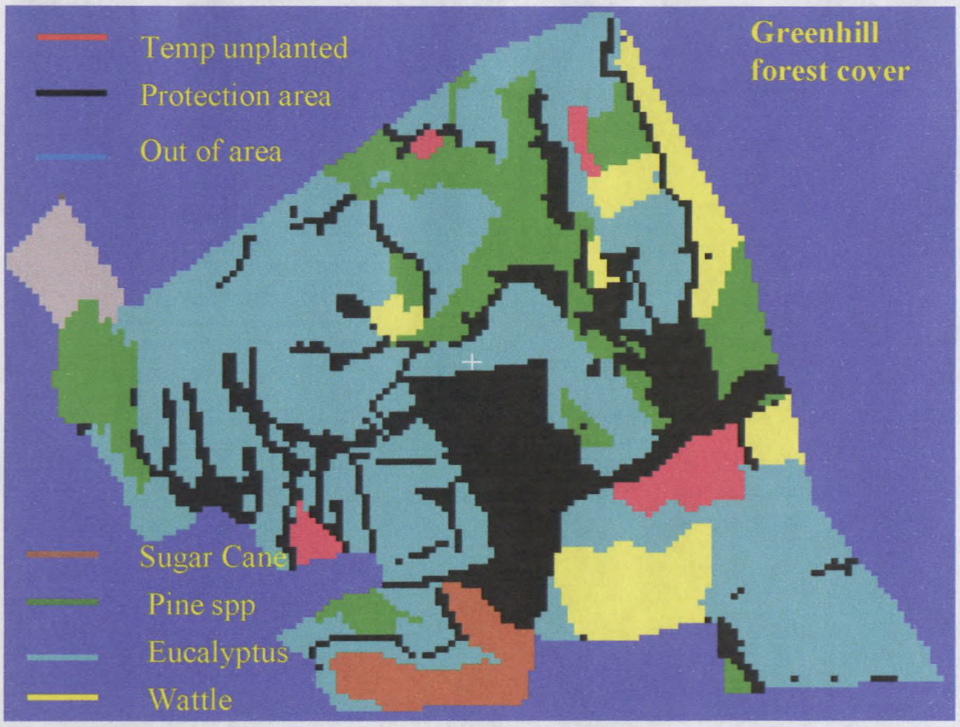

Highlands tessellation
map with roads 50%
Depot 1
Depot 2
Depot 3
Depot 4
Sink

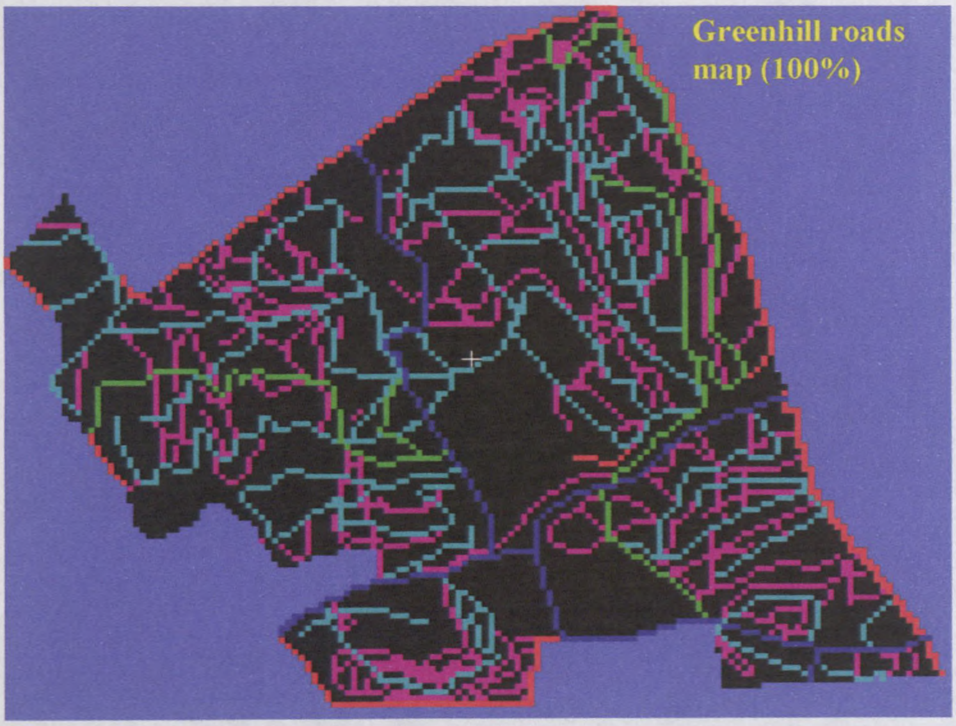

Highlands tessellation
map (50%)

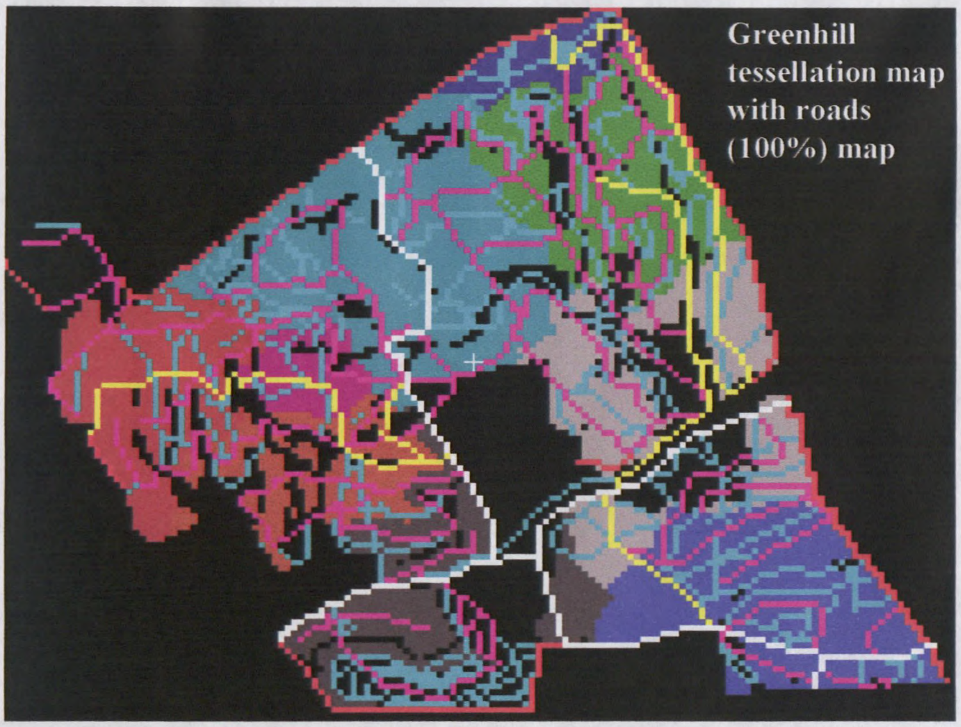

Highlands roads
map (30%)
Depot 1
Depot 2
Depot 3
Depot 4
Sink

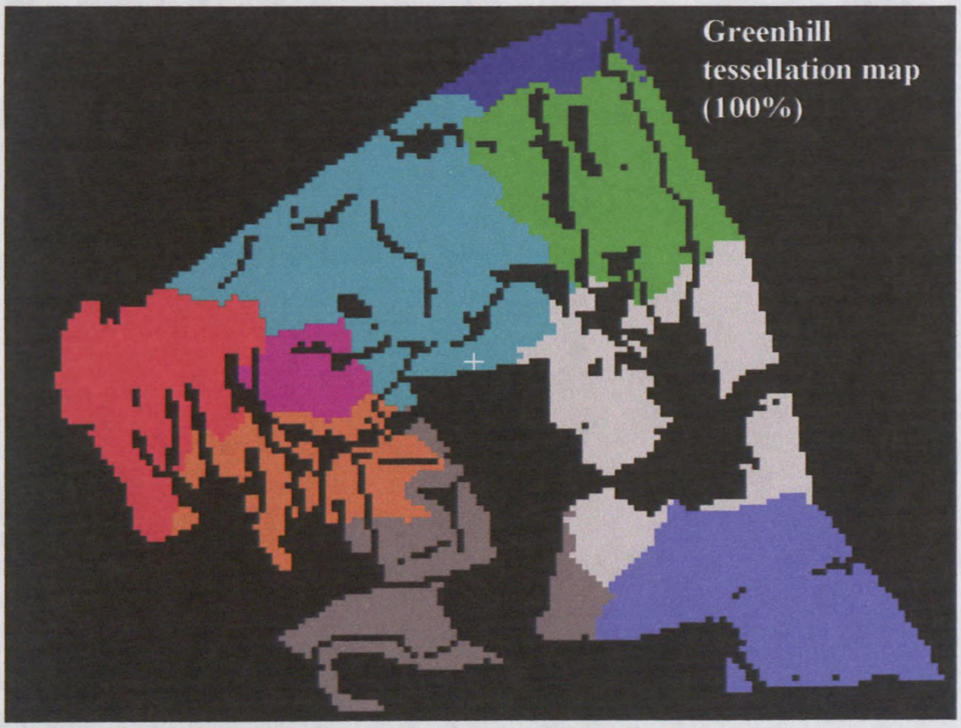

Highlands tessellation map with roads 30%
Depot 1
Depot 2
Depot 4
Sink
Depot 3

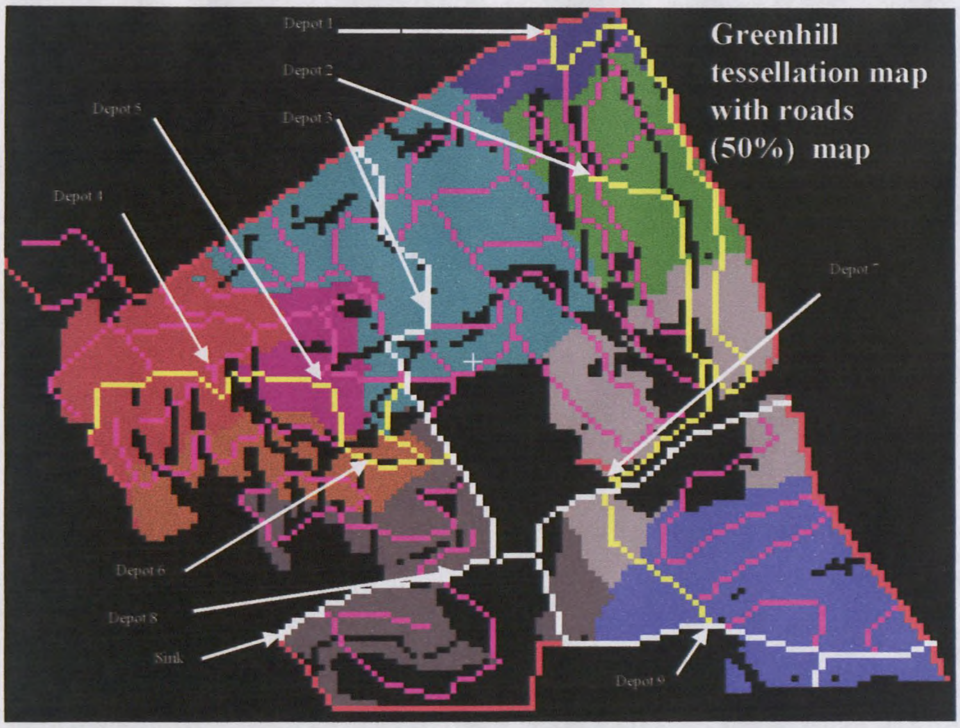

Highlands tessellation map (30%)


Temp unplanted
Protection area
Out of area
Greenhill
forest cover
Sugar Cane
Pine spp
Eucalyptus
Wattle

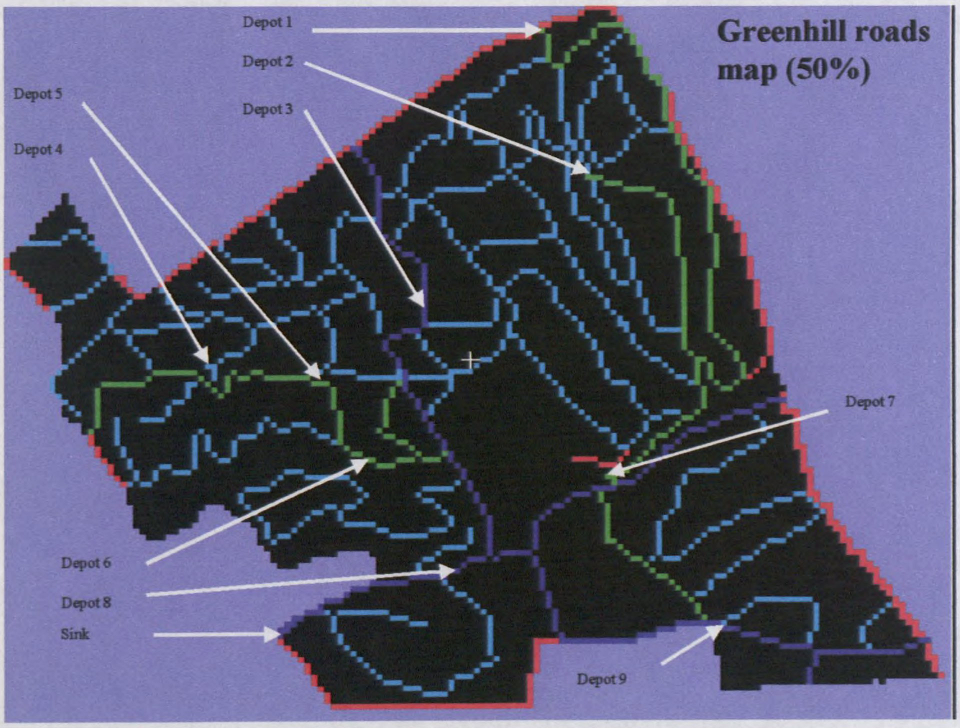

Greenhill roads
map (100%)


Greenhill
tessellation map
with roads
(100%) map

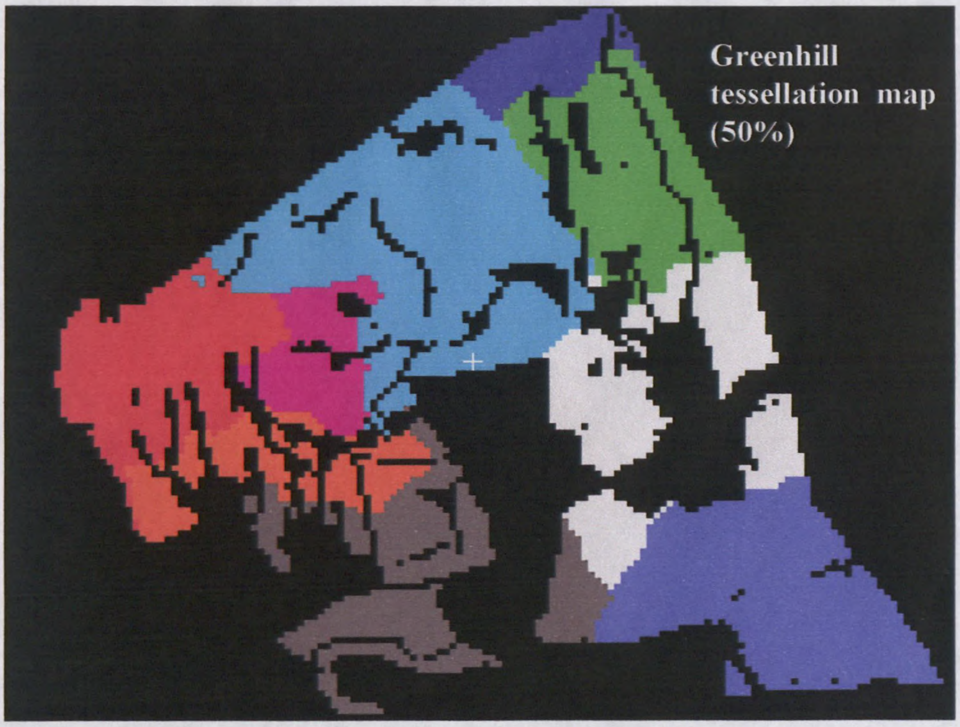

Greenhill
tessellation map
(100%)



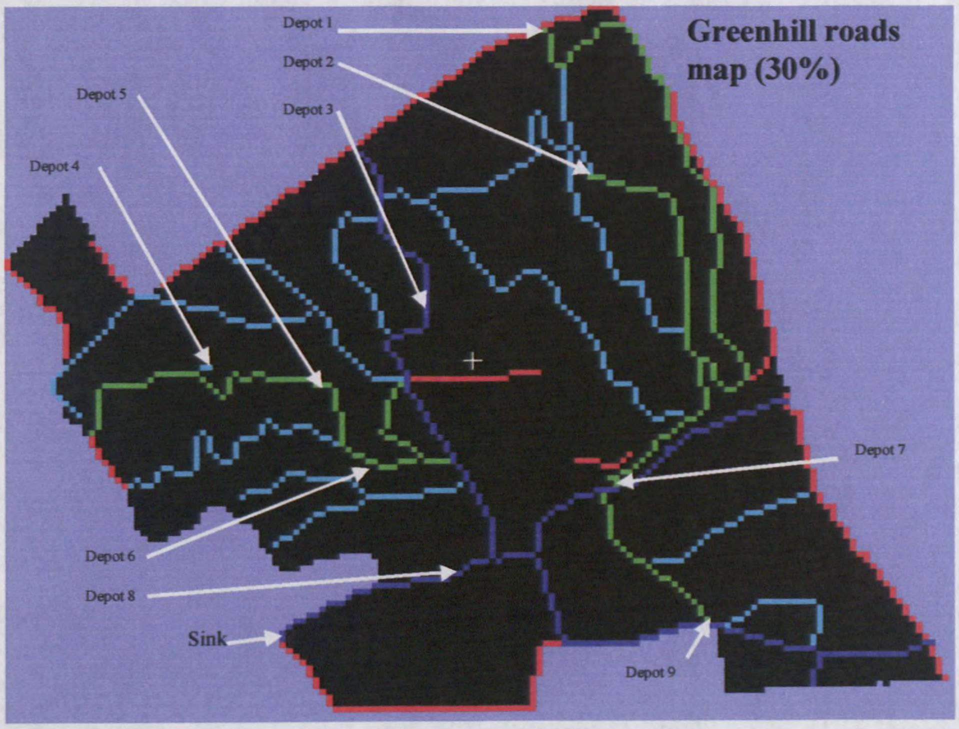
Greenhill tessellation map with roads (50%) map
Depot 1
Depot 2
Depot 5
Depot 3
Depot 4
Depot 7
Depot 6
Depot 8
Sink
Depot 9



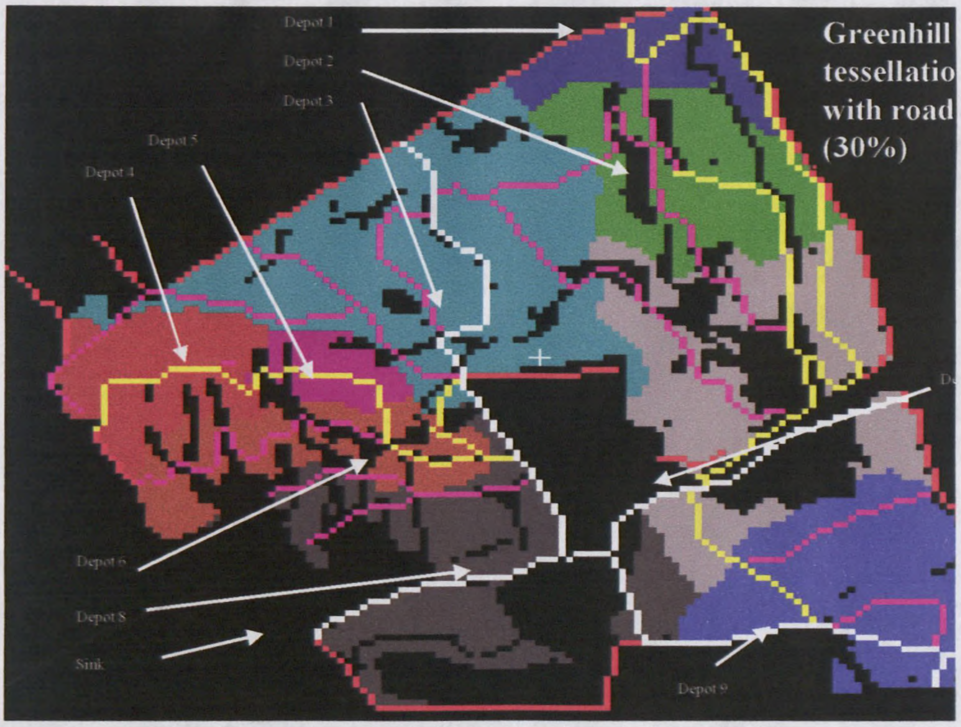
Greenhill roads map (50%)
Depot 1
Depot 2
Depot 5
Depot 3
Depot 4
Depot 7
Depot 6
Depot 8
Sink
Depot 9



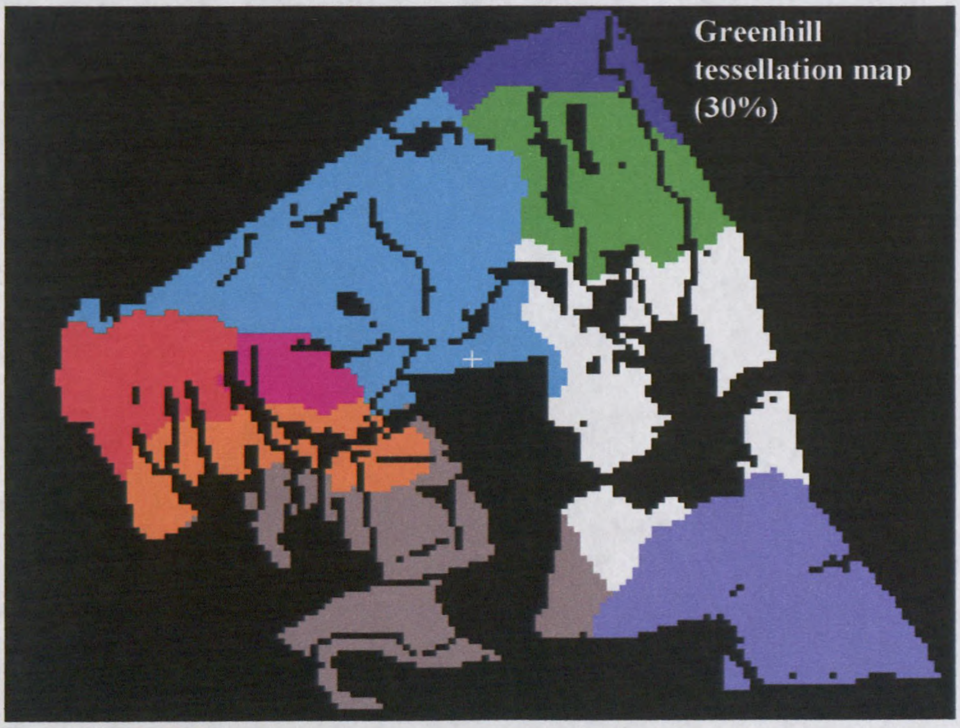
Greenhill tessellation map (50%)



Greenhill roads map (30%)
Depot 1
Depot 2
Depot 3
Depot 4
Depot 5
Depot 6
Depot 7
Depot 8
Depot 9
Sink



Greenhill
tessellatio
with road
(30%)
Depot 1
Depot 2
Depot 3
Depot 5
Depot 4
Depot 6
Depot 8
Sink
Depot 9



Greenhill
tessellation map
(30%)

Appendix G

Wood flow analysis to depots per plantation

- Uplands
- Highlands
- Greenhill

Uplands 1(100%)	1	2	3	4	5	Total
Volume (m^3)	1150.00	837.00	2258.00	749.00	2552.00	7546.00
Transport to depot (Rands)	5800.43	3489.50	9966.57	2448.95	14861.43	36566.88
Cost (R/m^3)	5.04	4.17	4.41	3.27	5.82	4.85
Transport to sink (Rands)	270.36	1406.39	5213.17	2918.33	7997.78	17806.03
Cost (R/m^3)	0.24	1.68	2.31	3.90	3.13	2.36
Total cost (Rands)	6070.79	4895.89	15179.74	5367.28	22859.21	54372.91
Total cost (R/m^3)	5.28	5.85	6.72	7.17	8.96	7.21

Uplands 2(100%)	1	2	3	4	5	Total
Volume (m^3)	1110.75	846.25	2205.75	801.50	2581.75	7546.00
Transport to depot (Rands)	5533.81	3547.25	9620.89	2774.67	15041.16	36517.78
Cost (R/m^3)	4.98	4.19	4.36	3.46	5.83	4.84
Transport to sink (Rands)	181.17	986.50	3533.07	2166.58	5613.34	12480.66
Cost (R/m^3)	0.16	1.17	1.60	2.70	2.17	1.65
Total cost (Rands)	5714.98	4533.75	13153.96	4941.25	20654.50	48998.44
Total cost (R/m^3)	5.15	5.36	5.96	6.17	8.00	6.49

Uplands 1(50%)	1	2	3	4	5	Total
Volume (m^3)	1002.75	958.75	2190.75	675.50	2718.25	7546.00
Transport to depot (Rands)	6293.12	5417.69	11623.16	2574.40	16931.61	42839.98
Cost (R/m^3)	6.28	5.65	5.31	3.81	6.23	5.68
Transport to sink (Rands)	235.74	1595.70	5023.04	2621.20	8475.53	17951.21
Cost (R/m^3)	0.24	1.66	2.29	3.88	3.12	2.38
Total cost (Rands)	6528.86	7013.39	16646.20	5195.60	25407.14	60791.19
Total cost (R/m^3)	6.51	7.32	7.60	7.69	9.35	8.06

Uplands 2(50%)	1	2	3	4	5	Total
Volume (m^3)	973.70	943.75	2197.25	700.00	2731.25	7545.95
Transport to depot (Rands)	6006.98	5406.96	11587.28	2740.11	16997.75	42739.08
Cost (R/m^3)	6.17	5.73	5.27	3.91	6.22	5.66
Transport to sink (Rands)	158.82	1089.74	3495.20	1884.48	5908.23	12536.47
Cost (R/m^3)	0.16	1.15	1.59	2.69	2.16	1.66
Total cost (Rands)	6165.80	6496.70	15082.48	4624.59	22905.98	55275.55
Total cost (R/m^3)	6.33	6.88	6.86	6.61	8.39	7.33

Uplands 1(30%)	1	2	3	4	5	Total
Volume (m^3)	1072.25	1480.25	1576.50	405.00	3012.00	7546.00
Transport to depot (Rands)	7063.82	9202.56	8706.62	1742.56	21996.85	48712.41
Cost (R/m^3)	6.59	6.22	5.52	4.30	7.30	6.46
Transport to sink (Rands)	252.08	2463.67	3589.57	1407.31	9261.71	16974.34
Cost (R/m^3)	0.24	1.66	2.28	3.47	3.07	2.25
Total cost (Rands)	7315.90	11666.23	12296.19	3149.87	31258.56	65686.75
Total cost (R/m^3)	6.82	7.88	7.80	7.78	10.38	8.70

Uplands 2(30%)	1	2	3	4	5	Total
Volume (m^3)	1037.75	1486.75	1577.75	405.25	3038.50	7546.00
Transport to depot (Rands)	6693.67	9346.73	8690.51	1724.28	22165.07	48620.26
Cost (R/m^3)	6.45	6.29	5.51	4.25	7.29	6.44
Transport to sink (Rands)	169.26	1716.74	2492.33	1086.51	6539.33	12004.17
Cost (R/m^3)	0.16	1.15	1.58	2.68	2.15	1.59
Total cost (Rands)	6862.93	11063.47	11182.84	2810.79	28704.40	60624.43
Total cost (R/m^3)	6.61	7.44	7.09	6.94	9.45	8.03

Greenhill 1(100%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	744.00	2080.75	4226.25	2131.50	735.00	1442.00	2431.75	2076.00	3205.25	19072.50
Transport to depot (Rands)	2300.75	7956.02	22735.16	10361.21	1703.30	6181.33	14200.55	8459.55	13717.45	87615.32
Cost (R/m^3)	3.09	3.82	5.38	4.86	2.32	4.29	5.84	4.07	4.28	4.59
Transport to sink (Rands)	4675.65	11500.89	10729.43	9748.90	2237.99	3661.96	4672.59	1798.95	7478.88	56505.24
Cost (R/m^3)	6.28	5.53	2.54	4.57	3.04	2.54	1.92	0.87	2.33	2.96
Total cost (Rands)	6976.40	19456.91	33464.59	20110.11	3941.29	9843.29	18873.14	10258.50	21196.33	144120.56
Total cost (R/m^3)	9.38	9.35	7.92	9.43	5.36	6.83	7.76	4.94	6.61	7.56

Greenhill 2(100%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	806.00	2517.75	3616.75	2625.00	808.50	1424.50	2197.25	1842.50	3237.25	19075.50
Transport to depot (Rands)	2690.37	10741.40	18368.32	12921.88	1925.82	5484.27	12018.20	7289.72	13872.78	85312.76
Cost (R/m^3)	3.34	4.27	5.08	4.92	2.38	3.85	5.47	3.96	4.29	4.47
Transport to sink (Rands)	2960.90	7977.02	6303.16	6217.97	1340.56	1816.34	2956.67	1142.15	5381.48	36096.25
Cost (R/m^3)	3.67	3.17	1.74	2.37	1.66	1.28	1.35	0.62	1.66	1.89
Total cost (Rands)	5651.27	18718.42	24671.48	19139.85	3266.38	7300.61	14974.87	8431.87	19254.26	121409.01
Total cost (R/m^3)	7.01	7.43	6.82	7.29	4.04	5.13	6.82	4.58	5.95	6.36

Greenhill 1(50%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	798.75	1681.25	4254.75	2107.00	1064.00	1260.00	2102.00	2433.50	3371.25	19072.50
Transport to depot (Rands)	2566.61	6781.75	22984.83	9946.52	3472.07	8306.51	12665.16	13473.92	16389.08	96586.45
Cost (R/m^3)	3.21	4.03	5.40	4.72	3.26	6.59	6.03	5.54	4.86	5.06
Transport to sink (Rands)	4632.94	9301.25	10632.08	9132.55	3320.24	4346.45	4136.07	2174.35	8130.21	55806.14
Cost (R/m^3)	5.80	5.53	2.50	4.33	3.12	3.45	1.97	0.89	2.41	2.93
Total cost (Rands)	7199.55	16083.00	33616.91	19079.07	6792.31	12652.96	16801.23	15648.27	24519.29	152392.59
Total cost (R/m^3)	9.01	9.57	7.90	9.06	6.38	10.04	7.99	6.43	7.27	7.99

Greenhill 2(50%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	937.00	2115.25	3778.00	2336.25	1034.50	1324.75	1871.50	2273.50	3401.75	19072.50
Transport to depot (Rands)	3311.86	9487.31	19369.38	11589.88	3337.28	8361.61	10443.43	12186.41	16556.05	94643.21
Cost (R/m^3)	3.53	4.49	5.13	4.96	3.23	6.31	5.58	5.36	4.87	4.96
Transport to sink (Rands)	3251.10	6677.27	6549.75	5877.47	2010.34	2748.83	2515.19	1409.32	5670.45	36709.72
Cost (R/m^3)	3.47	3.16	1.73	2.52	1.94	2.07	1.34	0.62	1.67	1.92
Total cost (Rands)	6562.96	16164.58	25919.13	17467.35	5347.62	11110.44	12958.62	13595.73	22226.50	131352.93
Total cost (R/m^3)	7.00	7.64	6.86	7.48	5.17	8.39	6.92	5.98	6.53	6.89

Greenhill 1(30%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	946.75	1644.25	4782.75	1324.75	602.00	1384.25	2498.00	2589.50	3300.25	19072.50
Transport to depot (Rands)	4285.33	8795.55	33529.06	6779.81	1845.63	8946.32	18687.47	16109.16	19100.09	118078.42
Cost (R/m^3)	4.53	5.35	7.01	5.12	3.07	6.46	7.48	6.22	5.79	6.19
Transport to sink (Rands)	6239.59	9520.52	11925.80	6357.04	1973.14	3159.61	4796.00	2190.09	7801.41	53963.20
Cost (R/m^3)	6.59	5.79	2.49	4.80	3.28	2.28	1.92	0.85	2.36	2.83
Total cost (Rands)	10524.92	18316.07	45454.86	13136.85	3818.77	12105.93	23483.47	18299.25	26901.50	172041.62
Total cost (R/m^3)	11.12	11.14	9.50	9.92	6.34	8.75	9.40	7.07	8.15	9.02

Greenhill 2 (30%)	1	2	3	4	5	6	7	8	9	Total
Volume (m^3)	1029.25	2072.00	4480.00	1554.00	679.00	1289.25	2165.75	2461.00	3345.25	19075.50
Transport to depot (Rands)	4988.89	12169.72	30449.07	8742.99	2162.18	7747.21	15210.72	15303.63	19327.46	116101.87
Cost (R/m^3)	4.85	5.87	6.80	5.63	3.18	6.01	7.02	6.22	5.78	6.09
Transport to sink (Rands)	3841.12	6472.11	7531.50	4041.36	1280.85	1826.84	2838.90	1444.03	5465.46	34742.17
Cost (R/m^3)	792.46	1101.93	1108.12	718.32	402.23	304.01	404.21	232.22	945.98	5708.13
Total cost (Rands)	8830.01	18641.83	37980.57	12784.35	3443.03	9574.05	18049.62	16747.66	24792.92	150844.04
Total cost (R/m^3)	8.58	9.00	8.48	8.23	5.07	7.43	8.33	6.81	7.41	7.91

Highland 1(100%)	1	2	3	4	Total
Volume (m^3)	5203.50	4453.00	1984.75	4446.50	16087.75
Transport to depot (Rands)	34507.59	23074.01	9188.53	34360.40	101130.53
Cost (R/m^3)	6.63	5.18	4.63	7.73	6.29
Transport to sink (Rands)	17993.41	9941.13	5798.81	1740.46	35473.81
Cost (R/m^3)	3.46	2.23	2.92	0.39	2.21
Total cost (Rands)	52501.00	33015.14	14987.34	36100.86	136604.34
Total cost (R/m^3)	10.09	7.41	7.55	8.12	8.49

Highlands 2(100%)	1	2	3	4	Total
Volume (m^3)	5857.50	5306.75	2129.00	2794.50	16087.75
Transport to depot (Rands)	40180.10	29946.17	10025.10	17828.65	97980.02
Cost (R/m^3)	6.86	5.64	4.71	6.38	6.09
Transport to sink (Rands)	14052.35	5974.66	2850.93	741.53	23619.47
Cost (R/m^3)	2.40	1.13	1.34	0.27	1.47
Total cost (Rands)	54232.45	35920.83	12876.03	18570.18	121599.49
Total cost (R/m^3)	9.26	6.77	6.05	6.65	7.56

Highlands 1(50%)	1	2	3	4	Total
Volume (m^3)	5285.50	3558.25	1811.25	5432.75	16087.75
Transport to depot (Rands)	35113.10	19092.15	8841.36	43448.48	106495.09
Cost (R/m^3)	6.64	5.37	4.88	8.00	6.62
Transport to sink (Rands)	18276.96	7806.26	4682.06	2126.50	32891.78
Cost (R/m^3)	3.46	2.19	2.58	0.39	2.04
Total cost (Rands)	53390.06	26898.41	13523.42	45574.98	139386.87
Total cost (R/m^3)	10.10	7.56	7.47	8.39	8.66

Highlands 2(50%)	1	2	3	4	Total
Volume (m^3)	5882.00	4943.25	1917.25	3345.25	16087.75
Transport to depot (Rands)	40215.60	28883.78	9441.73	24240.65	102781.76
Cost (R/m^3)	6.84	5.84	4.92	7.25	6.39
Transport to sink (Rands)	14111.12	5503.23	2222.95	887.67	22724.97
Cost (R/m^3)	2.40	1.11	1.16	0.27	1.41
Total cost (Rands)	54326.72	34387.01	11664.68	25128.32	125506.73
Total cost (R/m^3)	9.24	6.96	6.08	7.51	7.80

Highlands 1(30%)	1	2	3	4	Total
Volume (m^3)	5451.00	4580.75	3980.25	2075.75	16087.75
Transport to depot (Rands)	43301.58	29312.36	33423.26	12187.93	118225.13
Cost (R/m^3)	7.94	6.40	8.40	5.87	7.35
Transport to sink (Rands)	18936.01	10480.89	1525.58	3944.95	34887.43
Cost (R/m^3)	3.47	2.29	0.38	1.90	2.17
Total cost (Rands)	62237.59	39793.25	34948.84	16132.88	153112.56
Total cost (R/m^3)	11.42	8.69	8.78	7.77	9.52

Highlands 2(30%)	1	2	3	4	Total
Volume (m^3)	5717.50	5469.75	2824.25	2076.25	16087.75
Transport to depot (Rands)	45766.42	38165.91	20229.05	12152.47	116313.85
Cost (R/m^3)	8.00	6.98	7.16	5.85	7.23
Transport to sink (Rands)	13779.61	6346.93	783.52	1942.43	22852.49
Cost (R/m^3)	2.41	1.16	0.28	0.94	1.42
Total cost (Rands)	59546.03	44512.84	21012.57	14094.90	139166.34
Total cost (R/m^3)	10.41	8.14	7.44	6.79	8.65