An evaluation of the socio-economic impact of timber production with and without the inclusion of biomass energy production

By

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DECLARATION

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ABSTRACT

The discussion on climate change is leading to a re-evaluation of tree plantations in South Africa; prompting the adoption of forest bioenergy system as one of the cost effective 'carbon mitigation options'. In an analysis of this changing paradigm, emphasis was placed on the socio-economic aspects of integrated commercial tree plantations and forest bioenergy systems with special attention to harvest residues recovery for bioelectricity production and construction and operation of a bioelectricity plant. The study also explored the direct and indirect benefits that adjacent communities derive from tree plantations in South Africa in order to determine the potential impact of integrated timber and bioelectricity production on rural livelihood and conventional forestry operations.

Structured questionnaires and in-depth interviews were used in randomly sampling twelve villages on Mondi tree plantations in the Piet Retief and Iswepe areas of South Africa. Six villages from each area were selected; and a systematic random sampling of ten households per village was carried out. The possibility of using harvest residues from final clear felling from these plantations for bioelectricity production was examined. The study developed and described a scenario for a five megawatt bioelectricity generation facility, requiring an annual volume of 19,569.85 dry tonnes of residues as feedstock for its operation.

The study revealed that adjacent rural communities to Mondi plantations in Piet Retief and Iswepe areas enjoy direct benefits such as employment opportunities, utilization of harvest residues, utilization of non-timber resources, and free accommodation. Indirect benefits that these communities enjoy include: free farmland and graze-land and various social benefits. Issues of concern and dislike such as: lack of electricity; poor health and sanitation and transportation problems were also identified.

Using NPV and IRR, the study estimated the economic impacts of integrated pulpwood and bioelectricity production, compared to conventional pulpwood production operation. The study concluded that integrated pulpwood and harvest residue recovery for

bioelectricity production is a profitable means of producing renewable energy. The approach was found to increase the profitability of conventional forest operations.

OPSOMMING

Besprekings rondom klimaatsverandering lei tot ‘n her-evaluasie van boom plantasies in Suid Afrika wat aanleiding gee tot die aanvaarding van bio-energie stelsels as een van die koste effektiewe “koolstof versagtende opsies”. In ‘n ontleding van hierdie paradigma verandering, is klem geplaas op die sosio-ekonomiese aspekte van die integrasie van boom plantasies en bos bio-energie stelsels. Spesiale aandag is gegee aan onginningsafval herwinning vir bio-energie produksie en die konstruksie en werking van ‘n bio-elektriese kragsentrale. Die studie ondersoek ook die direkte en indirekte voordele wat gemeenskappe, aangrensend aan boom plantasies in Suid Afrika verkry, om sodoende die potensiële effek van geintegreerde hout en bio-elektriese produksie op landelike lewensbestaan en konvensionele bosbou operasies te bepaal.

Gestruktureerde vraelyste en indiepte onderhoude is gebruik om ‘n lukraakte steekproef van twaalf dorpies op Mondi boom plantasies in die Piet Retief en Iswepe areas van Suid Afrika uit te voer. Ses dorpies in elke area is gekies en ‘n sistematiese lukraakte steekproef van tien huishoudings per dorpie is uitgevoer. Die moontlikheid om ontginningsafval van finale kaalkap van hierdie plantasies vir bio-elektrisiteit te gebruik is ook ondersoek. Die studie het ‘n senario ontwikkel en beskryf van ‘n vyf megawatt bio-elektriese kragsentrale wat ‘n jaarlikse volume van 11,708 droë ton ontginningsafval benodig as voermateriaal vir kragopwekking.

Die studie het getoon dat aangrensende landelike gemeenskappe langs Mondi plantasies in die Piet Retief en Iswepe areas direkte voordele soos werksgeleenthede, gebruik van ontginningsafval, gebruik van nie-hout hulpbronne en gratis akkommodasie geniet. Indirekte voordele wat gemeenskappe geniet sluit in gratis toegang to landbou grond en weiding, sowel as sosiale voordele. Probleemfaktore waarmee hulle saamleef is ‘n gebrek aan elektrisiteit, swak gesondheids en sanitasie dienste en vervoerprobleme.

Deur die gebruik van NPV en IRR analitiese metodes is die ekonomiese impak van geintegreerde pulphout en bio-elektrisiteits produksie bepaal en vergelyk met

konfensionele pulphout produksie. Die gevolgtrekking is dat geintegreerde pulphout en ontginningsafval herwinning vir bio-elektrisiteit produksie ‘n winsgewende manier van hernubare energie produksie is. Die benadering kan die winsgewendheid van konfensionele bosbou operasies verbeter.

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CHAPTER ONE

1.0 INTRODUCTION

Forest plantations are key resources, able to help satisfy many human wants, including material needs such as wood and paper; environmental needs such as protection against soil erosion and mitigation of climate change; and socio-economic needs such as employment, wealth creation, and recreation (Richardson, 2005).

Several studies (Ham and Theron, 2001; Shackleton, 2004 and Chamberlain *et al.*, 2005) have illustrated the historical dependency of humans on plantation resources. Rural households are often involved in harvesting, collecting, processing, consuming and selling plantation forest products to complement outputs from agricultural activities. For some households tree plantations-based income generating activities can be a major source of income. Tree plantations also provide a reserve of products upon which people can fall back on for subsistence and income in times of hardships, for example crop failure or unemployment (Arnold 1998 in Maduekwe, 2008).

Global trends and issues have proved to be a significant factor in decision making concerning forest plantation management objectives. Current debate centred on climate change and energy security forms part of the major global challenge that is currently shaping the forest industry. Among the forest based climate change mitigation strategy being promoted, biomass energy is becoming one of the most commonly used renewable sources of energy. It is such a widely utilized source of energy, probably due to its low cost and indigenous nature, that it accounts for almost 15% of the world's total energy supply and as much as 35% in developing countries, mostly for cooking and heating. Although tree plantations have "considerable promise" in supplying an energy source, "actual commercial use of plantation-grown fuels for power generation is limited to a few isolated experiences" (Alternative Energy, 2009).

1.1 ENERGY CRISIS AND FORESTRY

Energy plays a vital role in socio–economic development and raising standards of human beings. Energy is seen as the pivot of economic and social development all around the world. Energy source and consumption level is often used as the criterion to indicate the economic and social development level of a region. In rural areas of developing countries, energy usage (or more so the lack of energy) is often coupled with serious socio-economic problems (Guozhu *et al.*, 2008).

While energy security still remains a concern, the potential threat of global climate change resulting from the use of fossil fuels adds new urgency to the development of alternative energy systems (Daniel *et al.*, 2000). Increased consumption of fossil fuels has been the subject of ongoing debate centred especially around the destructive effects on the atmosphere of increased use, leading to greenhouse gas emissions, global warming and subsequent climate change (UN-Energy, 2007).

Unstable and unpredictable oil prices have complicated economic planning around the world; oil imports now consume a large and unsustainable share of the meagre foreign exchange earnings of many poor nations, in some cases offsetting any gains from recent foreign debt elimination agreements. Yet many of these same countries have substantial forestry bases well suited for biofuel production. Some of these countries even have the potential to become net exporters of biofuels (UN-Energy, 2007).

Forest bioenergy therefore present an opportunity to meet the enormous growing energy demand and hopefully to reduce the energy crisis effect. Questions include: What will be the role of the forestry sector in South Africa in the country's long run approach to bioenergy development? What share of the South African bioenergy sector can forest plantations supply on an economic competitive level? How can forest bioenergy sustainably contribute to poverty alleviation in South Africa?

An opportunity exists to explore the impact that bioenergy production will have on the forestry industry and the communities who are dependent on plantations for their livelihoods. This is based on an example of forest use and potential bioenergy production from forest plantations owned and managed by Mondi in the Iswepe and Piet Retief areas of the Mpumalanga Province, South Africa. This research will evaluate the socio-economic impact of using residues from these plantations for bioenergy production as well as the financial feasibility of incorporating bioenergy production into forestry operations.

1.2 PROBLEM STATEMENT/RESEARCH QUESTIONS

The production of bioelectricity presents an income opportunity for forest owners including small land-holders. However, large scale production of bioelectricity may require economies of scale to be profitable, which may displace vulnerable households if land tenure is insecure. Though employment opportunities may be available, labour rights and conditions may not be of an acceptable high standard and the trend to mechanize the production process could reduce employment opportunities (FAO, 2008a).

Creating a successful forest bioenergy business entails maximizing the benefits along the supply chain to stakeholders. Doing this will require a good understanding of the socio-economic implications of forest bioenergy production and utilization (Mayaki, 2008).
Given the range of interactions, the potential benefits and costs of investments in bioenergy should be assessed on a case-by-case or country-by-country basis (Guozhu *et al.,* 2008).

Plantation residues are typically low value products whose profitability is based on low production costs. Incorporating residue recovery cost into production cost of conventional products (timber), as well as ensuring its social acceptability and sustainability will thus help in increasing the profitability of producing electricity from plantation residues (Puttock, 1995). Utilizing plantation residue for bioelectricity may, however, pose a threat to dependent rural communities. The cost of doing so may make it unattractive for the company.

If forest bioenergy is to find a significant and secure place in South Africa's energy sector it must offer demonstrable benefits to the triple bottom line of environment, economics and community that make them a preferred choice for future energy needs. A thorough social and economic cost benefit analysis that will not only assess the economic efficiency of the project but also its social acceptability as well as account for all non-market impacts is therefore necessary in order to determine the suitability of this approach (woody biomass utilization) to the South African condition. This study therefore aims at investigating the profitability of utilizing plantation residue for bioelectricity production by addressing the following three questions:

1. What are the direct and indirect benefits that adjacent communities derive from forestry operations and from harvest residue utilization?
2. How will the integration of a bioenergy plant (biomass cogeneration) in the value chain affect forest dependent communities and the profitability of conventional forestry operations?
3. Is it financially viable for a forestry company to utilize forest residue for bio-electricity generation?

1.3 CHAPTER LAYOUT

This study is divided into eight chapters. Chapter one is the introductory chapter, chapter two, three, and four present a literature review of the socioeconomics impacts of plantation forestry, a review of the socioeconomics impacts of forest bioenergy systems and a review of the economic and financial aspects of forest bioenergy systems, respectively. Chapter five focuses on the methodological approach for this work. Chapter six presents the results from the study. Chapter seven presents the discussion of the results and chapter eight presents the conclusion and recommendations based on the findings of this work.

CHAPTER TWO

2.0 SOCIOECONOMIC IMPACT OF PLANTATION FORESTRY

This chapter takes a critical review of existing literature on the socio-economic costs and benefits of plantation forestry. The emphasis of this review is on the impact of plantation forestry on rural livelihoods. The social considerations of forestry projects is brought out in discussions of issues such as public participation in decision making, values and attitudes of citizens, and employment in poor, rural areas (Bill & Ryan, 2004).

2.1 INTRODUCTION

Forests and forest products add to the well-being and, at times, the very survival of millions of rural poor in South Africa. Shackleton *et al.* (2007) identified the following range of woody plant resources used by rural communities: fuelwood, charcoal, fodder for livestock, mulch/compost, and construction timber (poles for houses, kraals, and fences).

Fuelwood constitutes one of the largest forest product uses in South Africa. More than 80% of rural households still use fuelwood as a primary source of energy. Approximately 13 million m^3 of fuelwood is supplied from indigenous forests, savannas and plantation off-cuts annually (Lewis *et al.,* 2005a). Fuelwood consumption per household in the Kentani area of the Eastern Cape was for example estimated at 3,700 kg per annum in 2000 (Ham, 2000) while fuelwood usage has been estimated to have a gross national value of approximately R3 billion per annum (Shackleton *et al.,* 2004).

Plantation forestry provides the raw material for downstream activities such as pulp milling, paper manufacturing, sawmilling and furniture manufacturing and can thus be regarded as the root of the value chain of forestry, timber, pulp and paper industries in South Africa (Chamberlain *et al.,* 2005). Forest plantations also offer numerous benefits to adjacent communities and society at large in South Africa. Such benefits include consumptive resources, spiritual and aesthetic needs, employment, and ecological services such as carbon sequestration and water provision (Shackleton *et al.*, 2007).

The plantation sector provides a range of types of employment. These include full-time, part time and casual/seasonal employment. Key types of full-time employment include employment in plantation management and various types of contracting businesses. In fact, a large proportion of contractors appear to work full-time, including many employees working for nurseries, spraying contractors, earth moving and fencing contractors and harvesting contractors (Chamberlain *et al.*, 2005).

In 2007, forestry in South Africa (FSA, 2008):

- Contributed R5,167.0 million to National GDP and forest product contributed R18.4 billion to National GDP;
- Directly employed about 76,844 people;
- Export of forest product earned foreign exchange to the value of about R12.2 billion;
- Contributed substantially to the income of rural households through at least 31,500 small growers and about 7,875 small grower employees;
- Provided a livelihood directly and indirectly (through the dependency of others on the income earners named above) to an estimated 2.3 million South Africans.

2.2 SOCO-ECONOMIC BENEFITS OF PLANTATION FORESTRY IN SOUTH AFRICA

From the socio-economic perspective, plantation forestry provides large volumes of wood at low prices to meet the demand of the pulp and construction industries, generates revenue and foreign exchange for national governments, provides jobs and opportunities for local residents and provides residues and by-product left behind after harvesting for fuelwood or timber (Charnley, 2005).

Forest resources were ranked as a high contributor to livelihood by 60% of households consulted during ranking exercises in the Eastern Cape Province of South Africa. Forest resources generally contribute between one sixth and one quarter of total livelihood income streams (Ntshona, 2002 in Lewis *et al.,* 2005a). The five highest-ranking benefits that households obtain from forests are (Anon 2003 in Lewis *et al.,* 2005a):

- ❖ Fuelwood;
- ❖ Medicinal plants;
- ❖ Animal fodder;
- ❖ Construction timber;
- ❖ Craft materials.

Plantation woodlots were observed to provide neighbouring communities with poles and firewood. The supply of poles from these woodlots was for instance observed to be about 8,334 poles per woodlot per month in the Kentani area of the Eastern Cape Province in 1998 (Ham, 2000). It was estimated that a rural household could use up to 185 large poles per annum for household construction and fencing (Shackleton *et al.,* 2007).

It was also observed that woodlots help to reduce the exploitation of the indigenous forests for poles and fuelwood (Ham, 2000). The harvesting of specific types of poles (species and sizes) can have a significant impact on natural forest ecology with the eradication of certain age classes of high demand species (Lewis *et al.*, 2005a).

Plantation woodlots were reported to also provide various categories of job opportunity to rural people. Apart from direct job opportunities for workers involved in the management of these woodlots, it also provides indirect jobs to timber merchants who are involved in bulk buying and selling of poles (Ham, 2000).

A number of benefits other than income and employment for local communities are also attributed to the forestry sector. Forestry plantations are an integral part of the rural landscape where a combination of plantations, community settlements and other agricultural activities form a mosaic of land uses (Lewis *et al.,* 2005a).

The provision of housing in rural areas for employees of forestry companies is inextricably linked with the provision of other services and amenities required by communities. The larger forestry companies provide pre- and primary schools and clinics in areas where they have a concentration of employees (Shackleton *et al.*, 2007).

2.3 SOCIO-ECONOMIC COSTS OF PLANTATION FORESTS

While there are many benefits arising from goods and services attributed to forests and plantations, there are also many costs associated with forests and plantations that are often borne by poor rural communities neighbouring on forest and plantation area.
Examples of these include (Lewis *et al.*, 2005a):

- Losses resulting from run-away forest fires;
- Damage to crops by wild animals and livestock living in forest and plantation areas;
- Conflict over land for non-agricultural activities;
- Noise and air pollution associated with certain plantation activities (e.g. felling, fires, etc.);
- Increasing threats to security attributed to criminal elements taking refuge in forests and plantations.

Timber growing either on commercial plantations estates or small grower holdings competes with other rural land uses such as cattle grazing. Conflicts have occurred in particular within communities where tribal authorities have allocated large tracts of land for forestry. These conflicts were found to occur between timber farmers, pastoralists and the youth, who fear that unutilized land for future households would disappear (Cairns, 2000).

In Chile commercial tree plantations surrounding rural communities have been observed to cause considerable decrease in water courses, aridity in soils and extermination of a great number of medicinal species. In many zones and as a consequence of spraying from the air to control organisms affecting the plantations, water is polluted and impacts are felt on fruit trees, medicinal plants that have managed to survive and on crops. Many animals, birds and insects that maintained the ecological balance have also disappeared. All this has caused disorders in the health of people and domestic animals, leading to a serious deterioration of the economies of surrounding communities (Mella, 2005).

The majority of forest areas in South Africa are located within the rural areas where forestry plays an important role in the creation of economic activities (Shackleton, 2004). Within these areas, however, high levels of poverty are found despite the presence of forest plantations and industries (Lewis *et al.*, 2003). Though it can be argued that people living in forestry areas are not richer than in other non-forested areas, without forestry they might have been far worse off (Lewis *et al.*, 2005a).

Forest Companies in South Africa are faced with diverse socio-economic challenges. Mondi Forests for instance is confronted with the challenge of having 40% of its plantation area under land claim; with 20,000 squatters occupying forest land; and HIV/AIDS infection rates being around 35% among its workforce (Mayers, 2006; Cairns, 2000). Any forestry decisions will have to consider the impact on communities and people living adjacent to forestry areas.

2.4 ROLES OF FOREST INCOME IN RURAL LIVELIHOODS

Forest related income forms an important part of rural income in many poor regions Vedeld *et al.* (2004) have distinguished three different functions of forest income in rural livelihood:

- **Safety nets:** Forest products are used to overcome unexpected income shortfalls or cash needs.
- **Support of current consumption:** Forest products are important to maintain the current level of consumption and prevent the household from falling into (deeper) poverty. This role would largely correspond with the term “coping strategy.” Three distinct functions of forest income can be identified under this role. They are highlighted in Table 2.1 below.

- **A pathway out of poverty:** Forest products provide a way to increase household income sustainably (poverty reduction) either through a “stepping out” strategy (accumulation of capital to move into other activities) or a “stepping up” strategy (intensification and specialization in existing activities). Again, three different sets of activities can be distinguished. They are highlighted in Table 2.1 below.

These three roles are interlinked, and particular products can serve the three functions simultaneously (Vedeld *et al.,* 2004). These three functions of forest income in rural livelihood strategy are summarized in Table 2.1 below.

Table 2.1 Direct roles of forests in household livelihood strategies

Poverty functions	Function	Description
Safety net	Insurance	Food and cash income in periods of unexpected food and income shortfall.
Support current consumption	Gap-filling	Regular (seasonal, for example) shortfall of food and income.
	Regular subsistence uses	Fuelwood, wild meat, medicinal plants, etc.
	Low-return cash activities	A wide range of extractive or “soft management” activities, normally in economies with low market integration.
Poverty reduction	Diversified forest strategies	Forest activities that are maintained in economies with high market integration.
	Specialized forest strategies	Forest activities that form the majority of the cash income in local economies with high market integration.
	Diversified economy	Forest activities are maintained even in situations with a high degree of market integration.

Source: Vedeld *et al.*, 2004

2.5 PLANTATION FORESTRY AND JOB CREATION

Forest plantations often generate high levels of employment during tree establishment and harvest, with little in between. There may be high employment benefits where plantations replace degraded or unused land, or where alternative agricultural employment is low, or where rotation cycles require continuous replanting, maintenance and harvesting (Mayers, 2006).

The number of jobs created by plantations seems to be in the order of one to three jobs per 100 ha of plantation (Cossalter and Pye-Smith, 2003 in Mayers, 2006). In New Zealand, forest plantations employ four and half times as much labour per hectare as agriculture (Aldwell and Whyte, 1984). However, these jobs may displace other jobs from the land. They are also concentrated where processing facilities are located (Mayers, 2006).

In early years of plantation establishment, the majority of employment is generated via establishment of new areas of plantation. Employment per hectare as plantation resources are being established therefore fluctuates largely as a result of variations in the area of new plantations established. It is only when plantations reach maturity and a cycle of harvest and replanting occurs that a more steady level of employment per hectare is generated (Mayers, 2006).

Plantation industries have often been charged with perpetuating low-wage labour and poor conditions of employment, and some communities have been locked into dependency. Whilst these problems reflect wider socio-economic conditions and cannot be laid at the feet of plantation companies alone, some companies certainly recognize that they face pressing challenges. For example, managers within Mondi state the need for the company to do more in developing decent jobs, and long-term relationships with contractors and small-grower suppliers (Mayers, 2006).

The plantation industry is no exception to the global business trend to outsource all but company core business. Over the last fifteen years in South Africa, for example, the industry has outsourced the majority of its operations to contractors – resulting in some 300 forestry contractors employing more than 35,000 workers countrywide. A recent study noted that a 60-70% decrease in wages accompanied this shift to outsourcing, later somewhat improved by installation of minimum wage legislation (Clarke & Isaacs, 2005).

The creation of employment and business opportunities within forestry areas is probably the most significant contribution that forestry could make towards the upliftment of livelihoods. It is estimated that the South African forest industry employs approximately 151,000 full-time staff of which 46,000 work in forests and a further 106,000 in the processing sector. It is estimated that each job in the forestry sector creates four others in supporting industries, thus increasing the contribution of forestry to 600,000 jobs (Madula, 2004 in Lewis *et al.*, 2005a).

Within the formal forestry sector most of the larger companies and their sub-contractors comply with minimum wage levels for forestry set by government, as well as other employee benefits advocated by the labour law. It is also estimated that 63% of plantation workers are housed in company housing, which are serviced with water, sanitation and electricity. The capital investment of this housing is in the region of R320 million in current terms. The maintenance and servicing of these houses generate downstream jobs and benefits not linked directly to forestry (Shackleton *et al.*, 2007).

2.5.1 Outgrowing and company community partnerships

While the majority of plantation resources remain under corporate ownership, various forms of out-grower schemes are assuming greater importance in plantation expansion in many regions (Mayers, 2006).

In South Africa, out-grower schemes involve about 12,000 smallholder *Eucalyptus* growers on about 27,000 hectares of land. These schemes have contributed substantially to household income, providing participating households with an annual income of about US$130 per hectare – averaging about 20% of the income needed to be just over the national "abject poverty line" (Mayers, 2006).

The South African out-grower schemes have been available to even the poorest and most labour deficient of smallholders, because of the credit extended by companies, while non-landowners have benefited in some areas through employment as weeding, tending, harvesting or transport contractors to the landed smallholders. But smallholders have weak bargaining power with respect to the companies and face problems of opaque government policy and unco-ordinated service provision from agencies of national and local government. These schemes are yet to take households out of poverty (Mayers, 2006).

Cairns (2000) carried out quantitative studies of small grower timber schemes to determine reasons why new timber growers join the schemes. He found the following reasons:

- To obtain cash income at harvest - trees seen as a form of savings (some respondents mentioned that trees are better than cattle in this regard);
- To obtain the annual payments;
- To obtain fuel and sell wood to neighbours;
- To secure their rights over unutilized land;
- Ease of management compared with food crops;
- Reliability of yield;

- Persuaded by an extension officer or neighbours;
- Land was not suitable for other crops.

Securing of land tenure is another benefit that attracts people to timber out-grower schemes. This is particularly important for widows whose rights to land become insecure after the death of their husbands. The timber out-grower schemes were also found to be a major provider of credit through company-community loan arrangements in the areas where they operate (Cairns, 2000).

SAPPI operates grower associations in the areas where they operate. The grower associations function mainly to facilitate administration of the schemes (co-ordinate meetings and training days). In some cases they distribute advance payment cheques and assist companies to allocate the small-growers' quota among members and non-members (Cairns, 2000).

2.6 SOCIAL CONFLICTS IN FORESTRY PROJECTS

With all that has been said and discussed about the benefits and costs of forest plantations, there has been also considerable public comment on the possible desirable and undesirable social effects of forestry development.

In New Zealand, where commercial forestry is seen by the rural community as a threat to the established rural lifestyle which has its basis in agriculture, employment patterns of forest establishment resulted in depopulation of the farming community. Workers employed by the forest companies have not had a stake in the community arrangements such as family-owned farms (Farnsworth, 1983). Forestry tends to contravene a number of the values and norms by which life is organized within New Zealand rural communities. The following four conflict factors illustrate this (Smith and Wilson, 1980 in Farnsworth, 1983):

- Forestry as a large-scale land user immediately transgresses the traditional position of privately owned packets of land.
- Forestry introduces a new style of work that implies greater routine and less flexibility.
- There is a tendency for local political elite to be sensitive to new business and the different sort of professional being brought into the region by forestry.
- Forestry is seen to promote a loss of autonomy in local decision-making.

Social conflicts have been reported in the timber out-grower scheme as practised in South Africa. Various forms of conflicts were reported, these include (Cairns, 2000):

- Unwillingness to participate in the timber out-grower schemes by communities living in the area surrounding Richards' Bay as a result of their suspicions of the schemes as being a ploy on behalf of the companies to steal their land.
- In some communities plantations are seen especially by women as providing safe havens for thugs and criminals.
- Other conflicts associated with tree plantations in South Africa are centred on grazing rights and boundary disputes.

Case studies from the southern United States, South America, and Australia indicate that when plantations are established on private land, land ownership becomes concentrated in the hands of fewer people. Large landowners often benefit from this process. However, small landowners and landless are often displaced and move away (Charnley, 2005).

2.7 CONCLUSION

Forestry and forest industries play a critical role in sustaining the livelihood of rural communities, adjacent to plantations. Forestry is also a major contributor to the National GDP. Forest plantations are mostly located in the rural areas and are thus well positioned to support the livelihood of rural host communities. Forest products play a critical role in reducing the expenditure of rural communities while plantations provide numerous benefits to adjacent communities and society at large in South Africa (Shackleton *et al.,* 2007).

Though forestry provides a host of benefits to both the adjacent communities and national economy, it has some tradeoffs which are not very pleasing, especially to the host community. Forestry has often been charged with perpetuating rural poverty in areas where it operates, but rural poverty cannot be blamed solely on forestry as there are many factors that cause rural poverty. Forestry however has been found to help support the livelihood of rural poor people.

Forest management objectives in South Africa often change in response to global trends and issues in forestry. The challenge now facing the forest sector in South Africa is to meet the needs for wood and non-wood products and at the same time fulfil demands for environmental and social services from forests. Efforts to find an acceptable balance between production and protection and between use and conservation drive much of the debate surrounding the forest sector today in South Africa (FAO, 2008a).

Current debate on climate change and energy security forms part of the major global challenge that is currently shaping the forest industry. Climate change issues and energy security has the potential to greatly influence plantation management objectives. The next chapter takes a critical look at the socio-economic impact of forest bioenergy production in South Africa.

CHAPTER THREE

3.0 SOCIO-ECONOMIC IMPACT OF FOREST BIOENERGY

The previous chapter focused on the socio-economic impact of plantations. Plantations can potentially play an important role in bioenergy systems but the impact of such bioenergy systems on rural livelihoods is not always well defined. This second part of the literature review explores the socio-economic impact of forest bioenergy systems.

3.1 INTRODUCTION

Access by the general populace to forests for gathering woody biomass continues to be an important issue. About half of the global consumption of biomass fuels is for simple, small-scale, domestic cooking and home heating use in developing economies. Individual households and small rural communities depend on this fuel for their survival (EECA, 2007).

The transition towards forest bioenergy is a complex process of change that impacts on a large number of socio-economic factors. Well integrated forest bioenergy systems offer unique opportunities to boost the livelihoods of some of the world's poorest people and create a whole new development paradigm, centred on energy security, environmental sustainability, strengthened income and food security and more equitable socio-economic relations (BKC, 2009a).

The magnitude of the socio-economic impact of forest bioenergy systems depends on many things, including the final energy product produced, the quantity and quality of the feedstock under management, the nature of technologies available, and the production processes undertaken by the various bioenergy industry partners. The local economic structure, social profile, and engagement in trade with outside economies will also affect the ultimate impact (Hubbard *et al.*, 2007).

A case study from east Texas in the United States (US) illustrates the potential economic impacts of the utilization of logging residues for electricity production at the local level. There are about 1.47 million dry tonnes of collectable logging residues in the area annually, which could generate 1.44 terra watt hours (TWh) of electricity. This production would create as many as 1,340 jobs (570 jobs from logging residue procurement and 770 jobs from electricity production). These jobs would represent about 32.5 percent of the current logging employment in the area (Hubbard *et al.*, 2007). The United States study also shows that the output and value-added multipliers were smaller than the employment multiplier, meaning that the bioenergy project would have a stronger ripple effect on employment than on output. This is extremely crucial to rural areas like east Texas, looking for employment and economic development opportunities to sustain the prosperity of local economies (Hubbard *et al.*, 2007).

A similar employment ripple effect could be experienced in South Africa if the 6.7 million tonnes of waste material generated as a by-product of the 18 million tonnes of timber produced per annum can replace an estimated 1 million tonnes of coal per annum (Dobson, 2008).

3.2 OPPORTUNITIES FOR THE EXPANSION OF FOREST BIOENERGY SYSTEMS IN SOUTH AFRICA

There are significant opportunities for expansion of the forest bioenergy industry in South Africa based on distributed electricity generation and production of liquid fuels (ethanol, methanol and bio-oil). If the large amounts of forest residues already available annually could be utilized, this would deliver useful greenhouse benefits, assist regeneration of new forests that have increased environmental values, and benefit silvicultural management (Raison, 2006).

Creation of new forests in low rainfall environments for both environmental and commercial reasons will also provide residues in the future that could be used for energy production, thus enhancing overall viability of such ventures (Raison, 2006). Forest bioenergy could, potentially, encompass the use of forest residues (biofuel) for (Raison, 2006):

- Combustion and the production of heat and electricity;
- Production of liquid fuels (ethanol, methanol, and bio-oil);
- Production of hydrogen and other fuels that could be utilized in fuel cells (still very much emerging technology).

At this time, use of wood for heating and electricity generation is well developed globally and offers the best current potential for expanded forest bioenergy in South Africa. South Africa's energy needs are largely met by cheap fossil fuels (coal), so there is a relative lack of economic incentives to develop renewable energy sources. However, there is widespread recognition of the positive contribution that renewable energy can make to greenhouse gas abatement by substituting for fossil fuels in energy production (Raison, 2006).

3.3 DIRECT AND INDIRECT BENEFITS OF FOREST BIOENERGY DEPLOYMENT

Several studies have explored the benefits and costs of bioenergy development in different parts of the world. These indirect benefits/costs can generally be classified into two categories: environmental and socio-economic benefits or costs (Gan and Smith, 2007).

Though energy from forest biomass is generally not cost competitive with fossil fuels under current technology and market conditions in some countries (e.g. Netherlands), the production of forest biomass and bioenergy will produce a variety of socioeconomic benefits. Whereas these benefits vary from case to case, some noticeable ones include, among others, creation of jobs and income via the development of a new industry and the utilization of locally produced raw materials (Gan and Smith, 2007).

Silvicultural benefits such as increased opportunities for thinnings, intermediate cuttings, and stand and site rehabilitation have been identified to be associated with biomass production from conventional forests (Manley and Richardson, 1995 in Gan and Smith, 2007). The transformation process of forest biomass to bioenergy also qualifies as market tradable carbon credits from reducing greenhouse gas emissions, as green credits for generating electricity using renewable resources, and other government 'tax incentives'/'subsidies'. It has been suggested that co-products from transforming biomass will make bioenergy economically viable even in the absence of carbon credits/subsidies (CFR, 2004).

Woody biomass utilization can help improve forest restoration activities by using and creating markets for small-diameter material and low-valued trees removed from forest restoration activities, while at the same time helping to promote sustainable energy development (Rural Voices for Conservation, 2005). Related social issues such as community cohesion, employment, rural development, waste avoidance and health benefits can be of equal importance.

3.4 SOCIO-ECONOMIC IMPACT OF FOREST BIOENERGY SYSTEMS

Developing a forest bioenergy industry can have a number of positive effects on the rural economies of South Africa such as employment, tax-base, rural infrastructure and economic diversification (FAO/GBEP, 2007). Generating bioenergy from forest resources has an employment rate much higher than other renewable resources and has a lower investment cost for job creation; it also creates a hundred times more jobs than what results from adopting wind or solar thermal heating and 1,000 more jobs than with adopting photovoltaic systems (CFR, 2004; Domac, 2002).

A modest sized production plant that produced ethanol (plant capacity 15 million gal/yr) would create approximately 28 new jobs directly, with an additional 53-100 employees needed to collect and transport material to the plant. A softwood ethanol plant in Ketchikan, Alaska (capacity of 27 million litres/year) was estimated to provide 40 permanent year round jobs (QLG, 1997).

To revitalize rural economies will require the development of new economic opportunities. New economic options in rural areas can be produced from the collection of forest biomass materials of current low economic value (thinned materials, harvest residues, etc.) and converting these materials to higher quality products (i.e. bioenergy products) (CFR, 2004).

The rural areas are ideally suited to contribute to the development of new economic opportunities based on forest bioenergy systems because of (CFR, 2004):

- ❖ The significant amount of material that is available with high fire hazard when not managed and;
- ❖ It is difficult and expensive to provide electricity in rural areas because of their greater distances from centralized energy production systems.

Bioenergy developments have the potential of making energy available to rural populations with limited access to other energy sources, and this can promote economic development. The living conditions of poor households would be improved if bioenergy development led to a more efficient and sustainable use of traditional biomass (UN-Energy, 2007).

Bioenergy development is expected to benefit the community through job creation, infusing income to local households and accruing tax revenues to local communities (tax revenue from bioenergy projects will enable government to provide facilities for communities). The increase in household income will raise the standard of living. The tax revenues will help improve local infrastructures, public services or systems including utility supplies, roads, and public transportation, telecommunications, schools, etc.

Providing job opportunities for individuals, particularly younger residents, will allow them to remain in the community rather than migrate out in search of quality employment elsewhere, thus preventing aging of the community. All these will enhance social coherence, community stability, and the quality of life (IEA Task 29, 2008).

Provision of adequate, clean and affordable energy to rural residents is essential for eradicating poverty, improving human welfare and raising living standards worldwide. Sustainable energy in rural development, with wide utilization of renewable energy technologies, is capable of helping realize the UN Millennium Development Goals (MDG1: eradicate extreme poverty and hunger; and MDG7: ensure environmental sustainability) (Gan and Smith, 2007).

The essence of sustainability from a social aspect is how biomass production is perceived by society, and how different societies benefit from biomass production (Hall, 2002). Woody biomass utilization is a critical factor in development and poverty alleviation. The social sustainability of expanding woody biomass utilization will be determined in part by the ability of modern bioenergy markets to extend into poor communities in developing nations, in order to revitalize rural economies, which are often set back due to unreliable energy services (FAO/GBEP, 2007).

There are, however, many variables which determine whether the expansion of bioenergy has a net positive or a net negative impact on livelihoods. When small-scale farmers have the opportunity to produce biomass independently or through out-grower schemes, there may be net benefits. But there is a history of disputes. In Indonesia, the establishment of large palm oil plantations has been associated with alleged land grabbing and human rights abuses (Greenfacts, 2009a).

Social conflicts can be provoked by the introduction of large energy plantations supplying centralized conversion facilities. Conversion facilities should be located close to biofuel production sites to reduce transport costs and increase economic viability. It is possible that such arrangements could result in increased concentration of landownership and displacement of traditional farmers. With effective local planning, however, structures involving farmers as out-growers can be developed, resulting in opportunities for smallholder investment (Greenfacts, 2009b).

Forest dwelling or indigenous communities' livelihoods are put at high risk by the repercussions of large-scale bioenergy plantations which include deforestation and the loss of biodiversity. A prerequisite for the large-scale production and trade of biomass (biotrade) has thus been established to include that production and trade is beneficial with respect to the social well-being of the people, the ecosystem (planet) and the economy (profit) (Smeets *et al.,* 2005).

The following social criteria for sustainable biofuels value chain in developing countries have been identified (Brent and Wise 2008):

- Priority for food supply and food security for the export region's people;
- Avoiding health impacts for energy crop cultivation;
- Instead of displacement, integration of landless persons in energy cropping systems and subsequent local processing of the crops;
- Preservation and development of jobs in rural areas;
- Inclusion of local people in the distribution of economic revenue from bio-energy and;
- Participation of local people in decision.

From the social perspective there can be little doubt that bioenergy projects protect existing employment, provide new jobs, give learning opportunities, transfer skills, introduce new skills, and provide training and educational opportunities. The trend towards independent power production using smaller scale plants and embedded generation should result in a decline in urban drift once rural communities are able to develop and grow using the new sources of available bioenergy (Ralph and Keith, 2004).

3.5 BENEFITS OF WOOD WASTE UTILIZATION FOR BIOENERGY

Woody biomass for bioenergy conversion can be obtained from a diverse and widespread resource base which includes low value forest products such as logging residues and thinning of overstocked stands. These materials are left on-site, piled, and burned at additional cost, or left on-site for decomposition and incorporation into soil nutrients. As pressure for green energy develops, there has been strong interest in utilizing this material for bioenergy conversion (Perlack *et al.,* 2005 in Gustavo *et al.,* 2008).

Co-firing systems have demonstrated that combining coal and biomass for electricity generation increases boiler efficiency, reduces fuel costs, and significantly decreases emissions of nitrates and fossil carbon. Typically, the same power plants that generate renewable electricity also yield useful steam and heat (Dembira, 2003 in Gustavo *et al.,* 2008). It is expected that the combined share of biomass and other non-hydropower renewable electricity globally for the next 30 years will increase from 2.2 to 4.3 percent of total generation (Gustavo *et al.,* 2008).

If timber growers can access a market for the low-grade materials, especially the wood waste obtained from thinning operations, the income from selling that wood will help pay for the operations to be completed. By completing the thinning operations at the appropriate time in the life cycle of a plantation, it is possible to implement a highly efficient, timber production system and maintain the health and vitality of the plantation (NAFI, 2007).

By utilizing wood waste to produce renewable energy, the forest and timber industry can provide significant economic and social benefits while improving the health of forests to deliver a permanent reduction in carbon emissions without any negative impacts on ecosystem integrity or biodiversity (NAFI, 2007). However, there are also several characteristics (accessibility, stock density, etc.) of plantations/forests that could theoretically lead to under-utilization of the resources from a social cost-benefit perspective (Andersen, 1998).

There is a common public perception that cutting down trees and burning wood is bad because wood burning appears visibly more polluting than gas or oil and trees are inherently good for the environment by, for example, absorbing carbon dioxide. Further work is thus needed to inform the public and shift public attitudes towards using wood as a fuel from sustainably managed sources if this technology is to become an acceptable local alternative to oil and gas (Scrutiny Committee, 2005).

3.6 POTENTIAL NEGATIVE IMPACTS OF FOREST BIOENERGY SYSTEMS

There are challenges to overcome before the full potential of forest bioenergy can be realized. A number of problems associated with biofuel production, especially regarding large-scale operations, have been highlighted by the Food and Agriculture Organization (FAO). In order to minimize bioenergy development strategy risks, it is important to fully analyze the different aspects of bioenergy and wood energy development. The critical aspects of forest bioenergy development as identified by FAO (2008b) include:

- Rural development, equity and poverty reduction;
- Land and forest management, and biodiversity;
- Food and forest product prices;
- Greenhouse gas emissions and air quality;
- Water availability;
- Energy prices and energy dependence.

Potential negative impacts of bioenergy as presented by FAO are outlined below:

- Reduced local food availability if energy crop plantations replace subsistence farmland;
- Increased food prices for consumers;
- Demand for land for energy crops may increase deforestation, reduce biodiversity and increase greenhouse gas emissions;

- ❖ Increased number of pollutants;
- ❖ Modifications to requirements for vehicles and fuel infrastructures;
- ❖ Higher fuel production costs;
- ❖ Increased wood removals leading to the degradation of forest ecosystems;
- ❖ Displacement of small farmers and concentration of land tenure and income;
- ❖ Reduced soil quality and fertility from intensive cultivation of bioenergy crops;
- ❖ Distortion of subsidies on other sectors and creation of inequities across countries.

The impacts (both positive and negative) of bioenergy systems are shaped by the location and management. Establishing sustainable bioenergy systems requires attention to several issues, including the design of bioenergy systems that are carbon neutral, the implementation of sustainable practices when utilizing agriculture residues and forest residues, and the control of emissions (McCormick, 2005).

Large bioenergy projects require extensive land area and can affect food security, social structures, biodiversity, the wood processing industry and the availability of wood products. To mitigate these impacts, land-use planning, consideration of policies in other sectors and effective governance are necessary. The involvement of all stakeholders when developing bioenergy strategies is also of great importance in balancing trade-offs between economic, social and environmental impacts and benefits (McCormick, 2005).

In a national strategy, it is important to consider potential carbon and energy efficiencies of forest and agriculture-based energy as well as cost-effectiveness and environmental performance. Planting trees can help mitigate climate change, combat erosion and restore ecosystems especially in degraded areas; but large-scale monoculture plantations can have negative impacts on soil and water resources (Greenfacts, 2009b).

3.7 CONCLUSION

In summary, production of woody biomass feedstock and bioenergy products could induce significant socio-economic impacts, particularly in terms of job and income creation. As such, development of forest bioenergy industries could serve as a catalyst for rural economic development. However, socio-economic impacts of biomass and bioenergy development are influenced by many factors and vary from project to project. It is imperative to perform a project-specific assessment to understand the actual impact (Hubbard *et al.,* 2007).

Under current market conditions, cost remains a major barrier to market penetration of forest bioenergy. Compared to the biomass produced from energy plantations and forest fuel reduction thinnings, logging residues appear less costly, particularly when using an integrated harvest system, which allows for cost sharing between timber harvest and residue procurement (Hubbard *et al.,* 2007).

The next chapter discusses the economics and financial aspect of forest bioenergy production. In particular, factors affecting the production cost of forest biomass and bioenergy will be highlighted as well as the costs and competitiveness of this alternative energy source in terms of feedstock and electricity (Hubbard *et al.,* 2007).

CHAPTER FOUR

4.0 FINANCIAL FEASIBILITY OF FOREST BIOENERGY

This last chapter of the literature review focuses on the economics and financial feasibility of forest bioenergy systems. Specifically the chapter explores the viability of bioelectricity generation from biomass and starts by explaining the technology chosen for bioelectricity generation in this study. The technologies for the primary conversion of biomass for electricity production are direct combustion, gasification, and pyrolysis. Gasification was chosen as the primary technology for this study.

4.1 GASIFICATION

Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of carbon monoxide (CO), hydrogen (H_2) and traces of methane (CH4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition) to generate electricity; can be used as substitute for furnace oil in direct heat applications; and can be used to produce, in an economically viable way, methanol – an extremely attractive chemical which is useful both as fuel for heat engines as well as chemical feedstock for industries (Bain *et al.,* 1998).

The production of these gases is by reaction of water vapour and carbon dioxide through a glowing layer of charcoal. Thus the key to gasifier design is to create conditions such that (Bain *et al.,* 1998):

- Biomass is reduced to charcoal and,
- Charcoal is converted at suitable temperature to produce CO and H_2.

A gasifier fuel can be classified as good or bad according to the following parameters (Bain *et al.,* 1998):

- Energy content of the fuel;
- Bulk density;
- Moisture content ;
- Dust content ;
- Tar content ;
- Ash and slagging characteristics.

4.2 VIABILITY OF FOREST RESIDUE RECOVERY FOR BIOENERGY

A biomass recovery industry cannot succeed without being integrated into the forest industry as a whole. The recovery of logging residue can be carried out with a number of different systems, depending on where the residue is made available and on whether the current operation planning can be aptly modified (Visser, Spinelli and Stampfer, 2007).

Efficient recovery of high quality in-forest residues depends on good communication between biofuel contractors, harvesting operators and harvest planners. There are several factors critical to producing a biofuel which include: good access to residue for on-highway truck and trailer units; high volumes of residue collected in one place; and dry and clean residue (BKC, 2009b).

In Sweden, Finland and Norway a significant proportion of their harvest is from ground-based systems, which are highly mechanized. These have in many areas had their work methods adjusted to leave the logging residue in piles (as opposed to spread out) to enhance the efficiency of the residue harvesting operation (Visser *et al.,* 2007). Three principal systems have been developed for harvesting these residues (Visser *et al.,* 2007):

- Extract to roadside with a forwarder, pile and cover, store, chip with a trailer mounted mobile chipper, transport to point of use;

- Pile in the cut-over, bale with purpose-built residue baler mounted on a forwarder, extract bales to roadside, store, transport bales to point of use, chip whole bales at point of use;
- Pile in the cut-over, store, chip with a chipper forwarder, tip into setout bins, transport bins to point of use.

The chipper forwarders/terrain chippers are reported to be losing favour, in part due to handling issues around getting the chipped residues from the forwarder on to a truck, and in part due to the low utilization and subsequently high cost of the chipper function. A large fixed installation chipper may operate at one-third of the cost of a mobile unit (EECA, 2007).

Much modelling and research has been done in assessing the efficiency of residue recovery systems. Those with the least handling that take the residues from the forest directly to the point of use were found to be the most efficient. In general there are five different production systems or flows that can be used. Intermediate handling and processing add cost. The following flows are the simplest and most efficient, depending on the specifics of the situation, including transport distances (EECA, 2007):

1. Raw residues transported directly from forest to the point of use and then processed;
2. Raw residues transported from forest via a central yard or accumulation point to the point of use and then processed;
3. Raw residues transported to a central yard for storage and/or processing; comminuted material transported to point of use;
4. Raw residues processed at source and transported via a central yard to a point of use;
5. Raw residues processed at source and transported directly to heating plant.

To improve the viability of using forest residues as a biofuel, various issues need to be addressed at harvest planning stages. Harvesting operations can affect forest residues in a variety of areas:

Access to residue: Planning is required for on-highway configured trucks and/or low-loaders to access residue piles. This access must be maintained for periods of up to 6 to 12 months following completion of harvesting operations (BKC, 2009b).

Storage of residue: Planning is required for either in-forest storage or residue removal to an alternative site. In-forest storage on dry, open ground can result in reduced moisture content, minimal dry matter losses and reduced cost of delivered energy (BKC, 2009b).

Residue location: There are three possible systems of residue location. They are (BKC, 2009b):

- **Landing residues:** Landing residues are the most cost effective residue for producing biofuels as they are already at roadside. Hauler apparatus tend to produce more residues and often have slash disposal issues which are mitigated by removal (BKC, 2009b).
- **Ground-based cutover:** Residues from a ground-based harvesting operation can be collected from the cutover by forwarders or bundlers. This will only be viable if the demand for biofuel increases, with an accompanying increase in value (BKC, 2009b).
- **Hauler cutover:** Collection of residues from steep hauler country is not currently viable or practical.

Log making systems: The volume and size distribution of residue is influenced by the type of log making being used: motor manual, computer optimized, or mechanized.

Computer optimized log making tends to produce more residues in longer sections than motor manual operations. Mechanized operations tend to produce more residues in more pieces than motor manual operations (BKC, 2009b). Segregation of different residue types (pulp or chip logs, stem sections and large branch pieces) is important and can enable separate processing of residue types into higher value products such as pulp chips (BKC, 2009b).

Crop factors: The nature of the crop can also have a marked influence on the volume of residues. Open grown crops with significant stem malformation will produce relatively high volumes of residue. A high quality crop, with well formed stems and limited branching will produce low volumes of residue (BKC, 2009b).

4.3 CONSIDERATIONS FOR FOREST BIOENERGY FACILITY ESTABLISHMENT

Bioenergy enterprises can be run either with used wood from the recycling industry and industry by-products or with wood obtained directly from forestry. Linking forest biomass to technology platforms in the energy sector is producing new markets (CFR, 2004).

There are a wide variety of biomass-to-energy conversion technologies with the capacity for utilizing wood waste. They include direct combustion, gasification, pyrolysis, biomass to ethanol, and chemical processes (e.g. transforming wood waste into bio-oil). The energy products that can be made from these processes consist of heat, electricity, steam, liquid fuels, gases, bio-oil, charcoal and other fuels such as pellets and briquettes (NAFI, 2005).

There will be major trade-offs to consider – the size of the renewable energy plants, the relative costs of capital for each of the renewable energy products, the efficiency of renewable energy generation and the nature of the wood waste resources. NAFI (2005) have established four questions that need to be answered when evaluating the potential to produce renewable energy from wood waste:

1. Is there a secure volume of wood waste available for renewable energy generation?
2. Is there a readily accessible distribution network for the renewable energy products generated?
3. Are there proven (low risk) technologies available to utilize the scale and type of wood waste available?
4. How do the costs of wood waste-derived energy products compare with other similar energy products in the marketplace?

4.4 KEY PARAMETERS FOR FINANCIAL ANALYSIS OF BIOMASS GASIFICATION

Before undertaking any financial analysis to assist the commercial benefit of a biomass gasification project, the following technical parameters needs to be considered (UNESCAP, 2003):

- Heat-to-power ratio;
- Quality of thermal energy needed;
- Electrical and thermal energy demand patterns;
- Fuel availability;
- Required system reliability;
- Local environmental regulations;
- Dependency on the local power grid;
- Option for exporting excess electricity to the grid or a third party, etc.

Gasification is considered viable only if all forms of energy produced have a higher value than the investment and operating costs incurred on the cogeneration facility. In some cases, the revenue generated from the sale of excess electricity and heat or the cost of availing stand-by connection should be included. More difficult to quantify are the indirect benefits that may accrue from the project, such as avoidance of economic losses associated with the disruption in grid power, and improvement in productivity and product quality (CRES, 2002).

Following are the major factors recommended by UNESCAP (2003) that need to be taken into consideration for economic evaluation of gasification projects:

1. Initial investment;
2. Operating and maintenance costs;
3. Fuel price;
4. Price of energy purchased and sold.

Initial investment is the major variable that includes many items in addition to the cost of the gasification equipment. This also includes the cost of pre-engineering and planning. Barring a few exceptional cases, the project facilitator would normally hire a consulting firm to carry out the technical feasibility of the project before identifying suitable alternatives that may be retained for economic analysis. If the gasification equipment needs to be imported, the prevailing taxes and duties should be added to the equipment cost (UNESCAP, 2003).

The operating and maintenance (O&M) cost will include all direct and indirect costs of operating and running the new cogeneration facility, such as servicing, equipment overhauls, replacement of parts, etc. Wages for additional personnel as well as their training needed for operating the new facility should be included in the O&M cost (CRES, 2002).

Fuel costs could form the largest component of the operating expenditures. The price of energy purchased and sold could be a complicating parameter. This may include the net value of electricity or thermal energy that is displaced as well as any excess electricity or thermal energy sold to the grid or a third party. A good understanding of the electric utility's tariff structure is important, which may include energy charge and capacity charge, time-of-use tariff, stand-by charges, electricity buy-back rates, etc. With regard to the fuel, provision should be made to account for electricity price escalation with time. This is particularly true where power utilities depend heavily on fuel in their power generation-mix (CRES, 2002).

4.5 SOURCE OF FINANCING OF GASIFICATION PROJECTS

Gasification systems are capital intensive projects and the sources of capital financing can be an important consideration in the investment analysis in which different sources may be used. It is important, therefore, to know the rate of return for each alternative. The sources of capital financing could be one of the following (CRES, 2002):

1. Self financing: capital generated from developer's own activities;
2. Borrowing: requiring certain equity and guarantee;
3. Leasing: ownership maintained by the leasing company;
4. Third-party financing: undertaken by an energy service company; and
5. Facility management: reduction of energy bill for user with zero capital risk.

4.6 TOOLS FOR FINANCIAL ANALYSIS OF GASIFICATION PROJECTS

Irrespective of whether the gasification project is a totally new facility or a retrofit of an existing operation, the project will materialize only if it is financially attractive. There are a number of financial indicators to measure the attractiveness of a project. Some indicators are used to compare several projects to decide which one is the best alternative (UNESCAP, 2003).

Commonly employed financial indicators for gasification feasibility study are the payback period (PBP), net present value (NPV), and internal rate of return (IRR). The easiest and basic measure of the financial attractiveness of a project is the payback period (PBP). It reflects the length of time required for a project to return its investment through the net income derived or net savings realized. It is the most widely employed quantitative method for evaluating the attractiveness of a gasification system (CRES, 2002).

The payback period gives an idea of the time frame necessary for the net energy cost saving (or cash benefits) to pay the total installation cost of a gasification system. It does not take into account the time value of money and the salvage value (CRES, 2002; Klemperer, 2003).

The net present value (NPV) of a stream of annual cash flows is the sum of discounted values of all cash inflows and outflows over a certain time period. For a gasification project, initial investment costs are assumed as cash outflows and net annual energy cost savings (or net annual benefits) are cash inflows (UNESCAP, 2003; Klemperer, 2003).

When different capacities of gasification systems are being compared, the net present value is an important financial parameter. The project that has the highest net present value would be chosen as the best alternative system (CRES, 2002).

In calculating the NPV for a gasification project, the total investment costs are taken as cash outflows, and cash inflows are the differences between the annual total cost of gasification systems and that of the conventional energy supplies (UNESCAP, 2003).

Investment decisions are based on the discussed financial indicators which are calculated from the cash flow streams. The cash flows are estimated based on a number of factors such as future costs, interest rates, fuel costs, expected investment levels, tax rates and so on. Thus changes in these parameters can drastically affect the financial indicators and investment decisions (CRES, 2002).

In summary, the assessment of the feasibility of a gasification project involves four distinct steps, as follows (CRES, 2002):

1. Analysis of the energy demand pattern (electricity, thermal energy);

2. Identification of the different technical options (considering technical constraints, equipment availability, space constraints, etc.);
3. Optimization of each technical option (overall efficiency, part load performance);
4. Financial analysis for selecting the best option (payback period, internal rate of return).

4.7 ECONOMIC AND FINANCIAL VIABILITY OF FOREST BIOENERGY SYSTEMS

Cost is a major barrier to market penetration of forest bioenergy. Research has compared the cost of delivered woody biomass with that of delivered coal on a per unit energy basis. The production cost of short-rotation woody crops in the United States of America was estimated to be about $52 (R399.49)/dry tonne, i.e. $10.80 (R82.97)/Megawatt hour [MWh], while the national average price of delivered coal was $5.32 (R40.87)/MWh in 2005. The average cost of delivered logging residues (at a maximum transport distance of about 100 km) was estimated at $28 (R215.11)/dry tonne [$5.80 (R44.56)/MWh] using the marginal cost method and $33 (R253.52)/dry tonne [$6.80 (R52.24)/MWh] using the full cost method (Hubbard *et al.,* 2007).

Under present conditions, economic factors seem to provide the strongest argument of considering gasification. Campbell *et al.* (2009) found that producing electricity instead of ethanol is a more efficient use of available farmland. After analyzing the energy produced by both ethanol and electricity production and their uses, the researchers found that bioelectricity is a better option, regardless of the types of energy crops (Hubbard *et al.,* 2007).

Viable forest bioenergy business requires that, the fuel processor (supplier) has both a good scale of operation and a reasonable continuity of work. The scale of work required for successful forest (residue recovery) bioenergy has been estimated by the New Zealand Bioenergy Knowledge Centre (BKC) to be in the order of 50,000 tonne per annum to make it viable to invest in a hogger capable of processing logging residues. In order to obtain the best fuel from the supplier, it was recommended that payment for the recovered residue should be by energy content (not mass) because mass is not necessarily directly linked to energy as it is with fuels such as diesel or coal (EECA, 2007). This will help in motivating the suppliers to supply high quality fuel with low moisture content.

4.8 CONCLUSION

Compared to the biomass produced from energy plantations and forest fuel reduction thinnings, logging residues appear less costly, particularly when using an integrated harvest system, which allows for cost sharing between timber harvest and residue procurement (Hubbard *et al.*, 2007).

The next chapter examines the methods and approach employed in this study in evaluating the social and economic impact of utilizing forest residue for bio-electricity generation. The chapter also examines the impact of integrated pulpwood and bioenergy production on both adjacent communities and forest company (Mondi). The economic impact analysis focused on profitability of bio-electricity generation via forest residue utilization, while the social impact analysis focused on the impact of the operation on forest dependent communities.

CHAPTER FIVE

5.0 RESEARCH DESIGN AND METHODOLOGY

"*Finding the most economical way of carrying out a task is determined by a systematic study of methods, materials, tools, and equipment used within a specific task. The objective of this is to maximize efficiency by finding the best way to link all factors to the economy of the task. This means considering the economy in monetary terms as well as the economy in motion, materials, tools and equipment involved in the work process*" (Jong, 1967).

This chapter contains a detailed description of the steps taken in this study in answering the research questions raised at the beginning of this work. The methods and assumptions employed in fulfilling the objectives of this study are also presented in this chapter.

5.1 SCOPE/LIMITATIONS

This study was carried out in two phases. The first phase was a baseline scenario study to evaluate the current direct and indirect benefits that adjacent rural communities are deriving from plantation forestry and an analysis to determine the current economic returns (benefit to the company) from plantation forestry. The second phase was a hypothetical study that evaluated the social and economic impact of integrated plantation forestry and bioenergy production on both the adjacent rural communities and Mondi.

The socio-economic impact assessment of harvest residue recovery was primarily focused on the assessment of the social impact of harvest residue utilization. Impacts on livelihood, employment/job creation and income generation were the dominant criteria used for this assessment.

The assessment of the socio-economic impact of biofuel facility establishment was based on a model and assumptions developed following discussions and interviews with experts in bio-energy production. The assessment was focused on estimation of economic return of such a facility to Mondi and its impact on adjacent communities via impact on employment/job creation and livelihood.

5.2 GENERAL DESCRIPTION OF MONDI

This study was carried out at Mondi Mkhondo. Mondi is an international producer of paper. Mondi Mkhondo controls approximately 75,000 hectares of land, and supplies pulpwood directly to the Mondi Packaging mills at Piet Retief. Mondi Mkhondo has an annual turnover of R284.7 million (US$43.8 million) and accounts for the direct employment of 4,041 people, and indirectly supporting 18,000 people in the district (MBP, 2005).

There are five Working Plan Units in this District namely:

- Amsterdam;
- The Bends;
- Zoar;
- BVM (Vrede and Mooihoek);
- TD (Tower Forest and Derby);

The survey was conducted in the Zoar and BVM (Iswepe and Piet Retief) working plan units (MBP, 2005). Annual pulpwood production from Mondi Piet Retief is presented in Table 5.1.

Table 5.1 Annual production of timber from Mondi plantations in Piet Retief

Wood product	**Associated wood product**
Product	**Output (tonnes per year)**
Wattle pulp	100,000
Mining timber	60,000
Gum pulpwood	768,000
Pine pulpwood	151,000

Source: MBP, 2005

5.3 GENERAL DESCRIPTION OF COMMUNITIES WITHIN MONDI PROPERTY

There are approximately 80 villages within Mondi's Mkhondo property (these comprise of three areas namely: Amsterdam, Piet Retief and Iswepe), with a total of 18,000 people residing within them. These communities are almost exclusively black, and are largely impoverished. They are characterized by low-income levels; low levels of education; a high rate of unemployment; lack of access to basic infrastructure; and limited basic health care, and high levels of HIV/AIDS infection (MBP, 2005).

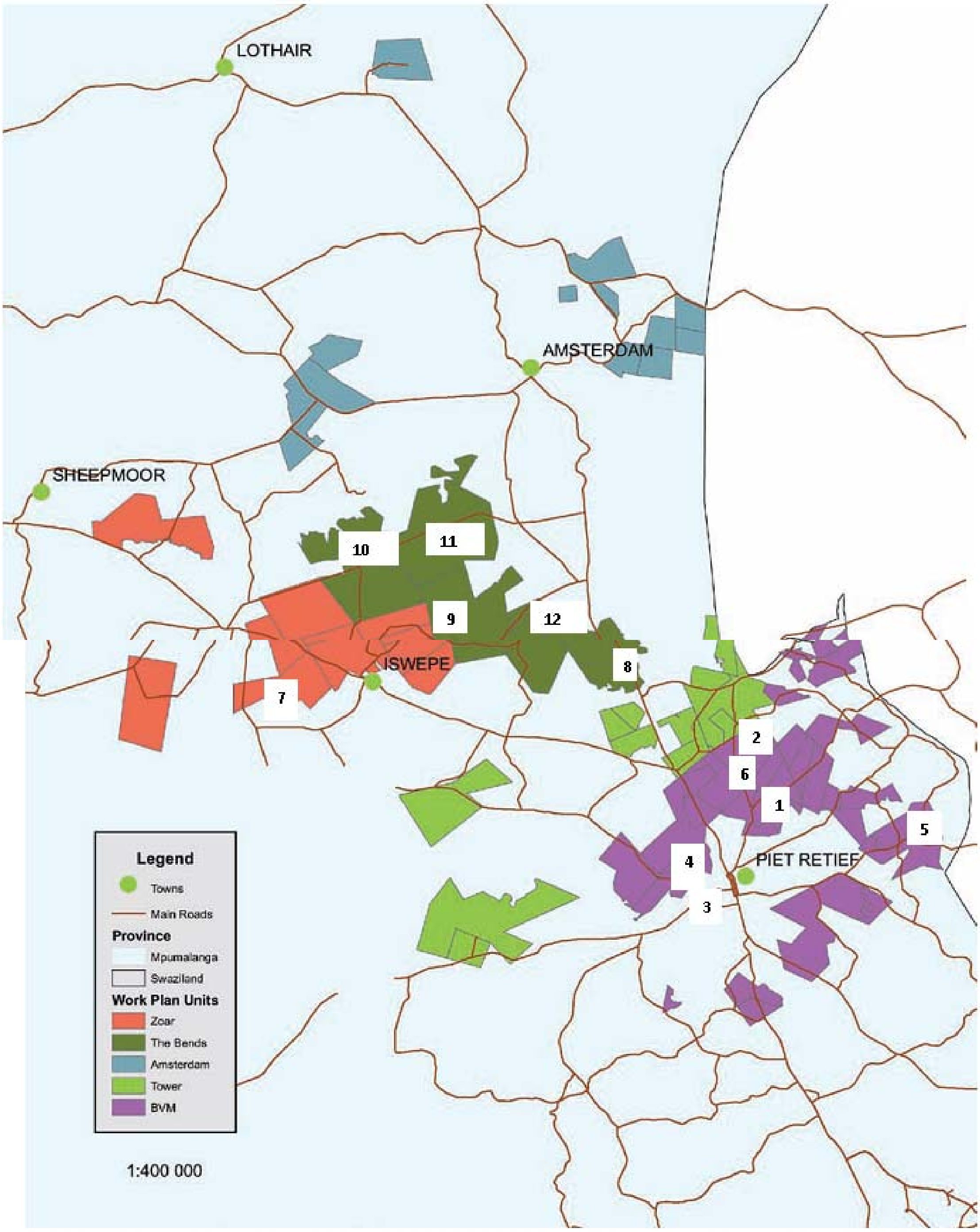
The study was carried out in the Iswepe and Piet Retief Areas. There are 56 villages located on Mondi property in the study area. Twelve villages were randomly selected from the population based on logistics (accessibility) and other social considerations (community willingness to participate). Six villages were selected from each of the Piet Retief and Iswepe areas. The names of the selected villages and the total number of households contained in each is presented in Table 5.2.

Table 5.2 Sampled villages and numbers of households

No	NAME OF VILLAGE	TOTAL NUMBER OF HOUSEHOLDS
	PIET RETIEF	
1	Mooihoek	48
2	Belfast (old)	65
3	Welverdiend	39
4	Bon Esperence	34
5	Athalia	51
6	New Belfast	37
	ISWEPE	
7	Zoar	32
8	Riverside	37
9	Watersmeet	142
10	The Bends Jabulani	30
11	New Plaas Ingwempisi	45
12	Geluk	49

Source: MBP (2007)

Ten households were randomly selected per village for sampling, resulting in a total sampled population of 120 households. The map of plantations in Iswepe and Piet Retief areas with locations of sampled villages is presented in Figure 5.1.



Source: MBP, 2005

Figure 5.1: Map of Plantations in Piet Retief and Iswepe areas and adjoining villages Numbers according to Table 5.2

5.3.1 Brief description of the villages

The villages on Mondi Forest property are all similar in terms of infrastructure and facility (schools and sport arena). However, distribution of houses in the villages and the type of dominant livelihood (livelihood here refers to means of living especially of earning enough money. The dominant livelihood activities in the area are farming and livestock keeping) activity in the villages differ. The villages (numbered according to Table 5.2) are grouped in terms of their similarity and briefly described below:

MOOIHOEK (1), WELVERDIEND (3) and BON ESPERANCE (4): These villages are very similar, with not much farming going on in them. The houses in these villages are located close to each other. There is little open space for cattle grazing.

ATHALIA (5), OLD BELFAST (2) and NEW BELFAST (6): These villages are agrarian, with active and ongoing farming and cattle grazing activities present. The houses are located close to each other, the villages are surrounded by plantations and there are many open spaces for cattle grazing.

ZOAR (7), GELUK (12), RIVERSIDE (8), WATERSMEET (9), THE BENDS JABULANI (10) and NEW PLAAS INGWEMPISI (11): These villages practise agriculture and can be refered to as agrarian. They have many open spaces for farming and cattle grazing. The houses in these villages are located far from each other.

5.4 SCOPE AND PROCEDURE OF QUESTIONNAIRE SURVEY

The main body of quantitative and qualitative data for this study was obtained through a structured questionnaire survey. Data were also received through direct correspondence with key informant stakeholders.

5.4.1 Questionnaire design

The structured questionnaire used for this study was designed in accordance with guidelines for questionnaire design recommended by Babbie and Mouton (2008). The questionnaire was structured to contain both open-ended and close-ended questions, the questions asked were clear and simple and with no double meanings. The questionnaire was developed in consultation with Mondi officials to prevent asking questions that might create expectations or jeopardize the relationship between Mondi and the communities. A copy of the questionnaire is included in *Appendix One*.

5.4.2 Pre-testing

The questionnaire was pre-tested before using it to collect data from the study population. Five people residing in a forestry area outside the study areas were asked to complete the questionnaire. The answers were examined to see if respondents understood the questions, and whether respondents were reluctant to answer some questions (De Vaus, 2002 in Ham, 2007). Necessary revisions were then made and the corrected questionnaire was used for data collection for the study.

5.4.3 Survey process

The sampling procedure used for this study, where 12 villages were randomly selected from 56 villages and a systematic random sample of 10 households per village was carried out within the selected villages, fits in well with cluster sampling procedure described by Babbie and Mouton (2008). They recommend that cluster sampling may be used when it is either impossible or impractical to compile/sample an exhaustive list of the elements composing the target population, which is readily applicable to this study.

Before the start of the survey process, the company’s community representatives briefed residents in all the selected villages about the research study, its aims and objectives. This was necessary in order to facilitate their participation in the study. This approach was used successfully by Ham and Theron (2001) and was thus adopted for this study. The sampling procedure for this study was by means of direct observation, face-to-face interview and administration of questionnaire forms. The survey was conducted over a two weeks period from 2nd to 16th June 2009, covering one village per day.

At the beginning of each day, a community representative facilitator from Mondi formally introduced the interview team to the community in order to facilitate their entry into the village. This approach was used as it is considered the most appropriate data collection method for evaluation studies (Swanepoel and Beer, 2006). The interview team comprised of the study facilitator and an interpreter from the Iswepe area. The interpreter helped to communicate the survey questions to the respondents in their mother language as recommended by Swanepoel and Beer (2006).

The interpreter was first briefed about the study, its aims and objectives to ensure that he understood the study before the actual survey process. Before the survey started, the questionnaire was discussed with the interpreter, allowing him time to familiarize himself with the survey questions. As recommended by Bless and Smith (1995), the survey process was thoroughly and critically carried out in order to avoid possible bias either from respondents or interpreter.

5.5 QUANTIFICATION OF RESIDUE, THATCH GRASS AND MUSHROOM CONSUMPTION

Respondents were asked about their frequency of collecting plantation residue, thatch grass and mushrooms. A spring scale was used to determine the mass of samples of bundles of firewood residue, thatch grass, building material and mushrooms.

The frequency of collection per week and the determined mass of each bundle were used to determine quantity of firewood consumed per month per household per village. The same procedure was followed in estimating the quantity of residue used per household per village for fencing and pens (enclosure for livestock) construction and in quantifying the amount of thatch grass and mushrooms consumed per household per village per month. This procedure has been successfully used by Ham (2000) and Makhado *et al.*, (2009) in a similar study where quantity of firewood consumed from woodlot per household per village and quantity of thatch grass and mushroom consumption per household were investigated respectively.

5.6 STATISTICAL ANALYSIS- METHODS AND APPROACH

Microsoft Excel was used to capture the data and STATISTICA version 8 (www.statsoft.com.) was used to statistically analyse the data. The data contained both continuous (interval) variables and categorical (nominal) variables (Keller and Warrack, 2003).

The continuous variables in the data set included: pick-up time, work time, number of people engaged in plantation forestry work per household, quantity of residue consumption per purpose per household and frequency of residue collection per household per week. All other variables in the data set are categorical variables.

Summary statistics were used to describe the variables. Distributions of variables were presented with histograms and frequency tables. Medians/means were used as the measures of central location for ordinal and continuous responses and standard deviations and quartiles as indicators of spread (Keller and Warrack, 2003).

The relationships between continuous response variables and categorical input variables were analysed using analysis of variance (ANOVA) (Keller and Warrack, 2003). Relations between nominal variables were investigated with contingency tables and likelihood ratio chi-square tests, as recommended by Keller and Warrack (2003) and Clewer and Scarisbrick (2001).

A p-value of $p < 0.05$ represented statistical significance in hypothesis testing and 95% confidence intervals were used to describe the estimation of unknown parameters (Clewer and Scarisbrick, 2001).

5.7 STAKEHOLDER CONSULTATION

Stakeholder consultation for this study was aimed at identifying potential suppliers of forest residue for the assumed biofuel plant and also for estimation of quantity of wood waste that can be obtained from these sources. The cost of delivery as well as logistics of long term wood waste supply from these identified sources was also analysed as part of the stakeholder consultation process.

Approaches used for stakeholder consultation included site visits and personal interviews. Stakeholders consulted for this process included forest base companies and experts from Mondi. The sampling technique employed for this process was based on purposive/judgmental sampling techniques described by Babbie and Mouton (2008).

5.7.1 Forest based companies

The Sonae Novo Board plant, Piet Retief sawmill, PG Bison plant and NTE mill were consulted to collect the following information:

- Types of wood used,
- Types of waste materials generated (off-cuts, chips, shavings and sawdust),
- Volumes of waste generated and available,
- Methods of disposing waste material,
- To establish whether sawmill owners would make waste material available to a bio-fuel project.

5.7.2 Consultation within Mondi

Experts from Mondi in Iswepe and Piet Retief were consulted for the following purposes:

- To obtain information on volumes of each timber species produced as an indication of potential residues available for harvesting for the production of biofuel;
- To identify the most cost-effective method of harvest residue recovery and delivery. And also to estimate the travel distance required for recovered residue delivery for profitable pellet production or biomass cogeneration;
- To develop the best model for the assessment of the socio-economic impact of biofuel facility establishment and operation.

The names of consulted experts from Mondi are presented in *Appendix Two*.

5.8 ESTIMATION AND QUANTIFICATION OF AVAILABLE FOREST RESIDUE FOR BIOENERGY PRODUCTION

The amount of harvest residues that Mondi plantations could yield for bioenergy production is directly related to the utilizable volume of timber from the plantations. In order to quantify the potential volume of harvest residue that could be generated from Mondi plantations annually, simple allometric ratios developed by Dovey (2005) for estimation of harvest residue from various species of timber was used in combination with the table of projected annual utilizable volume of timber (*Appendix Three*). The ratios are presented in Table 5.3.

Table 5.3: Ratio to convert volume to dry mass

Species	Oven dry density of utilizable timber (t/m^3)		Bark (t/ha)		Branches (t/ha)	
	A	**Standard deviation**	**B**	**Standard deviation**	**C**	**Standard deviation**
A. mearnsii	0.654	(0.08)	0.13	(0.01)	0.26	(0.06)
E. dunnii	0.536	(0.03)	0.16	(0.03)	0.12	(0.05)
E. grandis	0.450	(0.02)	0.12	(0.02)	0.12	(0.05)
E. macarthurii	0.551	(0.03)	0.15	(0.03)	0.21	(0.06)
E. nitens	0.526	(0.02)	0.12	(0.02)	0.34	(0.26)
E. smithii	0.581	(0.02)	0.10	(0.02)	0.21	(0.09)
P. patula	0.387	(0.04)	0.09	(0.03)	0.26	(0.10)

Source: Dovey (2005)

The allometric ratio developed by Dovey (2005) for estimation of the volume of harvest residue available from forest plantations works on the basis of knowledge of annual utilizable volume of timber species from the plantation. There are two steps involved in using the allometric ratio to estimate volume of harvest residues. These are:

- Step 1: Estimation of oven-dry stem-wood biomass from utilizable timber volume as the product of oven-dry basic density (column A) and stand volume for a particular species.

- Step 2: With stem-wood biomass estimated from Step 1, bark and branch biomass can be estimated by multiplying the stem-wood biomass by the appropriate ratio values in column B and C respectively (branches include tree tops and dead branches).

Microsoft Excel was used to build a model, based on these allometric ratios, to estimate annual available volume of residue from Mondi Forest. The model is attached in *Appendix Four*

Annual yield of utilizable volume of timber per hectare per species was determined for the projected five years from 2010 to 2014 by dividing total annual utilizable volume of timber with annual harvestable hectare in order to determine annual utilizable volume of timber per hectare. This was done for the three genera of timber (pine, wattle and gum) over the projected five years. The average yield of utilizable volume of timber per hectare per genus over the projected five years, was then determined.

The determined average yield of utilizable volume of timber per hectare per genus per annum, was then applied to Dovey's allometric ratio model in order to determine volume residue yield per hectare per genus per annum. When the value of annual utilizable volume of timber per hectare per genus was put into the Dovey model, it gave the corresponding yield of oven dry matter (tonnes per hectare) of residue (bark and branches) per hectare per genus. *Appendix Five* summarizes the available biomass per genus per annum.

5.9 RESIDUE HANDLING COST

The logistical supply chain approach for harvest residue recovery and delivery to the gasification plant adopted for this study is based on the experience of similar works in Finland and Sweden (LIRO, 1995).

The integrated harvest system which has been observed in Finland to be more cost effective, is proposed for residue recovery for this work (LIRO, 1995). This system entails whole tree harvesting and involves the following steps:

- Fell/bunch,
- Clam-bunk skidder to roadside,

- ❖ Delimb and cut to length at roadside.

A research study in Finland showed that when this system is used, it involves:

- ❖ Whole tree harvest integrated with use of branches and tops;
- ❖ It works best in clear-fell situations;
- ❖ When done this way cost of wood chips is similar to that of other fuels (LIRO, 1995).

Whole tree harvest system entails piling of residue at roadside. A number of logistical supply chains have been developed to remove the residues from the forest and transport them to the energy plant. The logistical approach adopted for transporting the residues to energy plant is based on Swedish experience (Oldenburger and Probos, 2006) and a study done in KwaZulu-Natal, South Africa by Lewis *et al.* (2005b).

For this study two supply chain logistics for harvest residue recovery and delivery to the energy plant were investigated:

- ❖ Transport of loose residue from roadside to energy plant and chipping at the plant,
- ❖ Chipping at roadside and transport of chips to energy plant.

Chipping cost for residue adapted for this study was based on a research study in West Virginia (USA) by McNeel *et al.* (2008). The study found chipping costs for forest residue to be:

- ❖ $7.14/tonne, *i.e.* R55.59/tonne (conversion rate as at 28th August 2009) for chipping at landing and;
- ❖ $3.57/tonne, *i.e.* R27.78/tonne (conversion rate as at 28th August 2009) for chipping at energy plant.

The flow charts for two scenarios of harvest residue recovery and transportation to the energy plant are presented in Figures 5.2 and 5.3.

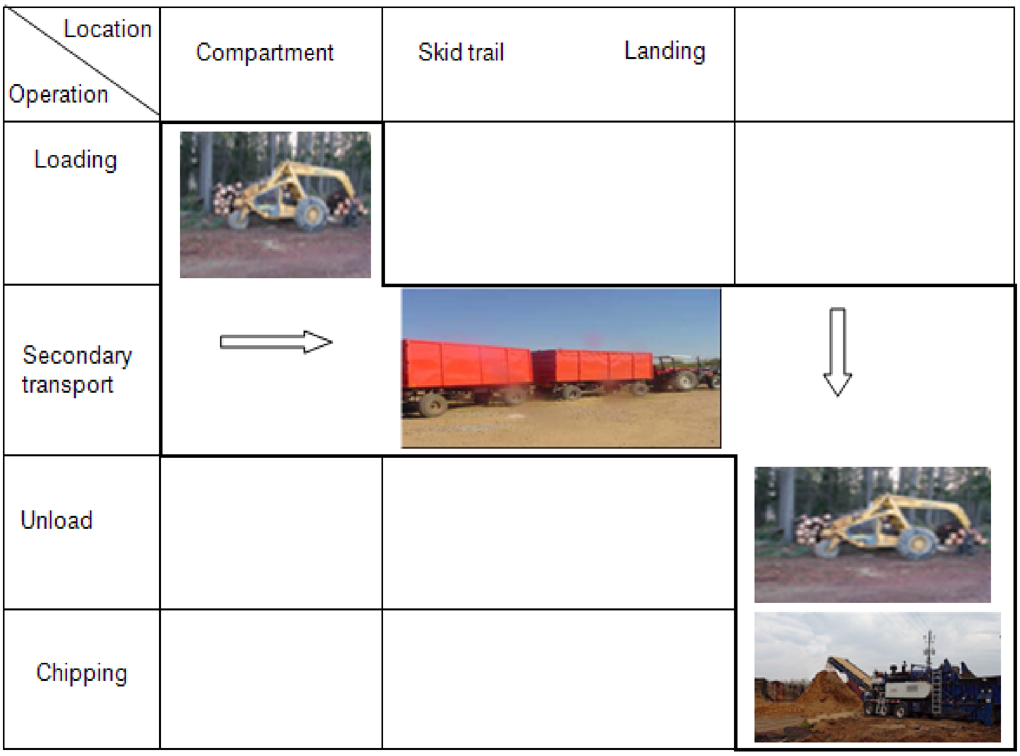


Figure 5.2: Transport of loose residue to energy plant

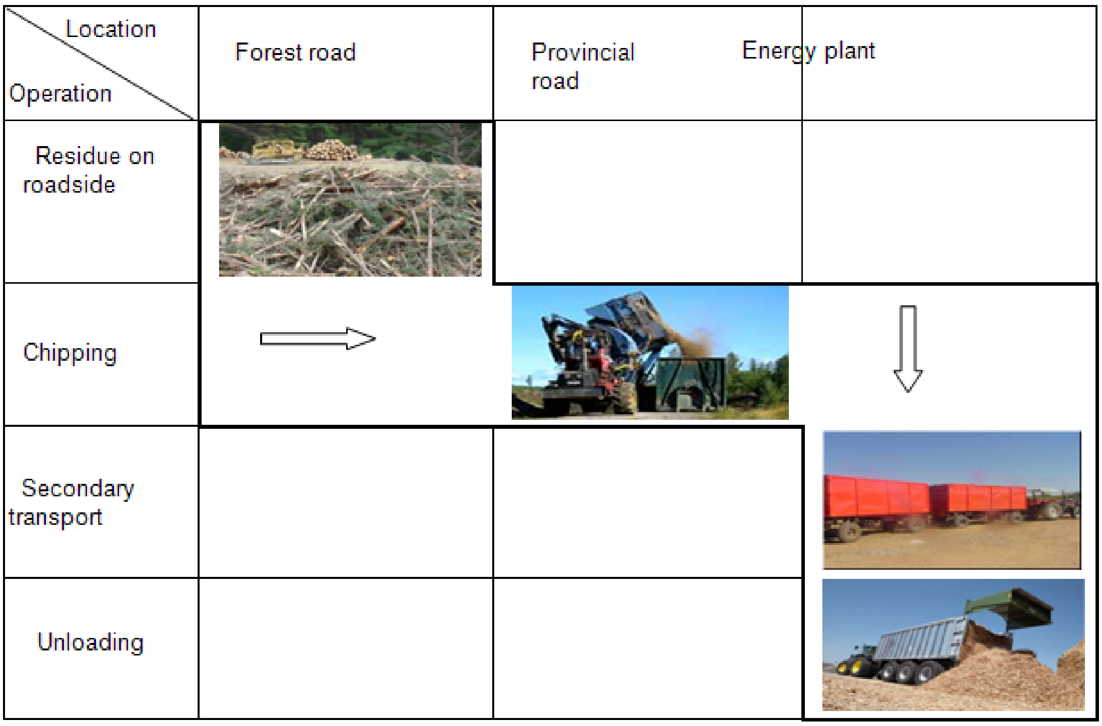


Figure 5.3: Transport of chips to energy plant

Transportation cost for forest residue adapted for this study was based on a similar study done in United States by McNeel *et al.* (2008). Two logistical approaches for delivering forest residue to the energy plant were adopted from this study. These are:

- Transport of loose residue from landing to energy site,
- Chipping at landing and transport of chips to energy plant.

A truck with maximum capacity of 25 tonnes was used in the study, and it was found that the truck can carry a maximum of 16 tonnes loose material and 20 tonnes chips. This result was adapted for South African conditions using the vehicle cost schedule published by Road Freight Association of South Africa (2007). This gives the following transport costs, which was used in this study:

- R0.60/tonne/km for loose material
- R0.48/tonne/km for chips

In calculating the transport cost for harvest residue delivery to the energy plant, a distance of 26 km was assumed. The lead distance was determined by using map-window GIS (www.mapwindow.org) to measure the distances of the plantations to the proposed energy site using topographical maps of the plantations imported into map-window software. The average of the measured distances was found to be 26 km.

5.10 ESTIMATION OF AMOUNT OF ELECTRICITY GENERATED FROM PLANTATION RESIDUE

A model for electricity generation, based on a 5 MW (for Mondi to be independent of ESCOM grid, they will need a 10 MW plant, hence the choice of 5 MW used in this study which could serve as the first phase analysis of the entire process) Greenforze gasification plant (Persson, 2007) was developed and is presented in *Appendix Six*. Table 5.4 presents the assumptions made in the development of the model.

Table 5.4: Assumptions used for estimating cost of electricity generation (R/Kwh)

ASSUMPTIONS	REFERENCE	REMARK
35% electricity conversion efficiency and 65% heat conversion efficiency	Persson (2007)	Manufacturer manual of the Greenforze 5MW integrated gasification plant showed the plant has efficiency of 65% to 75%
8,760 hours of operation hours per annum		Total possible operation hours per annum. This is the product of (24x365)
80% availability		This is assumed with consideration to plant shut down period for maintenance purpose.
Annual operation hours (7,008)		Product of plant technical availability and total possible operation (8,760).
Plant capital cost R 55,272,244 for the 5MW plant	Persson (2007)	Project proposal for feasibility study for the development and Turn-Key installation of an integrated and combined biomass gasification plant for the production of electrical power by Tomas Persson, submitted to Mondi Zimele
Electricity sale to national grid (R 0.90/Kwh).	NERSA (2009)	Selling price of electricity based on NERSA value for landfill gas. The selling price of R1.18 per kWh has been proposed for bio-electricity from biomass, though it is yet to be approved.

Annual operation and maintenance cost	Doderer (2009)	Fixed at 1.5% of capital cost
Building and infrastructure cost. R 3,705,138.00	Doderer (2009)	This was for a 5MW carbo-consult plant, and was subsequently assumed for 5MW greenforze plant used in this study
Interest rate (real rate)	Statistics South Africa (2009)	
Depreciation of the energy plant	Ham, 2009	Over a ten years period
Transport cost	McNeel *et al.* (2008)	The cost was adapted for South African conditions. Two transport scenarios were used. The costs were found to be R0.60/tonne/km for loose materials and R0.48/tonne/km for chips
Labour cost R 3,277,084.00 This is total annual labour cost for all the workers involved in the operation of the energy plant	Doderer (2009)	This was for a 5MW carbo-consult plant, and was subsequently assumed for 5MW greenforze plant used in this study
Chipping of residue R 55.59/tonne for chipping at roadside R 27.80 for chipping at energy plant	McNeel *et al.* (2008)	Chipping at roadside and chipping at energy plant were used
Energy content of residue	(Munalula & Meincken, 2009)	Energy content of tree residue (pine, wattle and gum) at 15% moisture content (pine is 18.44GJ, wattle is

		18.56GJ and gum is 18.25GJ)

The model uses the estimated total energy content of recovered residue to determine the amount of bio-electricity that can be generated from such residue.

5.11 ESTIMATION OF THE COST AND REVENUE OF UTILIZING HARVEST RESIDUE FOR BIOELECTRICITY GENERATION

The cost of recovering, processing and transporting harvest residue to energy plant was estimated in terms of the energy content of the recovered residue. The average distance of 26 km was applied to the model (*Appendix Six*) in estimating the cost of recovering and delivering residues to the energy plant, from plantations in the Piet Retief and Iswepe area.

In estimating the cost and revenue of bioelectricity production from residue, the available volume of residue determined using Dovey allometric ratios (section 5.8) was applied to the electricity conversion model (*Appendix Six*). This gave the corresponding cost and revenue of bioelectricity generation based on the energy content of recovered residue. The electricity conversion model functions were based on the assumptions in Table 5.4.
The revenue and cost from bioelectricity generation were then used in the cash flow analysis of the viability of utilizing forest residue for bioelectricity generation.

5.12 FINANCIAL ANALYSIS: METHODS AND APPROACH

The financial analysis carried out in this study focused on the assessment of profitability of conventional forest operations, integrated pulpwood and biomass energy production and bioelectricity production.

The financial feasibility assessment carried out in this work was based on hypothetical testing of the viability of utilizing forest residue for bioelectricity generation at Mondi packaging mill. The power facility considered for this study is a 5MW integrated gasification and combined heat and power plant. The financial analysis also considered the viability of integrated timber and bioelectricity production.

The financial analysis aspect of this work investigated the viability of integrated timber and bioelectricity production. Cash flow analysis was used to compare the costs and income of conventional forestry operations per hectare with cost and income of integrated timber and bioelectricity production per hectare. This was aimed at investigating the viability of incorporating bioelectricity production into conventional forestry operations. Cost and income of bioelectricity generation per kilowatt hour from plantation residue was also analysed.

Several methods are used by companies and governments to evaluate the economics of projects. Net Present Value (NPV) and Internal Rate of Return (IRR) are the methods employed for financial analysis of projects in this study.

The NPV method determines the present value of the future costs and revenues of a project minus its initial investment. The NPV gives results in Rands, takes into account the time value of money using the present value factor, and can be used to reliably rank projects. A zero NPV means the project repays original investment plus the required rate of return. A positive NPV means a better return, and a negative NPV means a worse return, than the return from zero NPV (UNESCAP, 2003).

The IRR of an investment is the annualized effective compounded return rate that can be earned on the invested capital. IRR is a rate of return used in capital budgeting to measure and compare the profitability of investments (Klemperer, 2003). The IRR of an investment is the interest rate at which the cost of the investment leads to the benefits of the investment. This means that all gains from the investment are inherent to the time value of money and that the investment has a zero net present value at this interest rate (Klemperer, 2003).

5.13 DETERMINATION OF THE REAL INTEREST RATE

The real interest rate used in cash flow analysis of projects in this study was estimated using equation 5.1 given below (Klemperer, 2003):

$r = (1+i)/(1+f) - 1$ ………………………..equation 5.1

Where:

r = real rate

i = nominal rate, and

f = inflation

The nominal rate was estimated from the average of prime lending rate over a period of 10 years starting from 1999 to 2009. This gave an estimate of 13.6%. (Statistics SA, 2009). Inflation was estimated from the average of annual percentage change in the producer price index over a period of 10 years starting from 1999 to 2009. This gave an estimate of 7.56 % (Statistics SA, 2009).

5.14 COST DETAILS USED IN CASH FLOW ANALYSIS OF CONVENTIONAL FORESTRY OPERATIONS

The cost details used for cash flow analysis of forestry operations in this study were from the Forestry Economics Services data for Mpumalanga South from 2008. The costs are presented Table 5.4.

Table 5.5: Cost parameters for cash flow analysis (FES, 2008)

OPERATIONS	COST	UNITS
Land	**R 2640**	**R/ha**
Annual cost	**R 304.5**	**R/ha**
GUM PLANTATIONS		
Land preparation	R 1,375.19	R/ha
Planting	R 1,940.26	R/ha
Blanking	R 224.24	R/ha
Fertilizing	R 860.68	R/ha
Weed control	R 293.54	R/ha
Clear felling cost	R 102.72	R/tonne
Revenue from timber sales	R 305.14	R/tonne

The details of these cost parameters are presented in *Appendix Seven*

5.15 ESTIMATION OF IMPACT OF RESIDUE USE FOR BIOENERGY ON ADJACENT COMMUNITIES

Data from the questionnaire survey and consultation with bioenergy experts were used to determine the potential impact of residue utilization for bioelectricity production on adjacent rural communities. The impact estimation was centred on employment creation and rural livelihood. Employment benefit of conventional plantation operations to adjacent communities was compared to potential employment benefits of integrated timber and bioenergy production to adjacent communities. The comparison helped in understanding the possible impact of bioelectricity production on adjacent communities. The importance and role of harvest residue on the livelihood of adjacent rural communities was explored in order to understand the potential impact of harvest residue utilization for bioelectricity production on rural livelihood.

5.16 CONCLUSION

The results obtained from the applications of the methods and approach described in this chapter is presented in the next chapter. The chapter is organized into two sections (A and B), with section A focusing on the results from the survey and section B focusing on results from the bio-energy study.

CHAPTER SIX

6.0 RESULTS

The results from this study are presented in this chapter. The chapter is structured in two main sections:

1. The first section addresses the direct and indirect benefits that adjacent communities derive from forestry operations and from harvest residue utilization. Direct benefits refer to main benefits that communities derive as a result of working on Mondi plantations. Indirect benefits refer to ancillary benefits that the communities derive as a result of working on Mondi plantations.

2 The second section of this chapter considered the following two questions:

   a. How will the incorporation of a bioenergy plant in the value chain affect forest dependent communities and the profitability of conventional forestry operations?

   a. Is it financially viable for Mondi to utilize forest residue for bioelectricity generation?

6.1 DEMOGRAPHIC OVERVIEW OF COMMUNITIES ON MONDI FORESTS

There are a total of 2,325 households in plantation villages on both Piet Retief and Iswepe areas. Iswepe area has 1,172 households and Piet Retief area 1,153 households (MBP, 2007).

An overview of the demographic structures of the sampled villages on Mondi land is presented in Table 6.1. As shown in Table 6.1, nearly all households in the sampled villages live with a monthly income of less than R 3,500. It is only at Bon Esperance, New Belfast, Riverside and New Plaas Ingwempisi where up to 50% of adults are unemployed. Thus there is high rate of job availability in the villages.

Table 6.1: Demographic structures of sampled villages

Communities	Total number of households per village	Number of households with income level per month of:		Average number of people per household	Average age of respondents (years)	Number of people working for Mondi	Percentage of adults unemployed
		< R3500	> R3500				
Old Belfast	65	63	2	5	56	29	49
Bon Esperance	34	33	1	3	46	6	55
Mooihoek	48	48	0	4	36	7	41
New Belfast	37	37	0	4	44	11	56
Welverdiend	39	39	0	4	45	10	61
Athalia	51	50	1	4	43	12	34
Zoar	32	30	2	4	30	16	34
Watersmeet	142	139	3	4	45	54	39
Riverside	37	37	0	4	39	7	69
New Plaas Ingwempisi	45	45	0	4	47	18	51
Geluk	49	49	0	3	37	17	36
The Bends Jabulani	30	30	0	5	46	27	48

Source: MBP (2007)

SECTION ONE

6.2 DIRECT BENEFIT OF FOREST PLANTATIONS

The direct benefits that communities residing in villages located within Mondi's plantations enjoy, are highlighted below.

6.2.1 Employment opportunity

Employment opportunity is a large part of the direct benefits adjacent communities derive from the plantations. The workers work for contractors who are contracted by Mondi to manage its tree plantations in the area. Seventy-five percent of the total number of households interviewed (n = 120) are employed in forestry operations. The type and category of work that the communities benefit from the plantation also varies much. The breakdown of plantation workers is as follow: 28% are engaged in silviculture work, 15% as debarkers, 12% are chainsaw operators, 5% work as tree pushers, 5% are drivers, 3% are log stackers, 3% work in the nursery (tending and planting of seedlings in the nursery), 2% work as markers (pulp wood markers) and 2% work in charcoal production.

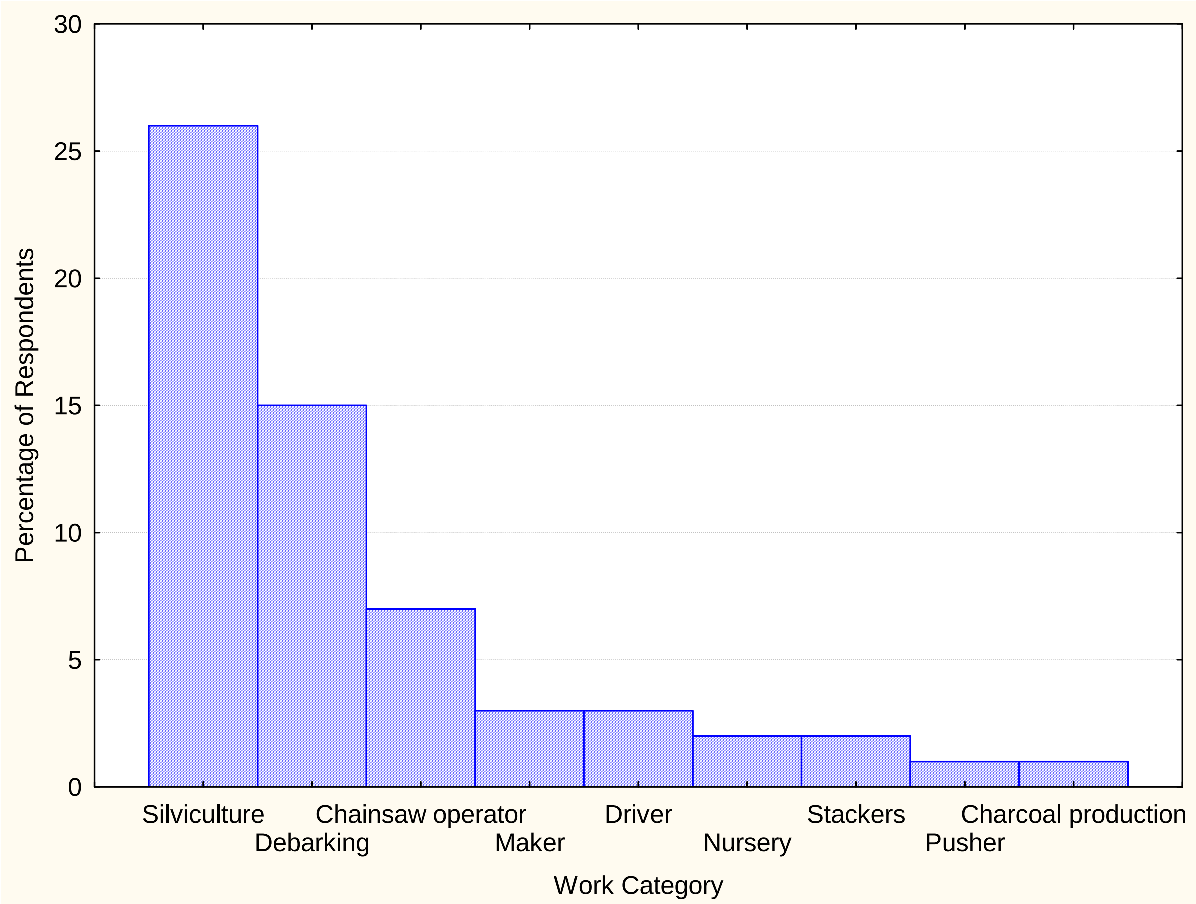


Figure 6.1: Category of plantation work (n=120)

The number of people working in plantation/forestry jobs between the villages (Figure 6.2) was found not to be significantly different (p=0.24), thus employment opportunity is fairly/ equally distributed across the villages. On the average, one person per household was found to be employed in forestry related jobs. Figure 6.3 graphically illustrates job distribution in the villages. Riverside had the highest mean number of people (2.5) per household employed in plantation work. In most other villages the mean number of people per household employed in plantation jobs was one (1).

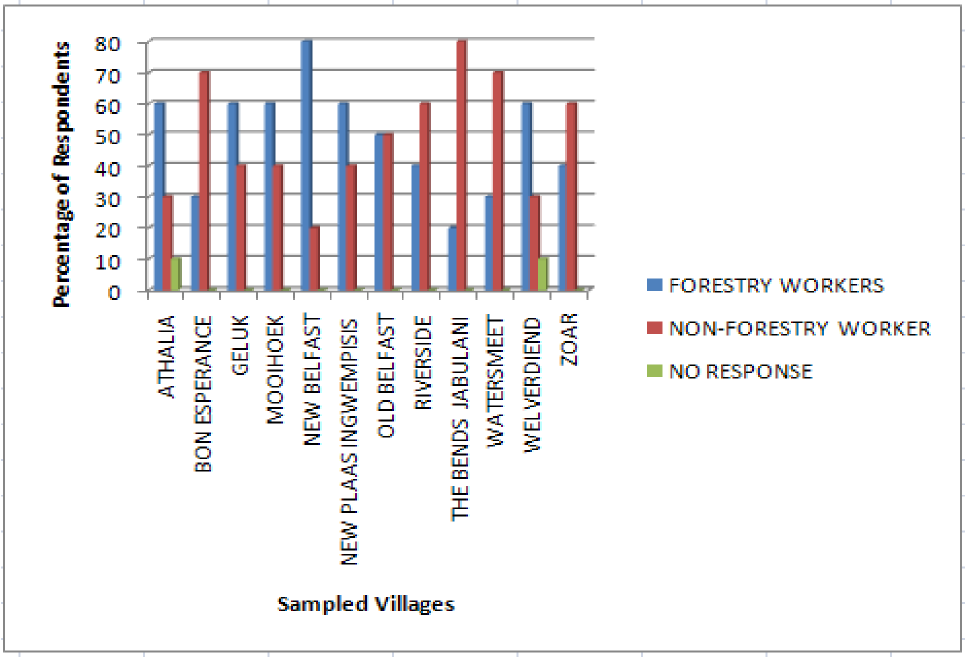


Figure 6.2: Percentage of plantation work distribution per village (n=118)

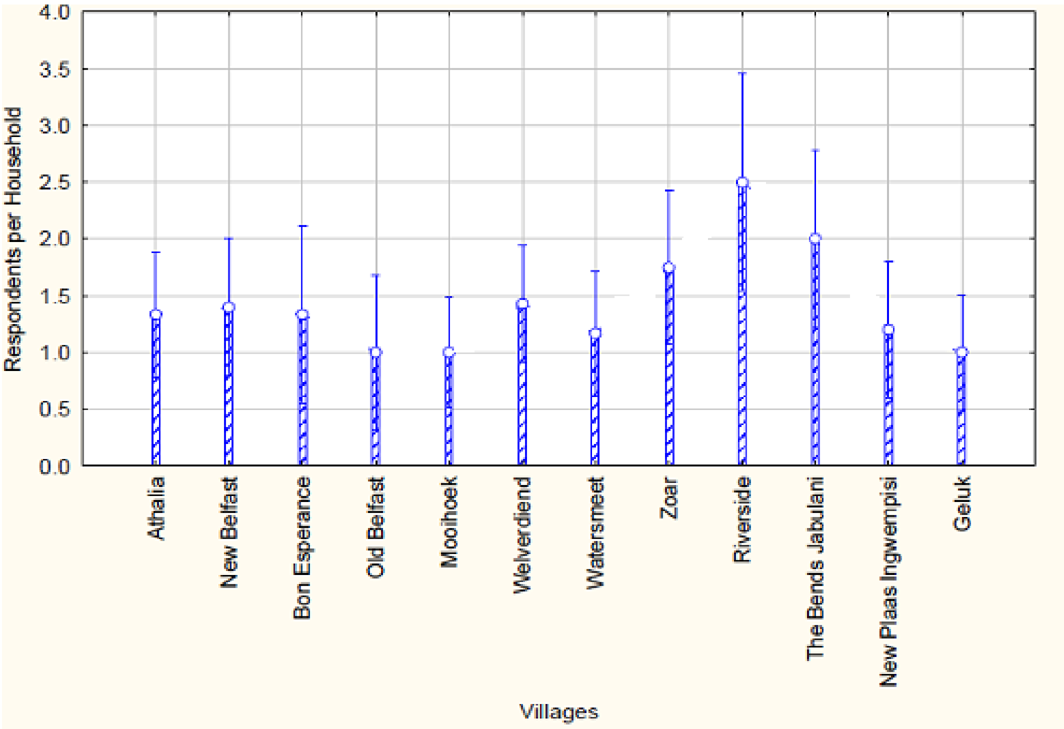


Figure 6.3: Mean number of respondents per household per village employed in plantation related work

6.2.2 Employment security

Plantation workers derive high levels of employment security with 60% of workers permanently employed, 32% as casuals and only 8% as seasonal workers. The number of permanently employed workers were significantly more than casual and seasonal workers (P= 0.004).

6.2.3 Collection and utilization of harvest residue

Residue collection

Harvest residue gathering was found to be one of the major benefits that the communities derive from the plantation (Plate 6.1). All households in the villages are involved in collection and utilization of harvest residues. The residues are available to the communities free of charge and they use it for various purposes. The residues are mostly used as firewood, but are also used for construction of pens for livestock, fencing and house building. On average 740 kg of residue is consumed per household per village on a monthly basis for agricultural purposes (garden fencing, etc.), 1,317 kg of residue is consumed per household per village per month for house building, and 946 kg of residue is consumed per household per month as firewood for cooking. The frequency of collection of residue for these purposes varies much. Residue collection for firewood is practised on average four times per week per household, collection for agricultural purposes and for building purposes is each practised on average once per week per household.

Residue use for fencing **Residue use for house building**

Plate 6.1: Pictures of residue utilization

Perceived importance of harvest residue

In trying to understand how much value the communities attach to harvest residues utilization, questions were asked on use of residues, its importance and utilization purposes. A total of 56% of the respondents said the residues are very important to them, 43% said it is important, while 1% said the residues are not important to them. All the respondents said that they use the residues for their daily living.

Residue type versus Residue use

The category of harvest residues that the people prefer to use also differs. Only 8% of the respondents used bark, 97% mostly used tops (upper part of the tree), 39% used the branches and 56% used stumps. In nearly all the villages, the people used a combination of these categories of residues. The use of bark (p=0.351) and tops (p= 0.120) was found not to differ significantly between the villages. The use of branches (p=0.00) and stumps (p=0.002) were found to differ significantly in all the villages.

Use of residue

Harvest residue is utilized in the communities for various purposes. Generally tops and thick branches are preferred. All the people interviewed reported cooking as their most important purpose of using the residues. There was no observed difference among the villages as regard to their most important purpose of using harvest residue. A total of 49% of households interviewed reported fencing as their least important residue utilization purpose, 38% said house building is their least important purpose of using the residue, 10% said house heating is their least important use. The remaining 3% did not respond.

Differences in least important useage of residue was found to be significant (p=0.02) in all the villages. Athalia had the highest number of respondents (16%) that reported fencing as least important residue useage. Watersmeet, Zoar and New Plaas Ingwempisi respectively had the lowest number of respondents (4%) reporting fencing as least important residue useage. House building was mostly (18%) reported as least important residue utilization purpose by respondents from New Plaas Ingwempisi, while respondents from Athalia and Bon Esperance reported it least (2%) as their least important residue useage. Heating, i.e. house warming was mostly identified (25%) by respondents from Watersmeet as their least important residue utilization purpose. There was however no mention of house warming as least utilization purpose for residue in Athalia, Old Belfast, Welverdiend, The Bends Jabulani and New Plaas Ingwempisi.

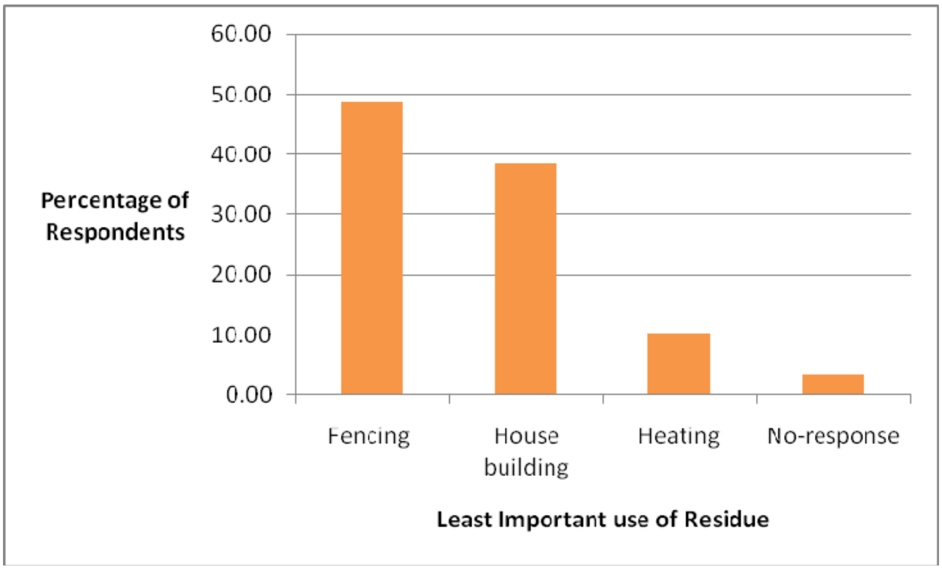


Figure 6.4: Least important use of residue in sampled villages (n=118)

6.2.4 Forest resource utilization

Apart from free collection and utilization of harvest residue, villagers also derive the benefit of free collection and utilization of available forest resources. The most prevalent forest resources, which the villagers collect, are thatch grass, edible fruits and vegetables, livestock fodder and mushroom. Thatch grass collection and utilization is not a popular activity among the villagers. Only 23% of the respondents were involved in thatch grass collection because thatch grass collection is mostly done in winter. On average, people utilize 4 kg of thatch grass per month per household. The number of people involved in thatch grass collection differed significantly (p=0.0003) between the villages.

Mushroom collection was practised only at Zoar village and it was reported that 10 kg of mushrooms is collected per household per month. Fodder collection was only done at Zoar and Geluk where people collect on average 11 kg of fodder per household per month. Collection of edible fruits and vegetables is practised only at Old Belfast, Welverdiend, Watersmeet and Geluk. Consumption is on average 3.5 kg per household per month. The frequency of collection of these resources varies between villages.

Mushrooms, thatch grass and edible vegetable and fruit collections are practised three times per week per household.

6.2.5 Free Accommodation

Free accommodation was indicated as direct benefit by 71% of the respondents, however the nature of these benefits differs immensely. In some cases the people live in mud and wattle houses while in some places they live in brick houses provided by Mondi. In other cases the people are granted controlled access to construction wood and land which they use to build their own huts. To some free access to building material from the plantation is of the same value as free accommodation. Some of the respondents value access rights to harvest building wood and permits to build houses as the same as living in Mondi houses (Plate 6.2).

Plate 6.2 Pictures of typical houses on Mondi tree plantations

The percentage of respondents who expressed free accommodation as a benefit they enjoy from the company is presented in Figure 6.5.

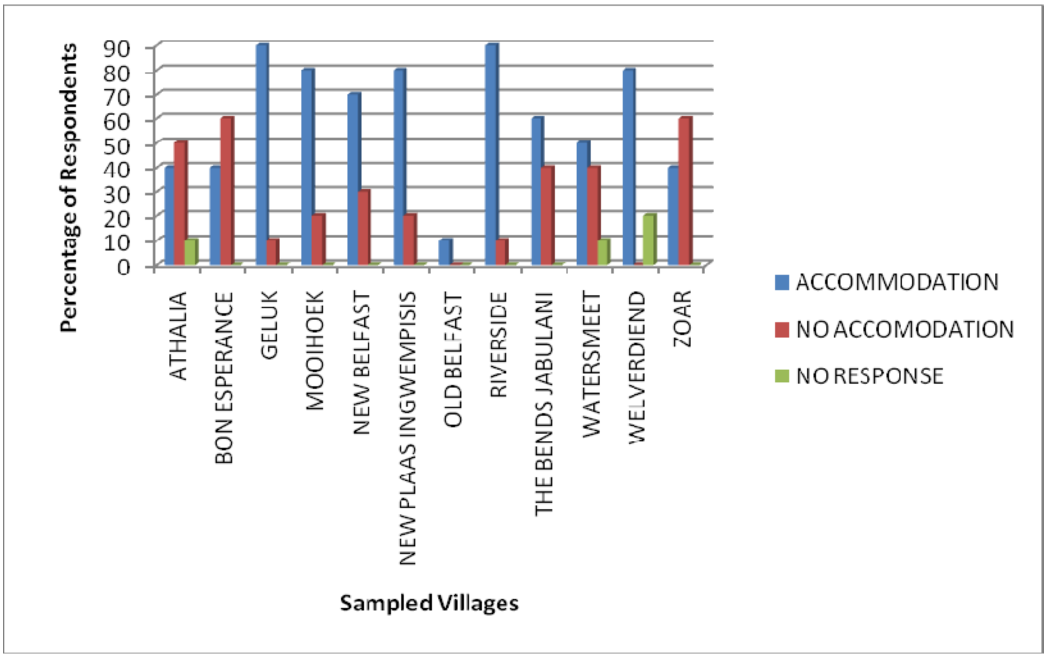


Figure 6.5: Accommodation benefit (n=120)

6.2.6 Water supply

Availability of borehole water is one of the indirect benefits of communities on Mondi Forests. All the villages on Mondi Forests are provided with borehole water; however the efficiency of these boreholes and location relative to village houses differs from one village to another. Overall water supply to the villages on Mondi Forests was rated as satisfactory by 70% of respondents although some villages experienced supply difficulties. Watersmeet (67%) and Bon Esperance (50%) are the villages with the highest level of water supply difficulty.

6.3 INDIRECT BENEFIT OF FOREST PLANTATIONS

The indirect benefits that the communities residing on Mondi Forests receive include the following:

6.3.1 Free Farmland

Free access to farmland is one of the indirect benefits that communities residing on Mondi Forests property derive. Fourty-seven percent of respondents practise farming (farming in the study context means cultivation of crops). The number of people practising farming was found to differ significantly (p=0.000) between villages. Welverdiend had no farming activity and only 10% of the respondents in Athalia, New Belfast and Bon Esperance were practising farming. In contrast at Zoar 40% of the community was involved in farming while at Riverside and Geluk 90% was involved and all respondents were involved in farming at New Plaas Ingwempisi. The villages where more than 50% of the population are practising farming can be regarded as agrarian villages.

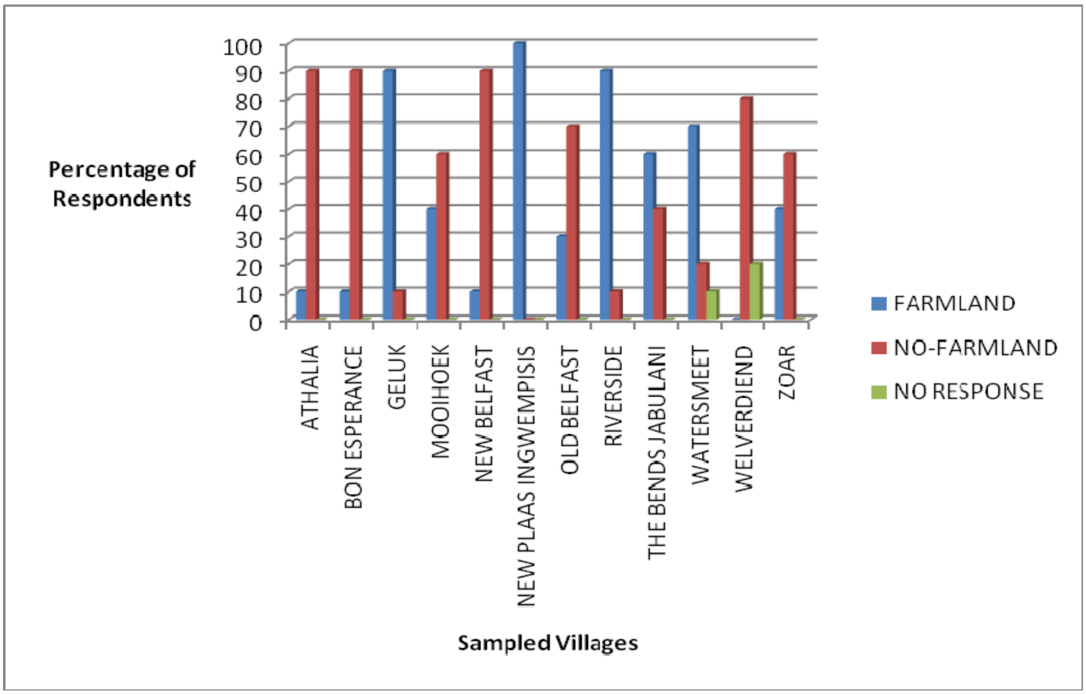


Figure 6.6: Farmland benefit per village (n=120)

6.3.2 Free Grazing

Abundance of open grassland in Mondi forest was found to be of value to the villagers for rearing their cattle. Free livestock grazing is one of the major indirect benefits derived by communities residing on property of Mondi Forests (Plate 6.3). However livestock grazing is not widely practised in the villages on Mondi land. Only 48% of the sampled population graze their cattle in the open grassland on Mondi Forests and it differed significantly between villages (P = 0.000). In New Belfast and Bon Esperance no one was found to practise livestock grazing. But in Riverside and New Plaas Ingwempisi all the sampled population were involved in livestock grazing. In the rest of the villages, people involved in livestock grazing ranged from 10% in Old Belfast, 40% in Mooihoek, 13% in Welverdiend, 78% in Watersmeet, 50% in Zoar, 60% in Bends Jabulani and 80% in Geluk.

Plate 6.3 Cattle grazing on Mondi tree plantations

6.3.3 Social benefits

Other indirect benefits to communities residing on Mondi Forests property can be regarded as social benefits. These include cemetery, low crime rate and good communication links between the communities and Mondi officials (i.e. good relationships between the communities and Mondi), which has helped in creating mutual benefits for the parties involved.

6.3.4 Reduced expenditure

Reduced expenditure is a major benefit that adjacent communities on Mondi forest land enjoy. Reduced expenditure is one of the major reasons why the people are comfortable with living on the forest even in some cases where social amenities and facilities are lacking.

Nearly all respondents (99%) used firewood for primary cooking activities. Other energy sources used included paraffin (69%), electricity (15%) and cow-dung (15%). Nearly all the respondents (98%) also used firewood as a primary source of energy for house heating. Other energy sources for heating included paraffin (55%), electricity (25%), cow-dung (10%) and liquid petroleum (LP) gas (10%). On average a household on Mondi's land spent R18 per month on cooking and heating material. Cost savings on accommodation, farmland, grazing land and free collection of firewood played a major role in helping the communities afford a decent standard of living.

6.4 CONCERNS LIVING ON MONDI LAND

There are issues of concern and dislike raised by the communities residing on property of Mondi Forests. These are highlighted in this section of the research report.

6.4.1 Electricity problem

Apart from Watersmeet where the brick houses were connected to the national electricity (ESCOM) grid, all the other sampled villages on Mondi Forests were not connected to electricity. Access to electricity was a concern expressed by the communities, however in some places it appeared the people were used to living without electricity and hence it was no longer an issue to them. This accounted for the reason why only 50% of the sampled population expressed lack of access to electricity as a concern. The number of people that noted lack of access to electricity did not differ significantly (p=0.011) from those that did not across all villages.

6.4.2 Relocation of families

As part of Mondi's commitment to improving the livelihood of people residing on its Land, Mondi initiated a resettlement programme. The long wait for the realization of this project was identified as an issue of concern to the villagers. However, only 20% of respondents were concerned about the relocation delay. It thus seemed like a fairly minor issue and that the people would actually rather stay in their current villages. The rest of the population were very happy with the current location of their village on the plantation.

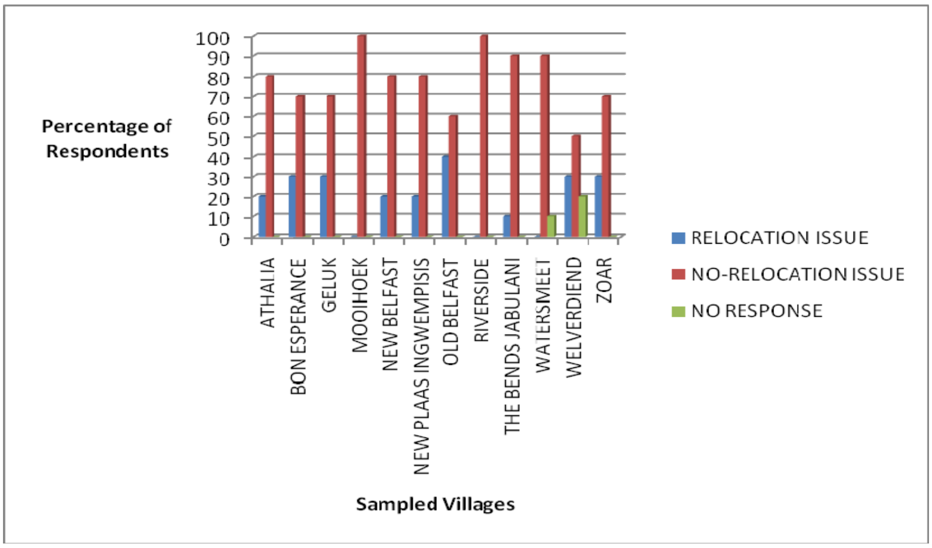


Figure 6.7: Percentage of respondents who had problems with relocation delay per village (n=120)

6.4.3 Building permits

Difficulty in obtaining permits from Mondi to either rebuild derelict houses or new ones were concerns expressed by the people living on Mondi land. In some cases repondents were unable to rebuild their fallen houses and this caused discomfort to them. The nature of this concern as expressed by the respondents ranged from difficulty in getting permits to collect building wood from the forest to obtaining permits for house building on Mondi Forests property.

Thirty-nine percent of the sampled population expressed frustration at difficulty experienced in obtaining permits for house building or rebuilding. The statistical test also showed that the number of people expressing concern about difficulty in obtaining permits for house building did not differ significantly ($p=0.148$) from those that did not express concern from one village to the other. Therefore, constraints to obtaining house building permits was not a major challenge across all the villages on Mondi's plantations.

6.4.4 Sanitation/health service delivery

Twenty-two percent of the repondents expressed their concern about sanitation and health service delivery in their communities. In some villages the health care workers visited them only once in a week, which the people complained was not enough, especially when there was an emergency or when someone was sick and needed regular attendance.

The sanitation issue expressed by the villagers was based mainly on lack of toilets in the area. Some houses in the village did not have a toilet, forcing the people to use open spaces around their dwellings as toilets. This also posed a challenge of its own especially where some had to use the toilet at night. The statistical test showed that expression of sanitation and health service delivery challenge did not differ significantly ($p= 0.697$) from one village to the other. Thus health service delivery and sanitation challenge was a minor issue and could be assumed to be similar across all the villages.

6.4.5 Transportation

Thirty percent of the respondents expressed their disapproval of the transportation system to and fro to work from their villages. Transportation challenges included poor road conditions (which were in some cases flooded in summer), long walking distance to collection points, long waits at the collection points before being transported by contractors to their place of work, and low number of taxis plying the route to the villages.

The transportation problem was highly evident in the difficulty experienced by the people in getting to work. In most villages it took the people four to five hours to get to their place of work. The long hours spent in going to work and coming back home forced the people to spend large proportions of their time away from home. In trying to solve this challenge the people built houses farther into the forest close to their work-place but away from social infrastructures and amenities.

6.4.6 Firewood collection permits

Constraints in obtaining permits for firewood collection was an issue of concern. The nature of this constraint differed between households even in the same village. These constraints included: bureaucratic delay in obtaining permits and difficulty in getting approval to use vehicles on Mondi land for residue collection. However it should be noted that the respondents did not express scarcity of firewood as a problem.

Twenty-nine percent of the respondents expressed their dissatisfaction with the firewood collection process in their communities. The expression of dissatisfaction in firewood collection process was concentrated in villages in the Iswepe area. The statistical test showed that the number of people not satisfied with firewood collection processes in their locality differed significantly ($p = 0.000$) between villages. Thus firewood collection challenge was not the same in the villages. The percentage of respondents per village expressing difficulty in firewood collection as an issue of concern is presented in Figure 6.8.

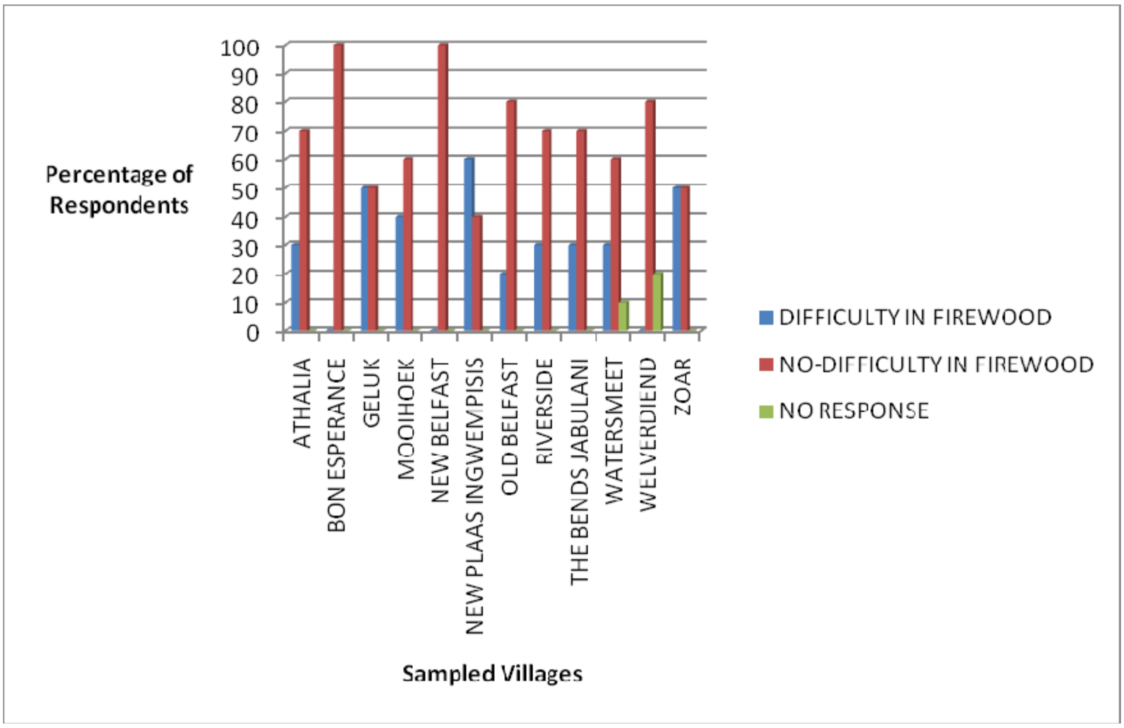


Figure 6.8: Expression of difficulty in firewood collection (n=120)

SECTION TWO

6.5 VIABILITY OF USING HARVEST RESIDUE FOR BIOENERGY PRODUCTION

In this section of the report, the results of the cost analysis of residue recovery and delivery to the energy plant, cost of electricity generation and revenue from sale of generated electricity (using the recovered residue) is presented. The analysis was carried out in order to determine the profitability of using harvest residue for bio-electricity generation. In the analysis, assessment of available volume of residue in Piet Retief and Iswepe area was first carried out.

6.5.1 Available residue from Mondi forest for bio-electricity generation

The result of the estimation of harvest residue yield per hectare from Mondi plantations is presented Table 6.2. The table shows total residue yield per genus (generic) per region per year. Tables showing this estimation in more detail are presented in *Appendix Five*.

Table 6.2: Total residue yield per area per annum

Year	Region	Combined (pine, gum & wattle) oven dry (tonne/ha)		Total (tonne/ha)	Total harvestable area per region (ha/annum)	Total annual available volume of residue per region (tonne/annum)
		bark	branches			
2010	Iswepe	25.60	49.17	74.77	2,923.30	63,310.71
	Piet Retief	28.86	56.90	85.76	1,895.30	39,952.06
2011	Iswepe	25.91	49.77	75.68	2640.30	55,345.81
	Piet Retief	27.40	52.27	79.67	1,836.60	39,418.71
2012	Iswepe	28.55	54.40	82.95	2390.3	54,699.72
	Piet Retief	28.08	55.01	83.09	1885.6	40,169.83
2013	Iswepe	28.14	53.03	81.17	2553.3	57,756.02
	Piet Retief	28.73	56.09	84.82	1756.7	35,487.14
2014	Iswepe	28.39	53.32	81.71	2347.8	52,254.56
	Piet Retief	28.36	53.89	82.25	1657.2	35,029.18

6.6 POTENTIALLY AVAILABLE VOLUME OF RESIDUE FROM STAKEHOLDERS

Forest industries around Piet Retief and Iswepe areas were consulted to identify types of residue they generate and to also establish the availability of these residues for bioelectricity production. Results of this consultation process is presented in Table 6.3.

Table 6.3: Potentially available waste from stakeholders

Stakeholder	Waste type	Available volume	Remark
Sonae Novo Board	Sawdust and sand-dust	Nil	Waste is recycled and the remaining is used for steam generation
Piet Retief Sawmill	Sawdust, offcuts and slabs	4,800 tonnes per annum	This volume is potentially available for bioenergy production at R20 per tonne FOB
NTE	Spent bark	Nil	70% of the waste is used in compost making while the remaining 30% is used for steam generation in the factory.
PG Bison	Harvest residues, sawdust, offcuts and slabs	Nil	Waste are recycled and also used in the factory for steam generation

Apart from potentially available residues from forest industries in Piet Retief and Iswepe area, there was also a possibility of sourcing harvest residues from private farmers in the area. However the logistics and potentially available volume from this source was not investigated.

6.7 RESIDUE SUPPLY ANALYSIS

The annual harvestable hectares of plantations in Piet Retief and Iswepe areas are capable of supplying 94,685 dry tonnes of residues. Residue supply analysis for the 5 mega watt plant showed that the plant will require 19,569.85 tonnes of residues per annum, i.e 20.67% of annual residue yield from the area (Piet Retief and Iswepe).

Analysis of the possibility of all residues required for the 5MW plant being solely supplied from gum plantations was carried out. The results showed that the 3,345 annual harvestable hectares of gum plantations in the area were capable of supplying 63,204 tonnes of residues per annum. If the required 19,569.85 tonnes of residues for annual running of the energy plant were harvested from the total (63,204), this would represent 30.96% of annual gum residue supply. If compartments were completely cleared of residue, then 1,035.71 ha of gum plantation would be required.

Supply analysis of residue from pine plantations showed that the average 500 annual harvestable hectares of pine plantation in the area would supply 15,332 tonnes of residues annually. Since the 5 mega watt plant would require 19,569.85 tonnes of residues, it thus means that pine plantations could not solely supply the annual required volume of biomass for the bioelectricity plant.

Analysis of residue supply from wattle plantations for the 5 mega watt plant showed that, from an average of 532 annual harvestable hectares of wattle plantations in the area, 16,148 tonnes of residues would be supplied annually. Since the 5 mega watt plant would require 19,569.85 tonnes of residues, the wattle plantations could not solely supply the annual required volume of biomass for the bioelectricity plant.

6.8 COST ANALYSIS OF BIOELECTRICITY GENERATION

The electricity generation model in *Appendix Six* was used to analyse the cost of electricity generation. The technology assumed for bioelectricity generation in this study is the integrated gasification and combined heat and power (CHP) plant developed by GreenForze Company. The capital cost for this plant, annual repayment and depreciation as well as other assumptions presented in Table 5.4 were used to estimate the cost of electricity generation from recovered residue. The analysis centred on the calculation of profit/loss of electricity generation from harvest residue using the two adopted residue recovery logistical approaches described in chapter five.

The result of the analysis showed that when chipping at landing and transport of chips to energy plant logistical approach is used, electricity generation cost will be R0.54/kWh and a profit of R0.36/kWh will be made if generated electricity is sold at R0.90/kWh. When transport of loose residue and chip at energy plant logistical approach is used, cost of electricity generation will be R0.53/kWh and a profit of R0.37/kWh will be made if generated electricity is sold at R0.90/kWh. Based on the findings of the cost analysis, transport of loose residue and chips at energy plant offers the best logistical approach for profitable generation of electricity from harvest residue.

Profitability of bioelectricity generation from recovered residue per genus per hectare was investigated. Based on the result of the cost analysis of electricity generation, transport of loose residue and chips at energy plant logistical approach was assumed for this estimation.

In investigating the profitability of bioelectricity generation per genus per ha, the amount of recoverable residue per genus (gum, pine and wattle) per annum was determined and compared to the amount of residue required to run the 5 mega watt plant annually. The comparison helped to determine whether the harvestable area from each genus is capable of annually supplying enough residues for the 5 mega watt plant. Only gum plantations was found to be capable of solely supplying sufficient residue for the energy plant. Pine and wattle plantations cannot solely supply annual required residue to the energy plant. Therefore, per hectare cost and revenue analysis of residue supply was done only for gum plantations.

In determining the per hectare cost and revenue of residue supply from harvestable areas of gum plantations, it was assumed that the 19,569.85 tonnes of residues required to run the 5 mega watt plant annually would solely come from gum plantations in the area. The analysis was based on two scenarios. In the first scenario the assumption was made that the annual required residue for the 5 mega watt plant would come from all annual harvested hectares of the individual genus (partial harvesting). The second scenario was based on the assumption that the required residue would come from ‘complete harvest’ of part of the annual harvestable hectares.

The results of the analysis showed that; when ‘partial harvest’ of residue was used, residues would be harvested from 3,345 ha of gum plantations and electricity generation cost per ha would be R5,547.02 and income per ha would be R9,427.80. But when ‘complete harvest’ was used, 1,035.71 ha would be harvested and cost of electricity generation per genus per hectare would be R 17,915.02 and income would be R30,448.67.

6.9 IMPACT ON PROFITABILITY OF FORESTRY OPERATIONS

In order to appreciate the impact of integration of bio-electricity production on the profitability of conventional forestry operations, NPV and IRR were used to analyse and compare the cash flow analysis of current forestry operations to that of integrated pulpwood and bio-electricity production. The comparison was based on per ha and per annum cost and revenue of integrated pulpwood and bio-electricity production. Only gum plantations were investigated for this purpose since it was the only genus that is capable of individually supplying annual required feedstock for the energy plant.

In carrying out this cash flow analysis, the cost and revenue per hectare per genus of bio-electricity production investigated in section 6.8 (where cost and revenue of electricity production per genus per hectare were determined using residue supply per genus per hectare and electricity conversion model in *Appendix Six*) along with cost details of conventional forestry operations in Table 5.4 and *Appendix Seven* were used. The results of the comparison is presented in Table 6.4. Full details of the cash flow analysis for these comparisons is presented in *Appendix Eight*.

Table 6.4: Cash flow anlysis of integrated pulpwood and bio-electricity production

GENUS	DIFFERENT SCENARIOS	NPV	IRR
GUM	Conventional plantation operation	R10,334.86	15.10%
	Integrated gum pulp and bio-electricity production (partial residue harvest approach)	R9,791.30	14.71%
	Integrated gum pulp and bio-electricity production (complete residue harvest approach)	R15,378.46	18.31%

Table 6.4 shows that incorporation of bio-electricity production into conventional gum production system in Piet Retief and Iswepe areas using ‘partial harvest’ of residue approach would not be very profitable. This approach reduced the NPV by R543.56 on per ha basis. The IRR was also reduced from 15.10% to 14.71%. But when ‘complete harvest’ approach would be used, the NPV increased by R 5,043.60 and the IRR also increased from 15.10% to 18.31%. Thus the use of gum plantations in Piet Retief and Iswepe areas for integrated pulpwood and bio-electricity production will be viable when complete harvest of residue from selected plantations approach is used.

6.10 POTENTIAL IMPACT OF INTEGRATED BIOENERGY PRODUCTION ON ADJACENT COMMUNITIES

Integration of biomass energy production into pulpwood production in Iswepe and Piet Retief areas can have both positive and negative impacts on forestry dependent communities. Positive impacts identified include employment opportunities in the bioenergy value chain especially in the sorting, collection and transportation of harvest residue. Establishment and operation of the energy plant is also expected to create some category of work that will generate employment for the rural communities. It was estimated that 15 employment opportunities with higher paying salary will be created in the establishment and management of the 5MW energy plant. The plant will require one semi-skilled person to oversee the team; one operator and one helper each per gasifier, but because the plant will have two gasifiers and will be run on 24 hours basis (3 shifts of 8 hours each), it will thus require 13 personnel to operate it smoothly. Added to this another two persons will be required on stand-by in case of core personnel members being absent, bringing the total number to 15.

Other positive impacts include reduction of forest fire risk, due to less harvesting residue left in the plantation, which is an important safety benefit to communities residing close to the forest.

For profitable harvesting of plantation residues, a whole tree harvesting system has been proposed. If introduced, the system will be operated on full mechanized basis and will incorporate log processing at landing, which will result in less manual work and hence job loss for certain categories of plantation workers, with job categories such as chainsaw operators, bark strippers, pushers, stackers and charcoal producers being the worst hit. Another potential negative impact of integrated bioenergy and pulpwood production is increased difficulty in firewood collection.

The management of generated waste (ash) in bio-electricity production is expected to form part of the cost of operating the facility. However there exists opportunity to boost the Black Based Economic Empowerment (BBEE) status of the company through the engagement of black contractors in the management of generated waste in bio-electricity production. These contractors can also be employed in forest residue recovery value chain activities.

6.11 CONCLUSIONS

The trends and patterns observed from the results of this study showed that plantation forestry was playing a large positive impact in the livelihood of adjacent communities. The result also showed that utilization of harvest residue was an important factor in the livelihood of adjacent rural communities. The prospect of utilizing harvest residue for bio-electricity production was found to be a viable option. Residue utilization for bio-electricity production was found to be more profitable than conventional forestry operations when complete harvest of residue from selected genus plantations approach would be used. The pattern and trend of the results from this study are discussed in detail in the next chapter.

CHAPTER SEVEN

7.0 DISCUSSION OF RESULTS

This chapter discusses the results presented in the previous chapter, it is structured in two sections, with section A focusing on the results from the questionnaire survey and section B focusing on the results from the study on the economics of residue use for bio-electricity production.

SECTION A

The survey questionnaire shed light on the direct and indirect benefits that adjacent communities derive from plantation forestry. The discussion of the main trends and patterns from the questionnaire survey was done with reference to the study research questions.

7.1 DIRECT IMPACTS OF CONVENTIONAL FOREST PLANTATION ON ADJACENT COMMUNITIES

The identified impact of conventional plantation forestry operation on adjacent communities in this study corresponds to observations in other parts of South Africa and elsewhere in the world (Chamberlain *et al*., 2005; Shackleton *et al.*, 2007).

7.1.1 Employment opportunity

Plantation forestry plays a dominant role in job creation (Chamberlain *et al.*, 2005). This study found that 75% of the interviewed people were employed by forestry in Piet Retief and Iswepe areas. Plantation forestry provided both skilled and unskilled job opportunities. The category of employment provided by plantation forestry was such that it fitted well into the rural settings in the Piet Retief and Iswepe areas. It provided employment mostly in low-income rural areas where economic alternatives are limited and skills are lacking (Chamberlain *et al*. 2005).

Plantation forestry provides various job categories to people in adjacent communities, many of which are secure and permanent (Chamberlain *et al*. 2005; Shackleton *et al*., 2007). In the study area 60% of sampled plantation forestry workers were permanently employed.

7.1.2 Collection and utilization of residue

The utilization pattern of harvest residue as found in this study followed the same patterns observed by Shackleton *et al*. (2007), Ham (2000) and Cairns (2000), where residues are mostly used as firewood, but are also used for construction of pens for livestock, fencing and house building. Consumption of residue as observed in this study (740 kg/household/month) is higher than what was observed by Ham (2000) where households in Kentani area of Eastern Cape were found to consume 308 kg of fuelwood per month. This difference can possibly be attributed to easy accessibility and abundance of residues in the study area. The high consumption of residue by the rural communities corresponds with the findings of Shackleton (2004) where it was reported that over 80% of rural households use fuelwood as their primary source of energy.

Residue collection and utilization from Mondi plantations are solely for subsistence use and not for commercial purposes, and adjacent communities are not permitted to sell collected harvest residues. As a result of this restriction, residue utilization in these areas can only support rural livelihoods but may not provide additional income necessary to lift the household out of poverty. However, residue utilization in this regard corresponds with reduced expenditure benefits that the rural people derive from Mondi plantations.

Though it cannot be guaranteed that 'selling of residue' as firewood by adjacent communities will provide additional income necessary to lift them out of poverty, access to forest goods would not necessarily lead to poverty alleviation but may prevent intensification of poverty (Shackleton, 2004). This finding is also supported by the findings of Lewis *et al.* (2003) where it was reported that forestry solely cannot lift the people out of poverty.

7.1.3 Consumption of non-timber resources

Plantation forestry does provide non-timber resources either as a co-product or by-product (Sunderland *et al.*, 2003). The available non-timber resources, which the villagers collect are thatch grass, edible fruits and vegetables, livestock fodder and mushrooms. The collection and consumption of these non-timber resources are seasonal and plays an important role in the household income and livelihood. In some cases the people are paid to collect these non-timber resources for companies utilizing them. In other cases the people collect and utilize it themselves. However, availability of these resources are seasonal. Thatch grasses are mostly harvested during the dry seasons (Makhado *et al.*, 2009). Edible mushrooms are mostly collected for subsistence use. This also corresponds to the findings of Makhado *et al.* (2009) in Limpopo Province where mushroom harvesting was found to be only for household consumption.

7.1.4 Accommodation

Provision of houses and building/construction wood by Mondi is a major benefit that plantation workers derive. This benefit plays a large role in enhancing the livelihood of adjacent communities. In Watersmeet for example free accommodation benefit comes in conjunction with free electricity. This order of benefit plays a major role in sustainance of the peoples' livelihoods. In villages where the people are living in huts and mud/or wattle houses; construction wood is highly sought after, because the huts, mud/wattle houses are less durable and need to be reconstructed periodically. The availability of permits for collecting this resource is therefore a contentious issue among villagers.

Forestry companies provide accommodation in rural areas, most of which are serviced with water, sanitation and electricity (Shackleton, 2004). Accommodation benefits provided by Mondi in this study also corresponds with what was observed by Lewis *et al.* (2003) and Chamberlain *et al.* (2005) where major forest companies were observed to contribute to their communities through social investment programmes such as housing projects. Often, the forestry companies have been the dominant social and development service providers in these areas.

7.2 INDIRECT IMPACTS OF FOREST PLANTATIONS ON ADJACENT COMMUNITIES

The trends and patterns observed in the indirect benefits provided by Mondi in the study areas are discussed in this section of the report. Grazing land and farmland contributes significantly to rural livelihood in all the surveyed villages. These facilities are present in all the surveyed villages; however the degree of availability varied.

7.2.1 Farmland

Generally, open areas within the plantations are used by the villagers for farming. The extent of the benefit that communities derive from this land is proportional to the size of the open area available, which is also related to the landscape and settlement pattern of the area. In communities where there are few open spaces, farmlands are limited and as such farming is not extensively practised. Also in places where houses are closely situated, limited open spaces were available for home gardens and other farming activities.

7.2.2 Grazing

Grazing benefit was found to follow the same pattern as farmland benefit. Available grazing land for livestock grazing was found to be greatly influenced by available open spaces within the plantation. In villages where houses were situated close to each other, livestock keeping was found not to be a major activity, but where there were enough open areas and houses were far apart, more people tended to practise livestock keeping. There was however conflict of interest with regard to cattle grazing in the plantations. The Mondi SEAT report (MBP, 2005) and Siyaqhubeka SEAT (SQF, 2005) have reported the nature and impact of grazing conflicts on productivity of plantations and rural community interest. The grazing conflict is centred on prevention of livestock owners from grazing in young plantations to prevent damage to the trees – this restriction was reported to be perceived as depriving local residents of traditional grazing rights. In some cases cattle have been reported to stray into the plantations and cause serious damage.

Education of livestock owners on grazing capacity and the impacts of over-grazing before issuing them with permits is a good procedure that in solving conflicts associated with livestock grazing (SQF, 2005). The relocation project initiated by Mondi as observed in this study offered a good prospect of solving this cattle grazing conflict.

7.2.3 Social benefits

Infrastructure such as boreholes, cemeteries and good communication links (i.e good relationships) provided and managed by Mondi were present in all the surveyed villages. This finding corresponded with the observation of Ham (2008) where it is reported that most of the commercial forestry companies in South Africa operate corporate social responsibility (CSR) programmes. The available infrastructure was found to be one of the dominant benefits that endeared the rural communities to Mondi, especially those who are not employed in plantation forestry related jobs. This finding also related with Ham's (2008) observations where it is reported that through social responsibility programmes, forest companies work with local communities to establish for instance gardening groups, sports programmes and small business ventures in order to promote cordial relationships.

These indirect benefits associated with plantation forestry in the study area had been observed to be associated with plantation forestry in other parts of South Africa by Lewis *et al.* (2003), Chamberlain *et al.* (2005) and Ham (2008). Infrastructure provided by Mondi fits into the overall integrated development plan of Mkhondo municipality where the government is planning to establish regional infrastrucuture projects (such as cemeteries) in order to facilitate provision of adequate services to meet community needs and stimulate economic growth and development (Mkhondo IDP review, 2008). Apart from direct provision of social infrastructure, Mondi also partners with local and provincial government in addressing priority needs among the local population (SQF, 2005).

7.2.4 Reduced expenditure

Reduced expenditure in this study refers to the cash saving benefits accruing to rural communities as a result of utilizing freely available plantation resources. Reduced expenditure benefit of plantation forestry as observed in this study falls in the same category with safety net and poverty reduction roles of plantations and forests as observed by Vedeld *et al.* (2004) and Shackleton (2004), where forestry plays a major role in helping the rural communities survive periods of crisis, i.e. periods of food scarcity and low income.

Farmland, grazing land, accommodation and firewood are freely available to the communities, while if they had to pay for utilizing these resources it would require a substantial amount of their income. Most of the respondents (96%) did not pay anything for fuelwood collection and even the 4% that paid for fuelwood utilization was not really buying the wood but rather paying little children to help them collect fuelwood.

The rural villagers use proceeds from the farmland and graze-land to support their livelihood. In some cases, especially in the villages where farming is highly practised, additional income is generated through sale from cattle rearing and farming. The generation of additional income from these resources is capable of improving the households' income and reduce their poverty risk. This supports the findings of Das and Sarker (2008) where it was observed that forest income plays a dominant role in reducing measured income inequality for poor households.

7.3 CONCERN OF PLANTATION FORESTRY

7.3.1 Electricity provision

Challenges associated with electricity provision as identified in this study include: unavailability of electricity for cooking and house heating and the resultant inability to use facilities such television, radio, etc. It is however difficult to determine the extent to which challenges of electricity provision have affected rural life in a broader context. Though electricity provision was an issue it was not significant. This correlates with Gugushe (2006) where it is reported that in some villages in the former Ciskei area of South Africa, most villagers prefer firewood for cooking and house heating despite the fact that they have access to electricity. Therefore it is possible that even if villagers in the study area are provided with electricity, they might still not be able to afford it.

7.3.2 Firewood and construction wood

Issues such as constraints in obtaining permits for firewood collection and constraints in obtaining house building permits are more pronounced in villages in the Iswepe area. The grievances of the villagers are more directed to charcoal producers (they use residues for charcoal production) and bureaucratic delay at Mondi office in Iswepe area. The charcoal producers are often accused of collecting residues from plantations close to the villages, thereby forcing the villagers to travel longer distances in sourcing for residues.

However, none of the respondents expressed scarcity of fuelwod as an issue of concern. Often difficulty in obtaining permits either for firewood or building wood collection was blamed on difficulty in having access to relevant Mondi officials; they claimed it was difficult to get the relevant Mondi official ‘on-seat’. Similar complaints were often raised when expressing difficulty in obtaining permits for house building or rebuilding.

7.3.3 Transportation

The main concern with transportation as observed in this study was centred on difficulty in getting commercial taxis to commute between the villages and Piet Retief or Iswepe main town and also on the poor condition of some of the roads that link the villages with the main town. Transportation concern such as difficulty in getting commercial vehicles that plies the village route is an issue that characterizes most rural communities around the world (Irwin, 1978). However, this type of challenge can be solved through an integrated approach by both the municipality and Mondi.

7.3.4 Relocation delay

The relocation project initiated by Mondi offers a ‘win-win’ opportunity to both the rural communities and Mondi, in that Mondi has an opportunity to reduce their plantation management risk, i.e. fire disaster, and provides rural communities improved facilities and infrastructure. The main issues associated with relocation delay as identified in this study were lack of proper access to information about their rights and options with regard to resources that will be available in the new sites. These uncertainties about the availability of resources, i.e. firewood, graze-land and farmland in the new site exacerbated their trauma. This accounts for why most villagers in the agrarian villages were not exited about the relocation project.

This relocation challenge is not unique to the forest industries. This type of challenge is found in the mining industries and in the petroleum industry where communities in some cases are relocated as part of company operational policy (Yakovleva, 2005). It is envisaged that through improved participatory approach, the issues around relocation delay will be solved. Relocation challenges have also been experienced in government developmental projects in various departments of the South African government. After the fall of apartheid in 1994, the new ANC government wrote into the constitution that shack dwellers, living four or five to a room in hovels at the centre of South Africa’s wealthiest cities, should have homes (Saunder, 2009). The attempted relocation of shack dwellers from prime real estate in the Durban city centre has been resisted (Saunder, 2009).

However, despite the concerns of plantation forestry discussed in this section, most of the plantation villagers are happy living in the plantations. Since plantation forestry is often practised in rural areas of South Africa with the highest level of poverty where it creates positive impacts through the provision of employment, direct use and income generating forestry activities and institutional arrangements between forestry companies, NGOs, government and rural communities. It can thus be argued that the direct and indirect benefits associated with Mondi plantations out-weigh the cost and concern issues associated with the plantations.

SECTION B

Results from the research study on the financial viability of conventional plantation forestry operations and the potential impact of integrated timber and bio-electricity production on both adjacent community and company are discussed in this section.

7.4 ESTIMATED AVAILABLE VOLUME OF RESIDUE FOR BIO-ELECTRICITY PRODUCTION

7.4.1 Trends in residue yield assessment

Two sources of residues were assessed for bio-electricity production; residues from Mondi plantations and residues from forest based industries in Piet Retief and Iswepe areas. Piet Retief sawmill is the only wood based company in the area that is able and willing to supply residue to the energy plant. The amount of residue from this source (4,800 t/ annum) is insufficient, and also the cost of procurement might make this residue source unattractive for the energy plant. However, the possibility of sourcing residue from this source is worth investigating as it has the capability of providing substantial amounts of feedstock to the energy plant especially in the event of unforeseen circumstance (e.g. fire outbreak) when the plantations are unable to supply the estimated amounts of residue. However, all things being equal, Mondi plantations in the study area are capable of annually supplying enough residues both for community needs and feedstock for the investigated 5MW energy plant.

The trends and pattern observed from the annual residue yield from Mondi plantations indicate that only gum plantations are capable of individually supplying annually required residues for the energy plant, if feedstock were to be sourced on per genus basis. The trends observed in the two investigated residue removal approaches showed that:

- ❖ For gum plantations when complete harvest of residue approach is adopted, 1,035.71 ha of plantation need to be harvested annually to supply residue to the energy plant. When partial removal of residue approach is used 5.85 tonnes of residue per hectare from total harvestable hectares (3,345 ha) will be required.

- ❖ Pine and Wattle plantations cannot supply annual requirements of feedstock to the energy plant, if feedstock were to be sourced on per genus basis.

However, because of the potential negative impact of intensive residue removal on soil fertility and sustainability of forest management (Röser *et al.*, 2008) it is important to determine a removal approach that will be environmentally, socially and financially viable.

7.4.2 Residue for bio-electricity vs. Residue for rural livelihood: The way forward

For sustainable supply of plantation residue for bioenergy production, the EU bio net 2 (2007) recommends that the following factors be considered:

- ❖ **Soil quality:** no residue should be removed from poor soils.
- ❖ **Harvesting yield:** only 65% of the residues should be removed.
- ❖ **Market availability:** forest owner’s willingness to sell.

When the above-mentioned three factors were considered, the complete residue removal approach remained the preferred choice, due to:

- ❖ If the complete residue removal approach is applied, compartments with poor soil quality can be excluded during residue removal. But if the partial removal approach were to be used, residue will have to be removed from all annual harvestable sites irrespective of the plantation’s soil quality.

- ❖ Though the partial residue removal approach offers the best assurance of not removing more than 65% of generated residue from plantations, it is still possible to achieve this target through the complete residue removal approach. As reported by Oldenburger and Probos (2006) field experiments usually differ from operational forestry, no technology is able to remove all residues from the site. For example, in Finland the salvage of logging residues from the final harvest, irrespective of the system applied, accounts for only some 70% of the crown mass (Alakangas, 1999 in Oldenburger and Probos, 2006). Thus it is possible that when the complete residue removal approach is used, only 65%-70% of generated residues will be harvested; leaving behind some residue for soil nutrient replenishment.

Results from section 6.2.3 showed that average annual residue consumption per household per village is 13,409 kg, i.e. 13.41 t (740 kg for agricultural use is usually once in a year so also 1,317 kg for house building, except for 946 kg for firewood that is on a monthly basis). The question then is will these amounts still be available if bio-electricity production is to be introduced?

The plantations are capable of yielding 94,684.75 t of residues annually. If the annual community need of 31,178.25 tonnes is removed, the remainder (63,506.50 t) is still more than enough for the 5MW plant. Results of residue supply analysis in section 6.7 showed that gum is the only genus that can solely supply residue for community needs and bio-electricity production if residue removal per genus plantation is to be considered. Other genera plantations (wattle and pine) can only do so when combined together. The breakdown of residue supply from gum plantations for both community need and energy plant is illustrated in Table 7.1.

Table 7.1: Generic residue supply for community livelihood and bio-electricity production

Genus	Available volume of residue (tonnes)	Amount required for 5MW plant (tonnes)	Amount remained after energy feedstock is taken (tonnes)	Amount required for community livelihood (tonnes)	Amount left after removal of feedstock and community need (tonnes)	Remarks
Gum	63,204.01	19,569.85	43,634.16	31,178.25	12,455.91	Gum plantation is able to supply residue annually for both community needs and energy plant.
Pine	15,332.36	19,569.85	0.00	31,178.25	0.00	Pine plantation cannot solely supply residue for either community needs or energy plant.
Wattle	16,148.37	19,569.85	0.00	31,178.25	0.00	Wattle plantation cannot solely supply residue for either community needs or energy plant.

7.4.3 Residue for bio-electricity; NERSA perspective

In June 2007 the National Energy Regulator of South Africa (NERSA) commissioned the "Renewable Energy Feed - In Tariff (REFIT) to support renewable energy in South Africa" study which culminated with the approval of the REFIT guidelines on 26 March 2009.

Under the REFIT two qualifying technologies approved for biomass energy is based on 100% forest wood with no mill waste, plants and residues from agriculture as well as tree plantations. The approved technologies also covers power generation from solid fuel (pellets, briquettes), projects based on these technologies are required to be located in close proximity of the biomass source (NERSA, 2009).

Thus electricity generation from forest residue as described in this study does not qualify for feed-in tariffs and as such is not available for feedback to the national grid. This implies there is no possibility of generating revenue through selling generated electricity to the national grid (ESCOM). However the viability of residue use for bio-electricity generation can be viewed from the perspective of meeting the energy requirement of the processing plants.

The attractiveness of bio-electricity production from residue will depend on the ability of Mondi to generate enough electricity that will cover all their plant energy needs, thereby making them independent of the national energy supply body (ESCOM) and improve their ‘green label’. The possibility of earning carbon credits through the use of bio-electricity from recovered residue is another incentive that can promote the attractiveness of this project. The gasification of solid biomass to generate electrical power is a potential Clean Development Mechanism (CDM) project activity within the Kyoto Protocol. Thus, if the development of the project follows the CDM Project development guidelines, the project investors (Mondi) will be able to earn the extra income of Carbon Credits (Persson, 2007).

7.5 PROFITABILITY OF BIO-ELECTRICITY GENERATION

7.5.1 Partial removal versus complete removal: social and economic impact

The trends and patterns observed in residue supply analysis indicates that complete removal is financially more viable. As reported by Oldenburger and Probos (2006), the aggregation of residues is necessary to some extent to get a sufficient quantity of residues at one place to make processing them viable. This explains why complete harvest of residue from selected plantations is financially more viable than partial harvest of residue from all annual harvestable hectares of plantations. However, irrespective of the approach used, the implication on plantation management and rural livelihood needs to be carefully evaluated.

When residue procurement logistics is considered, partial removal appears impractical. Complete removal offers the best logistical option for residue harvesting. If partial harvesting is used, it is more likely that the equipment involved in the harvest will be under-utilized and the cost of procurement will be unnecessarily high. The EU bio net 2 (2007) have demonstrated that aggregation of residue at a site is essential in order to promote maximum utilization of recovery equipment and reduce cost of recovery.

In sections 6.2.3 and 6.7 it has been shown that plantations in the study area can annually supply sufficient residue for both community needs and the energy plant. If the partial removal of residue approach is used, this will likely have a negative social impact since it will entail partial harvest of residues even from plantations that are in close proximity to villages. Complete harvest of residue approach offers the best option in avoiding social conflict as a result of residue harvest, as residue can be sourced a distance from villages and not from areas near villages. With the complete harvest approach, plantations that are in proximity to adjacent communities can be excluded during residue harvest. Apart from its economic and social acceptability, complete harvest provides the best option for accounting for soil fertility during residue removal decision-making. When complete removal approach is used, compartments with poor soil quality can easily be excluded during residue removal. Also with the complete harvest of residue approach, compartments harvested at the end of one rotation could be skipped at the end of the next rotation, thereby creating more time for soil nutrient replenishment.

Decreases in soil fertility and enhanced soil acidity are associated with residue removal irrespective of the residue removal approach used. This is mainly due to high concentrations of nutrients in small branches, twigs, and leaves compared to stems (Dovey, 2005; Röser *et al.*, 2008). However, recycling of generated ash from bio-electricity generation process has been demonstrated to counteract soil nutrient export problems (Röser *et al.*, 2008). Wood ash contains all the major mineral plant nutrients, except nitrogen, and has a liming effect when returned to the soil. Recycling of wood ash to the plantation is a demonstrated possible way of solving soil fertility depletion problems associated with residue removal and counteracts increased soil acidity. Ash recycling also helps in managing the ash instead of just depositing it as waste (Röser *et al.,* 2008).

However the profitability of recycling generated ash will depend on the quantity of ash generated and the logistical cost involved in transporting it to the plantations. Munalula and Meincken (2009) reported ash content of gum wood to be 2.38%. This means that annual infeed of 19,569.85 t of gum residue to the plant will yield 465.76 t of ash. The cost of annually recycling 465.76 tonnes of ash to the plantation will thus need to be investigated in order to determine the profitability of such action.

7.5.2 Availability of residue supply from generic perspective

The analysis in section 6.9 indicates that on per genus basis, only gum plantations are financially viable for integrated pulpwood and bio-electricity production, with complete residue removal being the most profitable option. But the results of the analysis was based on the assumption that generated residue will solely be used for bio-electricity production. Also, if the amount of residue required for community livelihood is to be sourced from only one genus, only gum plantations would be capable of supplying the required amount for community needs. Wattle plantations and pine plantations can annually supply 16,148.37 t and 15,332.36 t of residues respectively which are less than annual community residue needs of 31,178.25 t of residues.

7.5.3 Cost sensitivity

Table 7.2 was used to elaborate the effects of the sensitivities of the various cost components of the entire energy plant system.

Table 7.2: Cost sensitivity analysis

Cost component	Total	Percentage of total cost
Financial charges (repayment plus depreciation)	R12,764,915.67	67
Maintenance cost	R829,083.66	4
Wages	R2,448,000.00	13
Harvesting cost	R1,663,437.36	9
Chipping cost (at landing)	R1,087,888.04	6
Transport cost (chips)	R244,231.74	1
TOTAL COST	**R19,037,556.47**	**100**

Source: Survey result

The table above can be used to deduce the impact of variation in cost of any component of the energy plant value chain on the entire system. The profitability of the plant is mainly dependent on variations in the financial charges (67%) of the plant. Any factor that either reduces or increases the financial charges will have a major impact on the profitability of the entire operation (bio-electricity production). Variation in wages (13%) will have the second most significant impact on the profitability of the plant. Variation in either maintenance cost or transport cost of residue will have a minor impact on the profitability of the entire system (energy plant). Harvesting costs and chipping costs are respectively the third and fourth most signifcant cost components of the energy plant.

7.6 BIO-ELECTRICITY PRODUCTION IMPACT ON PROFITABILITY OF CONVENTIONAL PLANTATION FORESTRY OPERATIONS

Partial residue removal is not a financial viable option for integrated bio-electricity and pulpwood production. The trend observed under the partial removal approach shows that as the number of annual harvestable hectares increase, the tonnes of residue to be harvested per hectare decreases. This is because a fixed 19,569.85 t of residue is required for the energy plant and if this is to be sourced from a particular genus plantation, then it has to be evenly sourced from all harvestable genus plantations.

Therefore, as the number of annual harvestable hectares increase and tonnes of residue harvested per hectare decrease, the profitability of doing this (partial harvesting of residue) also decreases. This accounts for why the approach was not viable for gum plantations, where the number of harvestable hectares was 3,345 and amount of residue to be harvested per hectare was 5.85 tonnes.

The complete residue removal approach was found to be the most profitable option for integrated bio-electricity and pulpwood production. The trends observed in complete removal approach showed that profitability of integrated pulpwood and bio-electricity production increases as concentration of residues, i.e. recoverable amount of residue per hectare, increases. This fact is supported by the findings of Hubbard *et al.* (2007) in their study where residue use for bio-electricity production was found to be more viable than use of residue for liquid fuel production and use of dedicated energy plantation (poplar) for bio-electricity production. Gan and Smith (2007) also reported the viability of residue use for bio-electricity production with its associated co-benefits.

7.7 INTEGRATED BIO-ELECTRICITY AND PULPWOOD PRODUCTION: IMPACT ON ADJACENT COMMUNITIES

Results from the field study was used to predict potential impacts of integrated pulpwood and bio-electricity production on both adjacent communities and Mondi. Integrated bio-electricity and pulpwood production will have both positive and negative impacts on adjacent communities. Currently Mondi uses manual, semi-mechanized and mechanized systems in its harvesting operations, thus a whole tree harvest system will negatively affect certain categories of plantation workers. Mechanization will have both positive and negative impacts on communities and Mondi. In a study conducted by Fakisandla Consulting (2005) to assess the social impact of issues relating to the introduction of mechanized harvesting systems in Mondi; it was concluded that mechanization will help in solving labour issues such as worker availability, productivity and absenteeism. However, the negative impact of increased mechanization on employment has been identified and a social impact evaluation is being carried out in order to propose suitable mitigation measures (SQF, 2005).

The unskilled categories of plantation workers are expected to be affected most with this anticipated job loss as a result of mechanization. Villages in Piet Retief area have 1,153 plantation workers residing in them, while villages in Iswepe area have 1,172 plantation workers. Thus if mechanisation is introduced 141 and 138 chainsaw operators in Iswepe and Piet Retief area respectively will be in danger of loosing their jobs. If other low categories of plantation workers are brought into consideration, it will give a good overview of the potential impact this anticipated job loss will have in the rural communities. The overall benefit of integrated bioenergy production will therefore depend on how job losses as a result of introduction of whole tree harvest system will be balanced by job gains in the operation of the energy plant.

Of the total delivered cost structure for wood procurement, the harvesting component makes up 35% and transport represents another 35%. The labour that is freed from mechanization of the harvesting process can be redirected toward safer, less physically demanding job functions that are relatively less expensive components of the cost structure. For instance, the silviculture component which includes site preparation, planting, early stage weed control and pruning can be de-mechanized and chemical herbicide applications eliminated (Larocci, 2007).

As identified in section 6.10, increased difficulty in sourcing firewood is a potential negative impact that could arise as a result of integrated pulpwood and bio-electricity production. However, these can be avoided through the complete residue removal approach and by ensuring that residues are not harvested from plantations close to rural communities.

7.8 CONCLUSION

Mondi Forests plantations in Piet Retief and Iswepe areas are financially viable for integrated pulpwood and bio-electricity production. Given the right approach, the possible social impact of integrated pulpwood and bio-electricity production can be managed in a manner that offers the best 'win-win' approach for all stakeholders. The conclusion and recommendations are presented in the next chapter.

CHAPTER EIGHT

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The findings of this research work are summarized in this chapter. The chapter also contains recommendations which are based on the conclusions of the findings of this work. The conclusions and recommendations focus on both conventional forestry operations and integrated timber and bio-electricity production.

8.1.1 Conventional forest plantation operations

Adjacent communities to Mondi plantations in Piet Retief and Iswepe areas enjoy both direct and indirect benefits from the plantation. These benefits are evident in issues such as employment opportunities, utilization of plantation resources, accommodation, farmland, availability of grassland and social infrastructural services such as the provision of borehole, cemeteries, etc. However, despite these benefits, there are costs associated with living on Mondi land. These costs are evident in issues such as electricity supply, difficulty in residue collection, transportation and health services.

The communities residing in villages on Mondi Forest property have free access to harvest residues. This study has revealed that utilization of harvest residues play a significant role in rural livelihood of communities on Mondi land. Harvest residues utilization is a cash saving factor for the plantation dwellers. Utilization of residues and other non-timber plantation resources are used as a safety net in times of hardship which correspond with the findings of studies conducted elsewhere in Southern Africa (Akinnifesi *et al.*, 2006 in Kalaba 2007). However, it was established that few households are involved in collection and utilization of non-timber resources which was strongly influenced by seasonality of the non-timber resources.

The study also revealed that harvest residue is utilized for various purposes, with cooking (food preparation) being the most important utilization purpose of the harvest residue. Other utilization purposes are house warming, construction of fences and pens, and house building. Tree tops were found to be the most preferred residue type. This is followed by stumps and then branches. Bark is rarely used. While the rural communities fully acknowledged the important role of harvest residue in their livelihood, there are however no evidence of trade either of the residues or non-timber resources in the area.

8.1.2 Integrated pulpwood and bioelectricity production

On average, Mondi plantations in Piet Retief and Iswepe areas are capable of yielding 94,684.75 t of residues annually, which is enough to cater for annual community needs, i.e. 31,178.25 t/a for livelihood and feedstock as well as 19,569.85 t/a for the 5MW energy plant. A complete residue removal approach will present a viable option if taking economic, environmental and social issues into consideration while carrying residue recovery operation for bio-electricity production.

Residues are a large and under-exploited potential energy resource and present many opportunities for better utilization, and thus deserve particular attention. Plantation residues obtained from sustainably managed forests do not deplete the resource base; on the contrary, it can enhance and increase future productivity of forests. The implications of integrated pulpwood and bio-electricity production are potentially large, in particular for rural areas.

Incorporation of residue recovery for bio-electricity production into conventional plantation forestry operations will have cost and benefit effects on both Mondi and communities. Employment opportunities have long been recognized as being a major advantage of bio-electricity production because of the many multiplying effects which help to generate more economic activity and help strengthen the local economy, particularly in rural areas (Gan and Smith, 2007).

The implications for rural development could be far reaching if generated bio-electricity can supply a significant proportion of the rural energy requirements. Many commercial possibilities can be created with many social and economic benefits. In addition, there is a considerable potential for improving the environment. Generation of electricity from a renewable source is generally more environmental friendly.

However, bio-electricity production is a complex issue that depends on many and varying factors. Bio-electricity production should not be regarded as the panacea for solving energy problems in the rural areas, but as an activity that can play a significant role in improving forestry productivity, energy supply, the environment and sustainability. Its final contribution will depend on a combination of social, economic, environmental, energy and technological factors.

There are a number of important factors which need to be addressed when considering the use of residues for energy. Firstly, there are many other alternative uses, e.g. animal feed, erosion control, use as animal bedding; use as fertilizers (dung). Secondly, there is the problem of agreeing on a common methodology for determining what is and what is not a recoverable residue, e.g. estimates often vary by a factor of five. This is due, among other things, to different opinions regarding the amount of residue assumed necessary for maintaining soil organic matter, soil erosion control, efficiency in harvesting, losses, non-energy uses (FAO, 1999).

The study also found that large parts of the wood waste generated by sawmills are not used by surrounding communities and as such are available for bio-electricity production. However, the cost and logistics of procuring them may be a hindrance to its utilization for bio-electricity production.

8.2 RECOMMENDATIONS

8.2.1 Conventional forest plantation operations

In order to promote the benefits that adjacent communities derive from Mondi plantations in Piet Retief and Iswepe areas and reduce the cost associated with them, the following recommendations are suggested:

- ❖ There is a need for Mondi to periodically brief and enlighten its rural communities on the developmental stages and status of its various community development programmes in order to enable them to understand the status of each programme thereby promoting transparency and Mondi's image in the area. This strategy will help to solve the deteriorating communication link between Mondi and villagers residing on her property. The communication problem is almost becoming a recurring problem, it had earlier been cited by MBP (2005) and also re-occurred in this study.
- ❖ There is need to review permit application processes for firewood and construction wood collection in order to avoid unnecessary bureaucratic delay.
- ❖ Enabling access to forest resources alone cannot solve the livelihood problems of the communities (Prah, 1997 in Gugushe, 2006). Because of the important role of forestry in integrated rural development, it is thus recommended that Mondi and the Mkhondo Municipality improve on their partnership in addressing the need of the rural communities.

8.2.2 Integrated pulpwood and bio-electricity production

Any future specification for wood waste boiler technology utilization should clearly address: fuel quality and supply guarantees, fuel transport and storage arrangements, responsibilities for loading the fuel into the boiler, and ongoing on-site monitoring and maintenance requirements and responsibilities. It is particularly important for end users to be aware from the outset of their responsibilities for these areas and for appropriate arrangements to be in place and understood (Scrutiny Committee, 2005).

Companies need to address and mitigate displacement impacts associated with their operations. Companies need to consider how mechanization of forestry operations impacts employment opportunities, especially in developing countries where labour is inexpensive and workers are most vulnerable to poverty (Heaton, 2005).

Removing excess biomass can restore the balance and natural sustainability of the ecosystem and provide feedstock for energy systems, but poses economic, environmental and socio-political challenges. It is envisaged that integrated assessments of forest management practices, environmental conditions and socio-economic factors will not only improve productivity and forest health, but also result in the most efficient use of forest resources, including biomass for energy, from both natural forests and plantations in the world's major forest (Richardson, 2005).

In order to promote sustainable integrated pulpwood and bio-electricity production, the following recommendations are suggested:

- ❖ Removing residues from harvest sites might affect long-term site productivity, although these effects could be mitigated via adopting appropriate management practices. It is recommended that these benefits and costs be evaluated in future research.

- ❖ While the assessment methods demonstrated here could be applied to other regions, some benefits evaluated, such as community impacts, are location sensitive and may not offer direct and similar implications for other regions. It is thus recommended that before integrated pulpwood and bio-electricity production is adopted in any region careful evaluation of the likely social and economic impacts of the approach in the region be carried out.

- ❖ The impact of biomass and bioenergy development is closely related to such factors as the nature of the technology, local economic structures, social profiles, and production processes. Thus, a region-specific model should be developed to assess the socio-economic impacts.

- ❖ In order to manage the difficulty being experienced by the rural people in sourcing and collection of residue, it is recommended that measures be put in place to ensure that residue for charcoal or bio-electricity production are sourced from plantations that are not in close proximity of the villages.

- ❖ In addition, Mondi and other stakeholders should consider identifying alternative income generating activities for the rural communities as a way of increasing available quantity of residue for community need and bio-electricity production.

At a high level dialogue conference on forest bioenergy system utilization organized by Pinchot Institute and Heinz Centre; the following potential threats to a sustainable bioenergy industry establishment were identified (Heinz and Pinchot, 2009):

- ❖ The potential for over-harvesting on a local or regional scale caused by increased demand for biomass, sometimes compounded by multiple new facilities locating in close proximity to one another.
- ❖ Inflated perceptions of locally available and sustainable supplies of woody biomass stemming from oversimplified interpretation of forest inventory and growth statistics.
- ❖ The potential for site level impacts from biomass harvesting that may not adequately be addressed by current voluntary or regulatory mechanisms.

In addition Bauen *et al.* (2004) also recommended that bioelectricity schemes be subject to rigorous environmental impact assessments (EIAs) prior to implementation to address potential local negative impacts and capture the value of the benefits. Ash quality from conversion processes should be monitored and where possible efforts should be made to recycle ash back to plantations. They also recommend that biomass production practices must protect and / or enhance soil organic matter.

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APPENDICES

APPENDIX 1: FIELD SURVEY QUESTIONNAIRE

Socio-economic Aspects of Forest Bioenergy in Iswepe and Piet Retief area, South Africa

A questionnaire survey to solicit data as part of MSc. study in forestry. Information is for research only and every identity will be kept confidential.

Section 1: Demographics
1.1 Survey No: …………………………………………..
1.2 Date of Survey: ……………………………..
1.3 Community/Village Name. …………………………………………………..
1.4 Respondent Name: ………………..
1.5 Respondent Age: …………………….
1.6 Respondent ID number: ……………….
1.7 Name of Household/household head: …………………

Section 2: **Household Sample**

2.1 If working in a plantation/ forest company, what category of job do you mostly do? (Choose one)

Debarking…………. Machine operator ………….. Chain saw operator …………….

Silviculture work ……… Stacking …………

Others, please specify ………………………..

2.2 How many hours do you do work per day in the forest, indicate time spent on it?

…………………… Hours per day

2.3 Is the job seasonal, permanent or casual? (Choose one)

Seasonal …………….. Permanent……………….. Casual…………..

2.4 How many in your household work on the plantation or forest related job?

…………………..

2.5 What is your main benefit from the plantation? Tick the appropriate choice

	Tick
Thatch grass collection	
Farming	
Livestock grazing	
Wage labour	
Fuel wood gathering	

Others, please specify ………………………..

Section 3: Livelihood

3.1 Tick and quantify the things you get from the plantation to sustain your daily living, for consumption.

Product	Consumption(kg/m)
Rough wood for agricultural purposes	
Mushrooms	
Thatch grass	
Fodder for livestock	
Un-merchantable logs for building purposes	
Bark for domestic use	
Edible fruits and vegetables	
Fuel wood	

Others, please specify ………………………..

3.2 Indicate the frequency and season of collection of the plantation product you use?

PRODUCT	FREQUENCY (times per week)	SEASON
Fuel wood		
Rough wood for agriculture		
Mushrooms		
Thatch grass		
Fodder for livestock		
Un-merchantable logs for building		
Bark for domestic use		
Edible fruits and vegetables		

Section 4 Plantation benefit

4.1 State the most benefits of the plantation to your life and family

4.2 State the most dislikes, concerns and issues you have with the plantation.

Section 5: Harvest and thinning residue utilization

5.1 Are the harvest residues important to you?

Very Important: …….. Important: ……….. Not Important: ………

5.2 Do you make use of the residues?

Yes ……………… No …………………..

5.3 What category of the harvest residue do you use?

Bark ………….. Tops ……………. Branches …………

Stumps ……………

5.4 State the most important (a) and the least (b) important uses of the harvest residue

a. ……………….

b. ………………

5.5 What type of wood do you mostly collect as fuel wood? (Choose one)

Harvest left over ………. Bark ………… Un-merchantable logs……………….

Small round wood ………….. Others, please, specify ………………………

5.6 Do you buy your fuelwood?

Yes …………………….. No ………………..

5.7 If yes, how much does it cost you per month? ……………

5.8 What is the average size/diameter of the wood you mostly use as fuel wood?

……………….cm

5.9	Specify the quantity you collect per week (bundles)? …………………………..
5.10	What do you mostly use to cook your food? Rank from 1 to 4 Electricity:……………. Paraffin: ………… Firewood: …………………. Cow-dung: ………….. Others (please specify): ………..
5.11	What do you mostly use to heat your house? Rank from 1 to 5 Electricity: ……….. Paraffin: …….. Firewood: …….. Cow-dung: ……… Gas: …………. Others (please specify): ………
5.12	How important is wood to you for heating the house? Very important ………… Important …………….. Not important
5.13	How much do you spend per month on cooking and heating material? R …………
5.14	Does your community get compartments allocated from forest owners to collect firewood from harvesting residue ….? Yes………… No…………

APPENDIX 2: INTERVIEWED EXPERTS FROM MONDI BUSINESS PAPER

- Grant Ferguson – Area Manager, Piet Retief
- Renier le Roux – Area Manager, Iswepe
- Samson Muschabuki – Harvesting Manager, Piet Retief
- Hans Niebuhr – Mondi Packaging Mill, Piet Retief
- Stonie Steenkamp – Harvesting Manager, Iswepe
- Carolyn Chadwick – GIS Specialist, Piet Retief
- Johan Vivier – Mondi Packaging Mill, Piet Retief

APPENDIX 3: TABLE INDICATING ANNUAL YIELD OF UTILIZABLE VOLUME OF TIMBER

Area	Genus	Data	Year				
			2010	2011	2012	2013	2014
ISWEPE	Euc	Harvesting Ha's	1,930.6	1,909.1	1,749.1	1,912.7	1,901.9
		Util Volume m^3	339,366	317,560	319,087	354,410	360,218
		Util Volume Tonnes	271,493	254,048	255,270	283,528	288,174
		WtdAvg Age	10.1	9.4	9.4	9.6	9.8
		WtdAvg Mai tonnes/ha/yr	14.2	14.3	15.6	15.4	15.5
		WtdAvg tonnes/ha	140.6	133.1	145.9	148.2	151.5
	Pine	Harvesting Ha's	611.1	350.3	370.6	362.9	348.7
		Util Volume m^3	136,773	78,384	85,545	79,101	75,996
		Util Volume Tonnes	136,773	78,384	85,545	79,101	75,996
		WtdAvg Age	17.6	17.5	17.4	17.4	17.1
		WtdAvg Mai tonnes/ha/yr	12.6	12.7	13.3	12.5	12.7
		WtdAvg tonnes/ha	223.8	223.8	230.8	218.0	217.9
	Wattle	Harvesting Ha's	381.6	380.9	270.6	277.7	97.2
		Util Volume m^3	39,662	40,957	33,936	34,455	12,101
		Util Volume Tonnes	33,329	34,417	28,518	28,954	10,169
		WtdAvg Age	13.8	12.8	13.1	13.0	13.3
		WtdAvg Mai tonnes/ha/yr	6.3	7.1	8.0	8.0	7.9
		WtdAvg tonnes/ha	87.3	90.4	105.4	104.3	104.6

Area	Genus	Data					
			2010	2011	2012	2013	2014
PIET RETIEF	Euc	Harvesting Ha's	1,480.6	1,406.0	1,429.1	1,564.7	1,441.7
		Util Volume m^3	240,603	239,700	242,103	270,046	261,886
		Util Volume Tonnes	192,483	191,760	193,682	216,036	209,509
		WtdAvg Age	8.5	8.4	8.4	8.7	9.1
		WtdAvg Mai tonnes/ha/yr	15.3	16.2	16.1	15.9	16.0
		WtdAvg tonnes/ha	130.0	136.4	135.5	138.1	145.3
	Pine	Harvesting Ha's	83.8	92.4	82.5	86.6	111.3
		Util Volume m^3	21,515	19,969	21,343	22,246	25,114
		Util Volume Tonnes	21,515	19,969	21,343	22,246	25,114
		WtdAvg Age	20.0	20.4	20.4	20.4	18.3
		WtdAvg Mai tonnes/ha/yr	12.7	10.6	12.7	12.6	12.4
		WtdAvg tonnes/ha	256.7	216.1	258.7	256.9	225.6
	Wattle	Harvesting Ha's	330.9	338.2	374.0	105.4	104.2
		Util Volume m^3	43,399	42,410	43,619	12,968	13,103
		Util Volume Tonnes	36,470	35,639	36,655	10,898	11,011
		WtdAvg Age	14.2	11.1	11.0	11.3	11.7
		WtdAvg Mai tonnes/ha/yr	7.8	9.4	8.9	9.2	9.1
		WtdAvg tonnes/ha	110.2	105.4	98.0	103.4	105.7

APPENDIX 4: BIOMASS ESTIMATION RATIO (DOVEY, 2005 MODEL)

Ratios to convert Timber Volume to dry mass (ICFR Bulletin Series: No 13/2005)				
	INPUT ONLY			POTENTIAL BIOMASS
Species	**Utilizable Timber Volume (m^3/ha)**	**Oven Dry Stem Wood(t/ha)**	**Oven Dry Bark (t/ha)**	**Oven Dry Branches (t/ha)**
A. mearnsii	100	65.4	8.5	17.0
E. dunnii	100	53.6	8.6	6.4
E. grandis	100	45.0	5.4	5.4
E. macarthurii	100	55.1	8.3	11.6
E. nitens	100	52.6	6.3	17.9
E. smithii	100	58.1	5.8	12.2
P. patula	100	38.7	3.5	10.1

Notes:

1 Utilizable timber volume = ave m^3/tree * Spha.

2 Biomass = branches in oven dry tonnes/ha (no stem material > 5.0 cm dia), no bark or leaves.

APPENDIX 5: SUMMARY OF ANNUAL ESTIMATED RESIDUE YIELD FROM MONDI PLANTATIONS

EXPECTED YIELD OF HARVEST RESIDUE IN 2010

Area	Genus	Oven dry (t/ha)		Total yield per hectare (t/ha)	Harvestable hectare	Overall residue yield in the year (t)
		Bark	Branches			
ISWEPE	Gum (*E. grandis*)	8.98	8.98	17.96	1,930.6	34,673.58
	Pine (*P. patula*)	7.80	22.52	30.32	611.1	18,528.55
	Wattle *(A. mearnsii)*	8.82	17.67	26.49	381.6	10,108.58
	Total	25.60	49.17	74.77	2,923.30	63,310.71
PIET RETIEF	Gum *(E. grandis)*	8.77	8.77	17.54	1,480.6	25,969.72
	Pine *(P. patula)*	8.94	25.83	34.77	83.8	2,913.73
	Wattle *(A. mearnsii)*	11.15	22.30	33.45	330.9	11,068.61
	Total	28.86	56.90	85.76	1,895.30	39,952.06
Grand total		**54.46**	**106.07**		**4,818.60**	**103,262.77**

EXPECTED YIELD OF HARVEST RESIDUE IN 2011

Area	Genus	Oven dry (t/ha)		Total yield per hectare (t/ha)	Harvestable hectare	Overall residue yield in the year (t)
		Bark	Branches			
ISWEPE	Gum *(E. grandis)*	8.98	8.98	17.96	1,909.1	34,287.44
	Pine *(P. patula)*	7.79	22.51	30.30	350.3	10,614.09
	Wattle *(A. mearnsii)*	9.14	18.28	27.42	380.9	10,444.28
	Total	25.91	49.77	75.68	2,640.30	55,345.81
PIET RETIEF	Gum *(E. grandis)*	9.21	9.21	18.42	1,406.0	25,898.52
	Pine *(P. patula)*	7.53	21.74	29.27	92.4	2,704.55
	Wattle *(A. mearnsii)*	10.66	21.32	31.98	338.2	10,815.64
	Total	27.40	52.27	79.67	1,836.60	39,418.71
Grand total		**53.31**	**102.04**		**4,476.90**	**94,764.52**

EXPECTED YIELD OF HARVEST RESIDUE IN 2012

Area	Genus	Oven dry (t/ha)		Total yield per hectare (t/ha)	Harvestable hectare	Overall residue yield in the year (t)
		Bark	Branches			
ISWEPE	Gum *(E. grandis)*	9.85	9.85	19.70	1,749.1	34,457.27
	Pine *(P. patula)*	8.04	23.23	31.27	370.6	11,588.66
	Wattle *(A. mearnsii)*	10.66	21.32	31.98	270.6	8,653.79
	Total	28.55	54.40	82.95	2,390.3	54,699.72
PIET RETIEF	Gum (E. *grandis*)	9.15	9.15	18.30	1,429.1	26,152.53
	Pine (P. *patula*)	9.01	26.03	35.04	82.5	2,890.8
	Wattle *(A. mearnsii)*	9.92	19.83	29.75	374.0	11,126.5
	Total	28.08	55.01	83.09	1,885.6	40,169.83
Grand total		**56.63**	**109.41**		**4,275.9**	**94,869.55**

EXPECTED YIELD OF HARVEST RESIDUE IN 2013

Area	Genus	Oven dry (t/ha)		Total yield per hectare (t/ha)	Harvestable hectare	Overall residue yield in the year (t)
		Bark	Branches			
ISWEPE	Gum (E. *grandis*)	10.00	10.00	20.00	1,912.7	38,254.0
	Pine (P. *patula*)	7.59	21.93	29.52	362.9	10,712.81
	Wattle *(A. mearnsii)*	10.55	21.10	31.65	277.7	8,789.21
	Total	28.14	53.03	81.17	2,553.3	57,756.02
PIET RETIEF	Gum (E. *grandis*)	9.32	9.32	18.64	1,564.7	29,166.01
	Pine (P. *patula*)	8.95	25.85	34.80	86.6	3,013.68
	Wattle *(A. mearnsii)*	10.46	20.92	31.38	105.4	3,307.45
	Total	28.73	56.09	84.82	1,756.7	35,487.14
Grand total		**56.87**	**109.12**		**4,310**	**93,243.16**

EXPECTED YIELD OF HARVEST RESIDUE IN 2014

Area	Genus	Oven dry (t/ha)		Total yield per hectare (t/ha)	Harvestable hectare	Overall residue yield in the year (t)
		Bark	Branches			
ISWEPE	Gum *(E. grandis)*	10.22	10.22	20.44	1,901.9	38,874.84
	Pine *(P. patula)*	7.59	21.93	29.52	348.7	10,293.62
	Wattle *(A. mearnsii)*	10.58	21.17	31.75	97.2	3,086.1
	Total	28.39	53.32	81.71	2,347.8	52,254.56
PIET RETIEF	Gum *(E. grandis)*	9.81	9.81	19.62	1,441.7	28,286.15
	Pine *(P. patula)*	7.86	22.70	30.56	111.3	3,401.33
	Wattle *(A. mearnsii)*	10.69	21.38	32.07	104.2	3,341.70
	Total	28.36	53.89	82.25	1,657.2	35,029.18
Grand total		**56.75**	**107.21**		**4,005**	**87,283.74**

APPENDIX SIX: BIO-ELECTRICITY OUTPUT CALCULATION MODEL

INVESTMENT COST FOR 5MW GREENFORZE PLANT		
Capital cost for Greenforze plant in 2007	R39,066,000.00	Persson (2007)
Inflation	R 0.08	
Thus capital cost adjusted for inflation to give 2009 value	R 45,196,055.45	
Capital cost for Greenforze 5MW plant	R 45,196 ,055.45	
Foundation and building	R 3,705 ,138.00	(Doderer, 2009)
Miscellaneous	R 3,571 ,000.00	(Doderer, 2009)
Drying machine	R 2,800, 050.57	
Total	R 55,272, 244.02	

Annual Operation and Maintenance Cost						
MAINTENANCE		@	1.5%	of capital cost per year (Doderer, 2009)		R 829,083.66
WAGES	Annual labour (per 3 x 8 hour shifts); semi-skilled personnel,operator and helper					R 2,448,000.00
Semi-skilled personnel				R 816,000.00	(Doderer, 2009)	
Night-shift team leaders				R 816,000.00	(Doderer, 2009)	
Worker per shift (3 x 8 hours per day)				R 816,000.00	(Doderer, 2009)	
Total						R 3,277,083.66

Technical Assumptions				
Total hours per year	8760	(24x 365)		
Technical availability of plant	80%			
Operating hours per year	7008			
Electrical effecincy	35.00%	of plant efficiency		
Thermal efficiency	65.00%	of plant efficiency		
Gum biomass energy	18.25	MJ/kg/15%MC	(Munalula & Meincken, 2009)	
Pine biomass energy	18.44	MJ/kg/15%MC	(Munalula & Meincken, 2009)	
Wattle biomass energy	18.56	MJ/kg/15%MC	(Munalula & Meincken, 2009)	
Average biomass energy	18.42	MJ/kg/15%MC		
Harvesting cost biomass	R 85.00	Ton		Average of FES harvesting cost for pine wattle and gum
Chipping at landing	R 55.59	Ton	(EECA, 2007)	Converted to South African Rand with currency converter 5th September 2009
Chipping at plant	R 27.80	Ton	(EECA, 2007)	Converted to South African Rand with currency converter 5th September 2009
Lead distance transport	26	km		
Transport loose material	15.6	R/ton	(EECA, 2007)	Adapted to South African situation using the South African Road Freight cost
Transport chips	12.48	R/ton	(EECA, 2007)	Adapted to South African situation using the South African Road Freight cost

Cost and volume of biomass						
Installed Capacity MW	5	10	20	30	40	50
Infeed capacity required (electrical ouput) (MJ/s)	14.29	28.57	57.14	85.71	114.29	142.86
Infeed capacity required (electrical ouput) (MJ/h)	51,428.57	102,857.14	205,714.29	308,571.43	411,428.57	514,285.71
Infeed biomass per hour (kg)	2,792.50	5,585.00	11,170.01	16,755.01	22,340.01	27,925.02
Volume of biomass required (ton/annum)	19,569.85	39,139.70	78,279.41	117,419.11	156,558.81	195,698.51
Harvesting cost	R 1,663,437.36	R 3,326,874.73	R 6,653,749.45	R 9,980,624.18	R 13,307,498.90	R 16,634,373.63
Chipping costs at landing	R 1,087,888.04	R 2,175,776.07	R 4,351,552.14	R 6,527,328.21	R 8,703,104.28	R 10,878,880.35
Chipping costs at energy plant	R 544,041.87	R 1,088,083.73	R 2,176,167.47	R 3,264,251.20	R 4,352,334.93	R 5,440,418.67
Transport costs loose material	R 305,289.68	R 610,579.36	R 1,221,158.72	R 1,831,738.08	R 2,442,317.45	R 3,052,896.81
Transport cost chips	R 244,231.74	R 488,463.49	R 976,926.98	R 1,465,390.47	R 1,953,853.96	R 2,442,317.45
Cost of biomass at plant for chipping at landing	R 2,995,557.14	R 5,991,114.28	R 11,982,228.57	R 17,973,342.85	R 23,964,457.14	R 29,955,571.42
Cost of biomass at plant for chipping at plant (transport loose)	R 2,512,768.91	R 5,025,537.82	R 10,051,075.64	R 15,076,613.46	R 20,102,151.28	R 25,127,689.10

Financial assumptions		
Real interest rate	5.62%	
Depreciation period	10	Years
Repayment period	120	months
Monthly rate	0.47%	
Selling price of electricity Based on NERSA value for landfill gas (Nersa, 31 March 2009)	0.90	R/KWh

Income statement						
Installed Capacity MW	5	10	20	30	40	50
Investment cost	R 55,272,244.02	R 110,544,488.05	R 221,088,976.10	R 331,633,464.14	R 442,177,952.19	R 552,722,440.24
Income						
Electricity produced MW (7008 hours)	35,040.00	70,080.00	140,160.00	210,240.00	280,320.00	350,400.00
Electricty produced KWh	35,040,000.00	70,080,000.00	140,160,000.00	210,240,000.00	280,320,000.00	350,400,000.00
Income from electricity sales	R 31,536,000.00	R 63,072,000.00	R 126,144,000.00	R 189,216,000.00	R 252,288,000.00	R 315,360,000.00
Costs						
Depreciation (10 year straight line)	R 5,527,224.40	R 11,054,448.80	R 22,108,897.61	R 33,163,346.41	R 44,217,795.22	R 55,272,244.02
Finance costs (real rate 5.62% over 10 years)	R 7,237,691.27	R 14,475,382.55	R 28,950,765.10	R 43,426,147.65	R 57,901,530.20	R 72,376,912.74
Maintenance cost	R 829,083.66	R 1,658,167.32	R 3,316,334.64	R 4,974,501.96	R 6,632,669.28	R 8,290,836.60
Wages	R 2,448,000.00	R 4,896,000.00	R 9,792,000.00	R 14,688,000.00	R 19,584,000.00	R 24,480,000.00
Cost of biomass if chipped at landing	R 2,995,557.14	R 5,991,114.28	R 11,982,228.57	R 17,973,342.85	R 23,964,457.14	R 29,955,571.42
Cost of biomass if chipped at plant	R 2,512,768.91	R 5,025,537.82	R 10,051,075.64	R 15,076,613.46	R 20,102,151.28	R 25,127,689.10
Total cost (chip at landing)	R 19,037,556.48	R 38,075,112.96	R 76,150,225.92	R 114,225,338.88	R 152,300,451.84	R 190,375,564.80
Total cost (chip at plant)	R 18,554,768.25	R 37,109,536.49	R 74,219,072.99	R 111,328,609.48	R 148,438,145.98	R 185,547,682.47
Profit/loss (chip at landing)	R 12,498,443.52	R 24,996,887.04	R 49,993,774.08	R 74,990,661.12	R 99,987,548.16	R 124,984,435.20
Profit/loss per KWh	R 0.36	R 0.36	R 0.36	R 0.36	R 0.36	R 0.36
Profit/ loss (chip at plant)	R 12,981,231.75	R 25,962,463.51	R 51,924,927.01	R 77,887,390.52	R 103,849,854.02	R 129,812,317.53
Profit/loss per KWh	R 0.37	R 0.37	R 0.37	R 0.37	R 0.37	R 0.37

APPENDIX SEVEN: COST DETAILS FOR CASH FLOW ANALYSIS

The cost details presented here are from FES (2008) for Mpumalanga province of South Africa

CAPITAL

Land value per hectare R2, 640.00

COST DETAILS FOR ANALYSIS OF GUM PLANTATION OPERATIONS.

- Rotation age 8 years

OPERATION	**COST**	**UNITS**
LAND PREPARATION		
Herbicides	210.60	R/ha
Contractors	1,164.59	R/ha
Total	1,375.19	R/ha
PLANTING		
Plants	1,113.05	R/ha
Contractors	756.96	R/ha
Insecticides/planting gel	70.25	R/ha
Total	1,940.26	R/ha
BLANKING		
Plants	90.94	R/ha
Contractors	133.30	R/ha
Total	224.24	R/ha
FERTILIZING		
Fertilizer	660.32	R/ha
Contractors	200.36	R/ha
Total	860.68	R/ha
WEED CONTROL		
Herbicides	85.72	R/ha
Contractors	207.82	R/ha
Total	293.54	R/ha

CLEARFELLING TO ROADSIDE		
Contractors	51.38	R/tonne
LOADING INFIELD AND AT DEPOT OR SIDING		
Contractors	8.32	R/tonne
SHORTHAUL TO TRANSHIPPING DEPOT		
Contractors	43.02	R/tonne
REVENUE		
Actual tonnes sold	140.47	Tonnes/ha
Timber sold free on rail or depot	305.14	R/tonne
Total revenue	42,863.00	R/tonne/ha

Total cost involved in clear-felling per tonne = R43.02 + R8.32 +R51.38 = R102.72

For Integrated bio-energy production clear-felling cost = R43.02+R8.32 +R85= R136.34

Total harvested ton of gum pulp per hectare = 140.47 tonnes

Cost of harvesting per hectare = R102.72 x 140.47 tonnes = R14, 429

Cost of integrated bio-energy harvesting per hectare = R136.34 x 140.47 tonnes =R19, 151.68/ha

ANNUAL COST

OPERATION	**COST**	**UNITS**
Forest protection and tree insurance	153.23	R/ha
Fire fighting	40.9	R/ha
Conservation and environmental management	21.71	R/ha
Road maintenance	59.24	R/ha
Building maintenance	22.51	R/ha
Maintenance of other improvement	5.37	R/ha
Community development	1.54	R/ha
Total	304.5	R/ha

APPENDIX EIGHT: CASH FLOW ANALYSIS TABLES

Table A: Conventional gum pulp production operations

Interest = 5.62%

Year	Activity	Direct Cost	Annual cost	Total Cost	Gross revenue	Net cash flow	Present Value
0	land	R 2,640.00					
0	land preparation	R 1,375.19					
0	Establishment	R 2,164.50		R 6,179.69		-R 6,179.69	-R 6,179.69
1	fertilizing	R 860.68	R 304.50	R 1,165.18		-R 1,165.18	-R 1,103.18
1	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 566.22
2			R 304.50	R 304.50		-R 304.50	-R 272.96
3	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 507.57
4			R 304.50	R 304.50		-R 304.50	-R 244.68
5			R 304.50	R 304.50		-R 304.50	-R 231.66
6			R 304.50	R 304.50		-R 304.50	-R 219.34
7			R 304.50	R 304.50		-R 304.50	-R 207.67
8	Clear fell	R 14,429.00	R 304.50	R 14,733.50	R 42,863.00	R 30,769.50	R 19,867.86
	Land				R 2,640.00		
						NPV	R 10,334.90
						IRR	15.10%

Table B: Integrated gum pulp and bio-electricity production (partial residue harvest)

Interest = 5.62%

Year	Activity	Direct Cost	Annual cost	Total Cost	Gross revenue	Net cash flow	Present Value
0	land	R 2,640.00					
0	land preparation	R 1,375.19					
0	Establishment	R 2,164.50		R 6,179.69		-R 6,179.69	-R 6,179.69
1	fertilising	R 860.68	R 304.50	R 1,165.18		-R 1,165.18	-R 1,103.18
1	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 566.22
2			R 304.50	R 304.50		-R 304.50	-R 272.96
3	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 507.57
4			R 304.50	R 304.50		-R 304.50	-R 244.68
5			R 304.50	R 304.50		-R 304.50	-R 231.66
6			R 304.50	R 304.50		-R 304.50	-R 219.34
7			R 304.50	R 304.50		-R 304.50	-R 207.67
8	Clearfell plus bioelectricity	R 24,698.70	R 304.50	R 25,003.20	R 52,290.82	R 29,927.62	R 19,324.26
	Land				R 2,640.00		
						NPV	R 9,791.30
						IRR	14.71%

Table C: Integrated gum pulp and bio-electricity production (complete residue harvest)

Year	Activity	Direct Cost	Annual cost	Total Cost	Gross revenue	Net cash flow	Present Value
0	land	R 2,640.00					
0	land preparation	R 1,375.19					
0	Establishment	R 2,164.50		R 6,179.69		-R 6,179.69	-R 6,179.69
1	fertilising	R 860.68	R 304.50	R 1,165.18		-R 1,165.18	-R 1,165.18
1	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 598.04
2			R 304.50	R 304.50		-R 304.50	-R 304.50
3	weeding	R 293.54	R 304.50	R 598.04		-R 598.04	-R 598.04
4			R 304.50	R 304.50		-R 304.50	-R 304.50
5			R 304.50	R 304.50		-R 304.50	-R 304.50
6			R 304.50	R 304.50		-R 304.50	-R 304.50
7			R 304.50	R 304.50		-R 304.50	-R 304.50
8	Clear fell plus bioelectricity	R 49,095.15	R 304.50	R 49,399.65	R 93,755.44	R 46,995.79	R 46,995.79
	Land				R 2,640.00		
						NPV	R 36,932.34
						IRR	21.16%