The importance of biomass and its supply chain: challenges facing forest fuel biomass supply chains in South Africa

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ABSTRACT

Globally organisations are faced with the increasing problem and focus on seeking to produce energy using processes that are less harmful to the environment, ensuring reduced environmental pollution that will result in a sustainable healthy environment for the future. Energy produced from non-renewable matter like fossil fuels, for example, has been shown to increase environmental pollution compared to energy produced from renewable matter like biomass. Therefore, many countries are developing national energy strategies or policies that target the reduction of the high dependency on energy produced from fossil fuel and moving towards renewable energy that is produced from biomass which is bioenergy.

This study explores the challenges of how a sustainable forest fuel biomass supply chain can be established in South Africa, to supply the required volumes of forest fuel biomass to multifuel biomass boiler organisations to produce bioenergy. This research study used a qualitative, exploratory and inductive research methods to gain insights into how this forest fuel biomass supply chain can be established. The data was collected through 12 in-depth, semi-structured interviews with farmers, biomass boiler operational stuff and forestry management personnel. The interviews were transcribed, coded and analysed to answer the research questions.

The study confirmed that transparency and openness through the forest fuel biomass supply chain was imperative as it has been identified through the review of the literature, and risk management needed to be incorporated when establishing the supply chain. A framework is presented that would help with the establishment of the forest fuel biomass supply chain.

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KEYWORDS

Forest Fuel Biomass Supply Chain, Biomass Supply Chain Decision Making Model, Supply Chain, Supply Chain Risk Management, Forest Fuel Biomass

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DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research

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Table of Contents

List of Tables

List of Figures

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CHAPTER 1 - INTRODUCTION TO THE RESEARCH PROBLEM

1.1. Introduction

This study explores the development of biomass supply chains in South Africa, as countries and companies are being forced to consider the increased environmental impact that is associated with energy generated from fossil fuel. The exploratory study will seek to identify challenges that farmers based in South Africa face in creating a biomass supply chain to ensure a sustainable forest fuel biomass supply to the organisations requiring this to generate energy.

1.2. Background to the Problem

Globally organisations are faced with the increasing problem and focus on seeking to produce energy using processes that are less harmful to the environment, ensuring reduced environmental pollution that will result in a sustainable healthy environment for the future. Energy produced from fossil fuel, for example, has been shown to increase environmental pollution compared to that produced from biomass (Asada & Stern, 2018; Mertens, Van Lancker, Buysse, Lauwers, & Van Meensel, 2019). Fossil fuel energy is energy generated from non-renewable matter like oil, natural gas and coal. Fossil fuel has been in abundance for a long time and has been the cheapest form of energy generation, but it is now being put under pressure because of its negative impact on the environment (Bebbington, Schneider, Stevenson, & Fox, 2020). Thus, many countries are developing national energy strategies or policies that target the reduction of the high dependency on energy produced from fossil fuel, and moving towards renewable energy that is produced from biomass which is bioenergy (Lochhead, Ghafghazi, Havlik, Forsell, Obersteiner, Bull, & Mabee, 2016). Bioenergy is renewable energy produced from organic renewable matter found in industries like forestry, fisheries and agriculture (Giampietro, 2019; Üster & Memisoglu, 2018).

The biomass industry is also receiving focus in the area of supply chain management because of the rapid growth of this industry, generated by the environmental regulations and renewable energy growth (Álvarez-Rodríguez, Normey-Rico, & Flesch, 2017). With the increased focus on renewable energy resulting from increased environmental regulations by governmental agencies, it is important that the biomass supply chain is understood and developed to ensure sustainable supply of biomass to organisations that have started to diversify their energy production processes to incorporate renewable bioenergy production and to slowly move away from fossil fuel based energy production processes.

1.3. The Research Problem

As the focus on renewable energy is enforced by governments worldwide, strategies and policies to reduce the use of fossil fuel-based feedstock to produce energy are being put in place because these non-renewable matters are being overexploited and depleted (Carraresi, Berg, & Broring, 2018). In addition their use thereof also impacts the environment in a negative way (Urmetzer, Lask, Vargas-Carpintero, & Pyka, 2020). Alternative processes of energy production that have less negative environmental impacts are therefore being researched.

These alternative processes include the production of energy using renewable resources like biomass. The bioenergy produced from these renewable natural resources called biomass is much cleaner and has less negative environmental problems. However, for organisations that are currently in transition from fossil fuel-based feedstock to biomass feedstock, there can be other problems and challenges, including the need for reliable, sustainable supplies of biomass to ensure they can produce sufficient energy to meet their requirements and to meet their market demand.

This transition on a global scale would ensure that world economies move from fossil-based economy processes towards a bioeconomy with respect to the production of food, feed, materials and energy from plant-based materials (Mertens, Van Lanker, Buysse, Lauwers, & Van Meensel, 2019). With this transition again comes the problems and challenges of developing technologies to harvest, transport and also process the biomass into competitive and valuable products (Mertens et al., 2019). Furthermore, these new products need to be distributed through existing and new supply chains.

With respect to the development of bio-economy supply chains, there appear in theory to be many options, for example with the abundance of forest biomass, this could be used as biomass feedstock to fuel biomass boilers in order to generate energy, however the various challenges involved need to be identified and understood. Forest biomass is matter that is left behind after the harvesting of forests that cannot be used for further processing at sawmills or for pulp and paper mills, and this includes tree branches, tree tops and low quality logs (Flisberg, Frisk, & Rönnqvist, 2018; Gunnarsson, Rönnqvist, & Lundgren, 2004).

Therefore forest biomass usage is rapidly becoming more important because apart from hydro plants and nuclear power plants, forest biomass is a major source of energy production that is not harmful to the environment (Flisberg et al., 2018). However, farmers need to understand how important a sustainable supply chain for this forest biomass and fuel is, how they can ensure that it is optimised for adequate supply throughout the year, for example incorporating seasonal fluctuations in demand (Gunnarsson et al., 2004), and what problems and challenges are associated with establishing and managing the supply chain. These questions and problems need to be addressed so that organisations will continuously have sufficient forest fuel biomass feedstock to optimise energy production and minimise the usage of fossil fuel for energy production.

These biomass fuel products, or forest fuel for example, cannot be transported as is, especially over long distances because they cannot be packed efficiently in trucks, and thus the truck will end up transporting dead space as compared to more economically packed round wood logs. The forest fuel will therefore have to be chipped, converted into smaller pieces, before it can be transported to the various plants where they will be used for bioenergy production (Gunnarsson et al., 2004). With the growing use of forest biomass for energy production, an effective planning system to establish and manage the supply chain of forest biomass needs to be in place to ensure that this forest biomass is transported in a cost effective way (Flisberg et al., 2018).

The biomass supply chain will also require the establishment of which areas are most profitable for the forest fuel biomass supply, which customers are profitable to supply to, which machines should be used for processing and production and where should they be located, and how should the forest fuel biomass be transported, including which combination of transport modes for example road and rail (Flisberg et al., 2018).

In addition, and in line with international trends, the South African government is also seeking to enforce more environmentally friendly fuel use and supply, therefore the various challenges involved therein will need to be identified and addressed within any existing or established biomass supply chain.

In conclusion, the environmental problems associated with fossil fuel supply and use, are adding impetus to the establishment of biomass fuel supply and use worldwide, including in South Africa, however several problems and challenges associated with this development need to be explored which this study aims to address, in a South African context, and which is further discussed in the following section on the research purpose.

1.4. The Research Purpose

With the increased focus on bioenergy production due to global environmental trends, and governmental regulations and policies that have been developed to protect the environment, it is important that the supply chain of the forest fuel biomass that is the feedstock to the biomass boilers and fuel production, be researched to ensure sustainable supply of the forest fuel biomass addressing challenges such as the fluctuating seasonal demands (Lochhead et al., 2016). For organisations to move away from a fossil fuel based economy that heavily relies on coal, natural gas and oil for its energy production, processes need to be put in place to ensure that organisations can provide sustainable energy produced from renewable matter like forest biomass to transition into the bio-economy (Giampietro, 2019).

Therefore, the purpose of this study, in line with the problems already outlined, is to explore the importance of and challenges in biomass supply chain development and management in South Africa, particularly with respect to how forest fuel biomass can be efficiently supplied and used as sustainable feedstock to generate bioenergy. The research will thus focus on how private farmers can derive value from their forest biomass and be involved in establishing a supply chain that will supply organisations that have biomass boilers with sustainable biomass at all times.

The study therefore be focuses on private farmers that are in partnership with the South African Pulp and Paper Industries (Sappi) to investigate (i) how the forest fuel biomass uses and distribution are understood by the entities, (ii) how a supply chain that can sustainably provide forest fuel biomass from private farmers to organisations like Sappi can be established, to produce bioenergy that has significantly less negative environmental impact compared to the fossil fuel that is currently being used, and (iii) what challenges these private farmers and their partners, in this case Sappi, may have in establishing and managing a forest fuel biomass supply chain.

1.5. Scope of the Research

The scope of this research was limited to understanding how a forest fuel biomass supply chain can be established to ensure a sustainable supply of forest fuel biomass to Sappi biomass boilers or any other biomass boilers. It focused on the supply chain of private farmers that are in partnership with Sappi and are already supplying Sappi with timber for their pulp and paper production processes. The pulp and paper industry has already developed systems that co-fire fossil fuel and biomass or black liquor which is the pulping by-product to generate energy in their combustion boilers (Young, Anderson, Naughton, & Mullan, 2018). Thus using Sappi Ngodwana mill which is a pulp and paper company was the best way to investigate the economic value and supply of the forest fuel biomass, the recognition of the value and supply, and the optimal distribution and use thereof, to benefit both Sappi Ngodwana mill and the private farmers. The scope of this research was thus restricted to farmers in South Africa, that are based in Mpumalanga Province and supplying timber to one of the Sappi mills namely Sappi Ngodwana and other entities that use timber logs.

1.6. Significance of the Research

Earlier research has shown that globally many countries are developing national energy strategies or policies to protect the environment against the impact of generating energy from fossil fuel based matter and thus they are reducing the high dependency on energy produced from fossil fuel and moving towards renewable energy that is produced from biomass which is bioenergy (Lochhead et al., 2016). However, more research and theoretical understanding and insight are required, for example with respect to various aspects of the biomass supply, and related challenges, as a developing field of study (Álvarez-Rodríguez et al., 2017; Bebbington et al., 2020).

This is also true in the South African business context, for example, regarding the importance of developing the biomass supply chain, and ensuring it can sustainably supply forest fuel biomass to the developing bioeconomy**.** The South African government has also introduced regulations that ensure organisations start thinking differently about their impact on the environment and how they can minimise it going forward. They have put initiatives in place like carbon tax that organisations have to pay based on a calculated method on how much greenhouse gases they emit in their industry (Rebublic of South Africa, 2019).

With this increased focus on fossil fuel usage reduction, it is important that organisations are aligned with farmers on how they can supply them with forest fuel biomass to produce bioenergy, which has less negative impact on the environment. Thus, ensuring that there is a supply chain of forest fuel biomass that is adequate to sustainably supply biomass to produce energy required to meet the market demand is crucial.

1.7. Conclusion

This chapter outlines the importance of having a biomass supply chain established and optimised to ensure it can sustainably supply forest fuel biomass to organisations that produce energy from biomass incorporating the seasonal fluctuations in demand and making sure the supply chain delivers sufficient biomass at all times to produce enough energy to meet the market demand (Gunnarsson et al., 2004). Government regulations and policies have been developed to ensure that organisations produce their products in a way that has less negative impact on the environment, and thus preserving the environment they are established in. These regulations and policies in South Africa are seen with the introduction of carbon tax, where organisations have to pay tax depending on the amount of greenhouse gasses they produce (Rebublic of South Africa, 2019).

This study focused on the private South African farmers based in Mpumalanga Province, that supply Sappi Ngodwana mill with timber for their pulp and paper production processes and supply other entities that use timber logs; it looked at Sappi forestry management and Sappi co-fired boiler operational stuff to get insight on their biomass operations. It looked at how these private farmers can derive value from their forest fuel biomass and establish a supply chain that will supply organisations that have biomass boilers with sustainable biomass at all times. This research study looked at how this forest fuel biomass supply chain can be established, if machines should be used for chipping and where should they be placed, and how should the forest fuel biomass be transported and risk associated with it (Flisberg et al., 2018).

This research study proceeds to chapter two, which is an overview of the literature review analysing the literature and different prior research studies that have been done in this field and how they identified some of the challenges that were faced by forest fuel biomass farmers in establishing a biomass supply chain and how models of this supply chain can be established to ensure sustainable forest fuel biomass supply. Chapter three presents the research questions that were used to form the basis of this study.

Chapter four depicts the research methodology that was used in carrying out this research and how the data was collected. Chapter five presents the results that were obtained from carrying out the interviews. Chapter six outlines the discussion of the results. Chapter seven concludes the findings that were obtained and gives further recommendations for future research.

CHAPTER 2 - LITERATURE REVIEW

2.1. Introduction

Bio-economy dates as far back 1918, and was first introduced as bio-economics by a Russian marine biologist who raised a concern about problems relating to over exploitation of natural resources (Giampietro, 2019). Nowadays, globally, governments are developing strategies and policies to reduce the use of fossil fuel based feedstock like coal, oil and natural gas, to produce energy because these are non-renewable matter and they impact the environment in a negative way, and because they are being overexploited they are getting depleted (Urmetzer et al., 2020). Thus, governments are playing the significant role in driving the transition to bioenergy. Bioenergy is the energy produced from renewable or organic matter, and people have been using bioenergy since they started burning wood to provide heat for cooking and keeping warm (Üster & Memisoglu, 2018).

The increased focus on bioenergy generation has resulted in an increase in various studies being conducted to understand, develop, implement and optimise sustainable biomass supply chains (Flisberg et al., 2018; Lochhead et al., 2016; Young et al., 2018). These studies focused on various biomass matter and how the use thereof can best be implemented to ensure that the organisations that have converted to full biomass boilers or are co-firing biomass with fossil fuels have enough sustainable supply of biomass throughout the year. This means that farmers need to understand the importance of having a sustainable supply chain of forest fuel biomass and know how they can ensure that it is optimised for adequate supply throughout the year incorporating seasonal fluctuations in demand (Gunnarsson et al., 2004), so that organisations will continuously have sufficient forest fuel biomass feedstock to keep their energy productions high and minimise on the usage of fossil fuel for energy productions.

This research study focused on the private South African farmers based in Mpumalanga Province region, that supply Sappi Ngodwana mill with timber for their pulp and paper production processes and supply other entities wood timbers. It looked at how these private farmers can derive value from their forest fuel biomass and establish a supply chain that will supply organisations that have biomass boilers with sustainable biomass at all times. The study also looked at the similarities between wood timber supply chain for paper production in comparison to the biomass supply chain to understand the challenges already being faced by the timber supply chain for pulp and paper production as these supply chains are comparable.

2.2. Forest Fuel Biomass

Forest fuel biomass are products that are left over after harvesting the farms or tree plantations for wood logs that are used for processing at sawmills and pulp and paper mills (Flisberg et al., 2018). The forest residue mainly consists of tree branches and tops that are cut off when harvesting the tree logs. The forest fuel biomass can also be obtained from by-products from saw-mills, this includes bark that was removed from the wooden logs and wood chips (Gunnarsson et al., 2004).

Forest fuel biomass is used as an alternative source of energy production to fossil fuel as it has the least negative impact on the environment, and it is a renewable source of energy (Young et al., 2018). Energy is produced by firing the forest fuel biomass into Power Boilers or Multifuel Boilers that generate steam to power turbines that coverts it to electrical energy (Giampietro, 2019).

For a sustainable transition to the bioeconomy, it is imperative that forest fuel biomass supply chain be studied and understood to ensure sustainable renewable energy supply from this renewable matter. Forest fuel biomass is also used in the production of charcoal, which is an important source of energy and income for a lot of people in Africa (Zorrilla-miras et al., 2018).

2.3. Supply Chain

Supply chain is a representation of all the processes or stages involved in the movement of a product or service from suppliers to customers (Mahdavi Mazdeh & Karamouzian, 2014). A supply chain is formed by a group of loosely related role-players linked in collaboration to achieve an agreed upon goal (Jain, Benyoucef, & Deshmukh, 2008). The value added to the product or service at the various stages in the chain or network, by these various role-players, either belongs to a fully vertically integrated organisation or different organisations.

As a supply chain consists of different entities and role-players, there could arise potential conflict because each organisation would be looking out for its own best interest or goals and if these conflicts are not resolved, they result in increased inefficiencies through the supply chain and thus increased cost (Mahdavi Mazdeh & Karamouzian, 2014). Therefore, most managers are focusing on supply chain management as a source of creating value and having a competitive advantage over their competitors (Ketchen, Wowak, & Craighead, 2014).

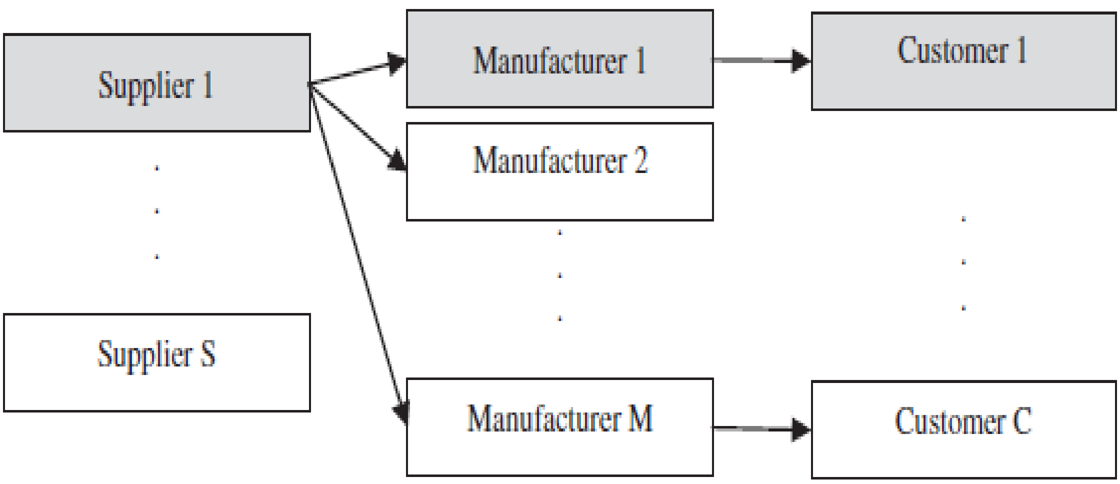

Figure 1: Supply chain schematic

Source: (Mahdavi Mazdeh & Karamouzian, 2014)

The figure above depicts a simplified flow process of a supply chain. It starts with the supplier that supplies an organisation with raw materials for the production of its product or service. There could be multiple suppliers that offer the raw materials required for a manufacturer to produce its product or service. This is followed by the company or manufacture of the product or service selling their product to their customers who may be end users or it can also be to another manufacturer.

2.4. Supply Chain Management

Oliver and Webber in 1982 first introduced the expression supply chain management (Corominas, 2013). Supply chain management helps organisations manage product supply, and for example failures that arises when a bad, faulty or tainted product enters the supply chain and has to be recalled (Ketchen et al., 2014). A supply chain challenge for example a glitch announcement, has been found to have an abnormal reduction in shareholder value of 10.28% (Hendricks & Singhal, 2003). Although product recalls or supply chain glitches are bad for the reputation of the organisation, if the supply chain management of the organisation is in place, there could be valuable information gathered to determine where this product is from and how to avoid it in future. Therefore if organisations do not experience and learn from their failures, they may enjoy a short term success but have greater difficulties in future to stay competitive because they would not have learned what needs to be improved on their systems and this is known as the paradox of success (Ketchen et al., 2014).

There are four types of products recall that has been researched namely, precise recall, over kill recall, cascading recall and incomplete recall. Precise recall is the type of recall were the company knows exactly what is wrong with the products and where the products are located and how to retrieve the faulty products. Overkill recall is the type of recall were the company cannot not exactly determine which products are affected and accurately locate where these products are, thus it recalls all products that could potentially be contaminated. The third type of recall which is cascading recall is the recall that is done in stages, whereby a company recalls one or two batches of a product and then over a period of time other additional batches are also added to the recall. The fourth type of recall is incomplete recall, where an organisation firstly does not know which products are bad, secondly it does not know where the bad products are located and thus thirdly it reacts too slow. Therefore, this results in not all bad products being recalled. These four types of recalls have different impacts on the health of the customer, the financial performance of the organisation and the brand image of the organisation (Ketchen et al., 2014). Whilst other nuances would come into play, the least harmful recall would be precise recall and the most harmful recall would be incomplete recall.

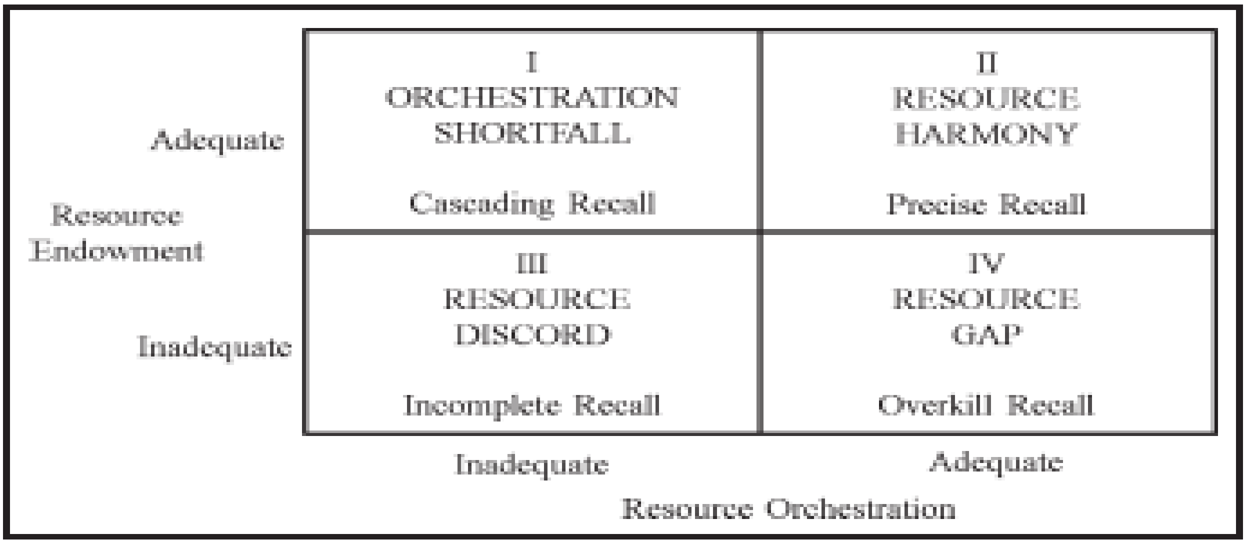

Figure 2: Product Recall types mapped with Resource Scenarios

Source: (Ketchen et al., 2014)

The figure above shows the link between resource orchestration and resource endowment. Resource orchestration shows the role of managers' actions to effectively orchestrate the activities in allocating the organisation's resources. It can be seen that when managers are actively involved in the allocation of the organisation's resources, supply is better managed.

It can be concluded from this theory that it is vital to understand what type of forest fuel biomass is required for the production on renewable energy by an organisation. This well prevent having the wrong quality forest fuel biomass being supplied and not being used by the organisation when it was required.

Supply chain glitches affects net cash flow of organisations in the short-term and long-term. As shown on Figure 3 below, the impacts of glitches on revenues can lead to reduction or loss of sales and market share, lower product selling prices due to excess inventories resulting in markdowns, and they can also prevent an organisation from capitalizing when the demand in the market is strong as result of unavailable products (Hendricks & Singhal, 2003). This relates to the seasonal availability of the forest fuel biomass. Thus, it is imperative that the supply of forest fuel biomass be managed closely all year round to prevent over and under supply of the raw material to the multifuel boiler or co-fired boilers, as this will lead to low pricing or markdowns of the forest fuel biomass during the high harvesting seasons and increased prices during seasons where there is scarce forest fuel biomass.

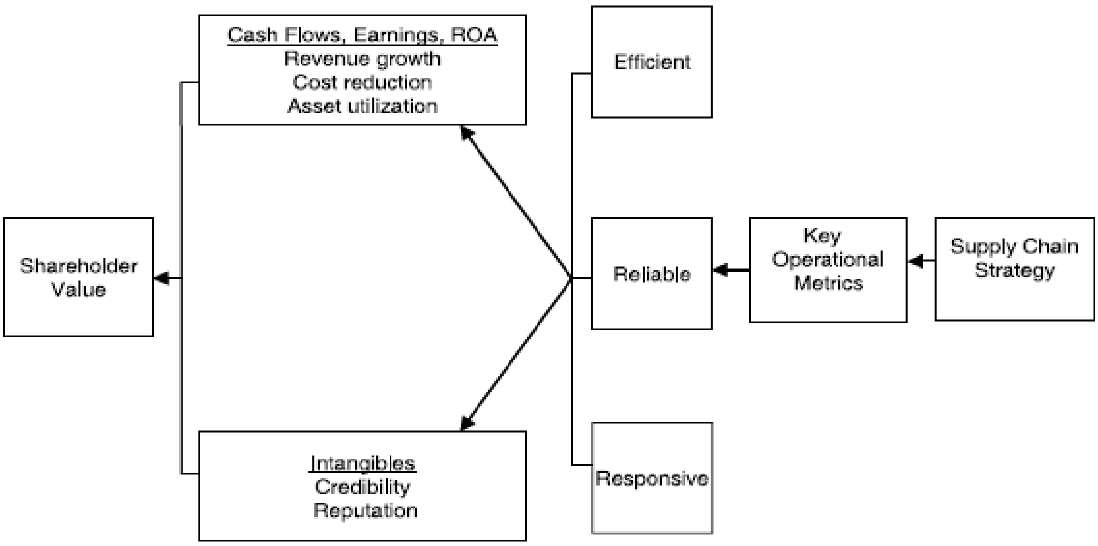

Figure 3: Link between Supply chain and Shareholder value

Source: (Hendricks & Singhal, 2003)

Figure 3 shows the link between supply chain performance to shareholder value. It can be seen from the figure that glitches in supply chain performance can negatively impact on asset productivity and utilization. This can be depicted by a company having excess inventory for some products but a shortage on other products, which will result in poor delivery to customers as they will not meet the customer's needs, for example the timeous supply of a product or service such as energy generation and delivery. Poor service or product delivery to the customer leads to customer dissatisfaction and lower loyalty from the customer and thus poor word-of-mouth publicity. Therefore, it is imperative that supply chain management should be in place, effective and efficient in managing all possible glitches that could potentially arise because regardless of who caused the glitches in the supply chain, the shareholders of the organisations that experience these glitches pay significantly (Hendricks & Singhal, 2003).

Supply chain management is important in business optimisation as it has been found that supply chains in other industries suffer from oversupply of certain products and undersupply of other products as a result of not being able to forecast demand (Fisher, 1997). To develop an effective supply chain strategy, the first step is to understand the nature of the demand of the product that the organisation or company is offering. The other characteristics are also important like product life cycle, product variety, market standard for lead times and demand predictability, but it has been shown that categorising the product according to its demand patterns is the most effective way to develop a supply chain strategy as it can be divided into two categories namely primarily functional and primarily innovative (Fisher, 1997).

Therefore, depending which category the product falls in, there will be a different supply chain required.

Figure 4 below depict the differences between primarily functional and primarily innovative product. It can be seen that a primarily functional products have a predictable demand, meaning that it has low margin of error when forecasting its demand, its life cycle is more than two years and it doesn't require forced markdowns due to end of season. These products are common items that are found in a variety of retail outlets like petrol stations and grocery outlets, they are staple items that people use frequently and thus their demand is predictable and have a long-life cycle (Fisher, 1997). With their high stability, increased competition occurs in their class thus resulting in lower profit margins.

Primary innovative products have an unpredictable demand, resulting in higher margin of error when forecasting its demand. Innovative products have shorter life cycle of about three months to one year, but this means that their contributions margins are higher because they are differentiated products and not found in common retail outlet stores, but only specific to certain companies. Due to their unpredictable demand nature, they have higher shortage rate in the stores and they also have higher forced end of season markdown rate from original price.

Forest fuel biomass is a primarily functional product as its demand can be predictable and be planned accordingly as it is a seasonal product. It has low profit margins and long-life cycle which can lead to increased competition. Thus, an optimized supply chain is vital in such an environment to ensure sustainable supply at all times which will increase loyalty of customers.

Functional Versus Innovative Products: Differences in Demand

	Functional (Predictable Demand)	Innovative (Unpredictable Demand)
Aspects of Demand		
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin*	5% to 20%	20% to 60%
Product variety	low (10 to 20 variants per category)	high (often millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40% to 100%
Average stockout rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

* The contribution margin equals price minus variable cost divided by price and is expressed as a percentage.

Figure 4: Primarily functional vs Primarily innovative

Source: (Fisher, 1997)

Therefore, it is important for organisations to develop capabilities that will ensure they adapt their supply chain to deal with the long-term, fundamental changes like structural shifts in key markets, rapid changes in technology and the socio-political and demographic changes (Eckstein, Goellner, Blome, & Henke, 2015). By developing key supply chain capabilities, organisations will ensure their supply chains are sustainable through varying financial and political environments. A sustainable supply chain can be defined as the capability of a supply chain to meet the current needs without impacting the capability of the future generations to meet their needs (Markman & Krause, 2016). Thus, for a supply chain to be sustainable it needs to improve the ecological health, follow ethical practices to advance social justice and enhance economic vitality. Hence this means that the environmental concerns should be addressed first, followed by societal challenges and lastly the economic challenges (Markman & Krause, 2016).

2.5. Lean and Agile Supply Chain

In addition to ensuring that supply chains are sustainable, they need to be lean and agile to ensure their sustainability. Being lean in manufacturing processes means developing systems that eliminates all possible waste by streamlining process flows and reducing resource usage (Sancha, Wiengarten, Longoni, & Pagell, 2020). Thus, lean supply chain management ensures that all waste is eliminated in its processes to ensure optimal supply chain process and being agile by using the market knowledge to enhance the profitability and sustainability of the supply chain in the volatile market place (Jain et al., 2008). For a supply chain to be agile, it need to rapidly align its network and operations to the dynamic and continuously changing requirements of the customers, and to do this it needs to ensure that its four main key capabilities are in place which are responsiveness, competency, flexibility and speed (Jain et al., 2008).

The figure below indicates a conceptual agile supply chain model. From this model it can be seen that for a supply chain to be agile, the four agile capabilities need to be in place as mentioned above. The first agile capability is responsiveness, which the ability to detect the changes in the marketplace and have a quick responsive plan to proactively recover from these changes. The second agile capability is competency, which is the ability to identify enterprise objectives, to manage them efficiently and effectively. The third agile capability is flexibility or adaptability, which is the ability to establish different processes and apply different resources or facilities to achieve the same goal. The last agile capability is quickness or speed, which is the ability to ensure all activities are executed with speed and completed quickly.

Building on the agile supply chain capabilities, the agile drivers in that supply chain need to be identified to cater for the turbulent business environment. These drivers are customer requirements, competition criteria, market and technological innovation.

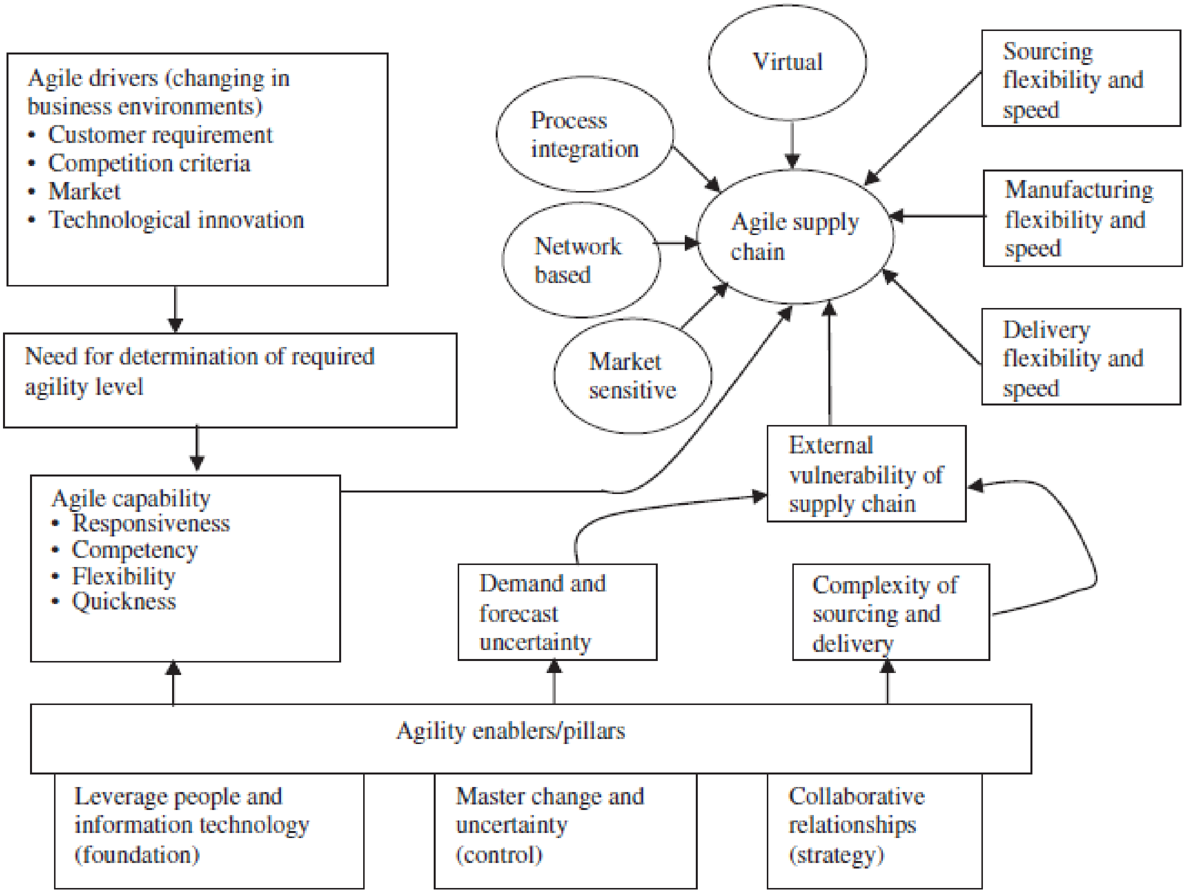

Figure 5: Agile supply chain model

Source: (Jain et al., 2008)

2.6. Supply Chain Risk Management

To ensure that a supply chains functions in a sustainable manner, risk associated with the particular supply chain must be identified and measures put in place to mitigate those risks. Supply chain risk has been defined in recent literature by

Heckmann, Comes, & Nickel (2015) as “the potential loss for a supply chain in terms of its target values of efficiency and effectiveness evoked by uncertain developments of supply chain characteristics whose changes were caused by the occurrence of triggering-events”. From this definition, supply chain risk management helps organisations conceptualise possible risks that could affect the supply chain negatively, arising from unforeseen environmental, social, economic and political factors. It is imperative that factors like delays in identifying triggering events are identified, which are events that results in poor performance of the supply chain, and could affect the supply chain risk (Kumar & Park, 2019).

Therefore supply chain risk management is important as it help in coordinating strategies amongst supply chain members to reduce losses, probability, speed of losses, frequency or exposure and the time to detect events that would to inefficiencies in the supply chain (Kumar & Park, 2019). Figure 6 below is a schematic representation of core characteristics that are encompassed in supply chain risk. These core characteristics are discussed below in detail.

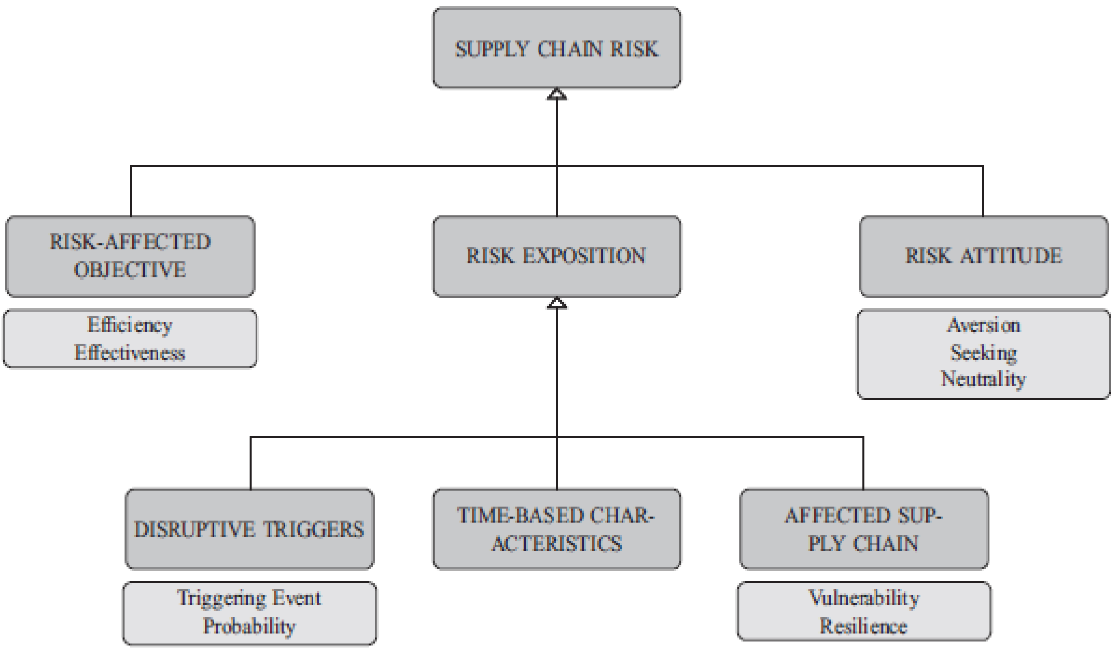

Figure 6: Supply chain risk core characteristics

Source: (Heckmann et al., 2015)

2.6.1. Risk Affected Objective

The first building block characteristic of supply chain risk is risk affected objectives. These incorporates the efficiency and effectiveness of the supply chain. The risk affected objectives aims at efficiently planning, monitoring and controlling the capital resources in an organisation. Thus, it is vital in establishing forest fuel biomass supply chain that risk affected objectives are identified. Therefore, identifying which machines are to be used in the forest fuel biomass supply chain is crucial, and how these machines would be funded. The planning of where these machines would be established is also critical because it will ensure an efficient usage of the machines.

2.6.2. Risk Exposition

The second building block characteristic of supply chain risk is risk exposition. Risk exposition is identified as the manifestation of triggering events, which is the probability of occurrence and its effect on the supply chain. Triggering events are events that cause a disturbance, disruption, disaster, or crisis on a supply chain (Heckmann et al., 2015). These triggering events can be as a result of natural disasters like forest fires as a result of lightning strikes in the plantations, or draught that causes the trees not to grow effectively and thus resulting in reduced forest fuel biomass production during the harvesting season.

2.6.3. Risk Attitude

The last building block characteristic of a supply chain is risk attitude. Risk attitude is divided into three main groups which are risk averse, risk seeking and risk neutral. Risk averse supply chain managers only take negligible reductions in the targeted value of efficiency in the supply chain with an expected increase of overall supply chain efficiency.

Risk seeking supply chain managers take higher margins of value deterioration for a specific goal in the expectation of increased value in another goal. The risk neutral supply chain managers prefer neither strategy, thus, if the targeted values for efficient based and effective based supply chain goals are close they perceive these objectives as mutually exclusive (Heckmann et al., 2015).

In establishing a sustainable forest fuel biomass supply chain, these risks must be identified and categorized with their mitigations put in place to ensure there is adequate supply of forest fuel biomass to the various organisations they contracted to supply throughout the year.

2.7. Supply Chain Risk Category

The two main supply chain risks that affect the design of a supply chain can be categorised into two. Firstly it is the risk of poor supply and demand management, and secondly the risk of events resulting from natural disasters, economic disruption, political situation, labour disputes or terrorists attacks (Ouhimmou, Nourelfath, Bouchard, & Bricha, 2019). The second risk category forms part of the triggering events discussed above. Therefore, it is imperative that supply chain risk management is established and incorporated in all supply chains to ensure they are managed sustainably and are flexible with the volatile business environment. By ensuring that there are risk mitigations of effectively and efficiently managing supply and demand of the forest fuel biomass, will lead to a sustainable continuous supply of the forest fuel biomass to all organisations that the supply chain is contracted with to ensure greener energy production.

2.8. Forest Fuel Biomass Supply Chain

Figure 7 below shows a schematic representation of a forest fuel biomass supply chain. It can be seen from the figure that forest fuel biomass is what is left behind after harvesting of forests and felling of trees. The biomass that cannot be used for further processing at sawmills and pulp and paper mills like tree branches, tree tops and low quality logs is what constitute to be forest fuel biomass (Flisberg et al., 2018;

Gunnarsson et al., 2004) as mentioned in Section 1.3. The forest fuel biomass is categorised into three main constituents namely; fuelwood (low quality logs), bundles and chips as seen on Figure 7 below. Due it increased demand in forest fuel biomass, it is believed that the amount of forest fuel biomass being collected in the plantations can be doubled (Flisberg et al., 2018).

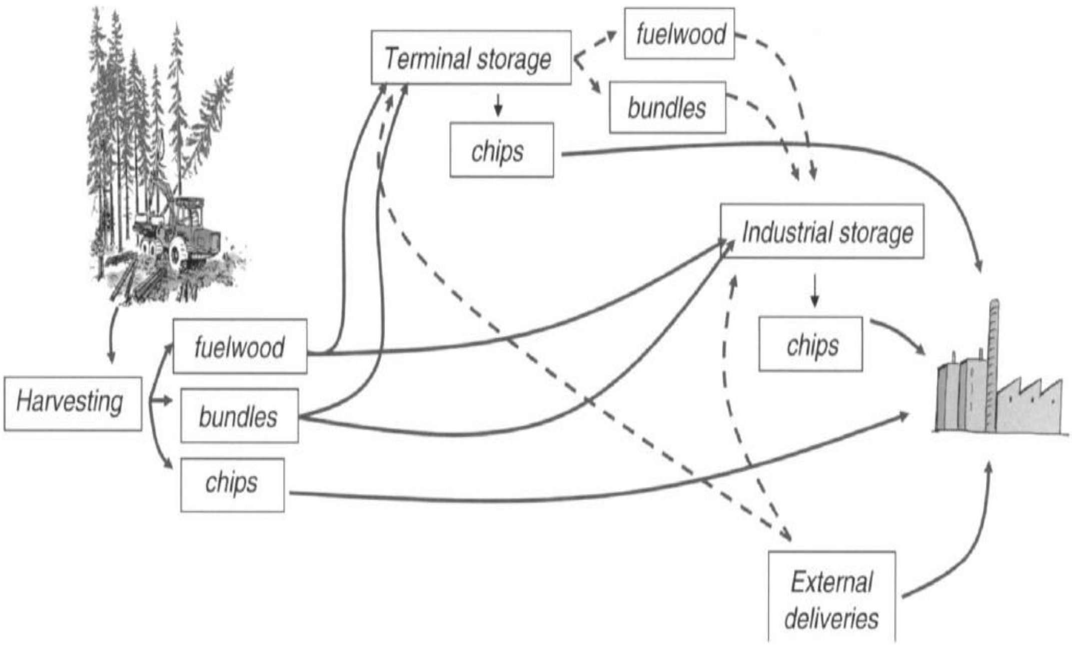

Figure 7: Forest fuel biomass supply chain

Source: (Flisberg et al., 2018)

The fuelwood can be transported to a terminal storage or industrial storage, where they can be chipped, and the chips are sent to the processing mill to generate energy. The bundles are also sent to a terminal storage or industrial storage, where they will also be chipped, and the chips sent off to a processing mill to generate energy. The chips can either be sent to an industrial storage facility or they can be sent directly to the processing mill to generate energy. These systems all depend on the distance between the place where the forest fuel biomass is being harvested and the processing mill (Flisberg et al., 2018).

2.9. Biomass supply chain model

For the biomass supply chain to be fully effective and sustainable, it needs to be analysed into three main levels namely strategic, tactical and operational (Zandi Atashbar, Labadie, & Prins, 2018). Figure 8 below depicts a schematic representation of how these strategies are divided into their three various levels. The strategic level involves gathering long term decisions that need to be made on yearly or more basis like financial investments and determining if new factories should be constructed for the supply of the forest fuel biomass, where they should be located and the machinery they should be equipped with.

It looks at what type of storage facilities should be used, how should the forest fuel biomass be pre-processed if it has to; it looks at the processing mills that the forest fuel biomass will be sent to and their locations; it again looks at the type of biomass and how it will be sourced, procured and finally it looks at how this forest fuel biomass will be transported to the various places and what type of transportation modes will be used.

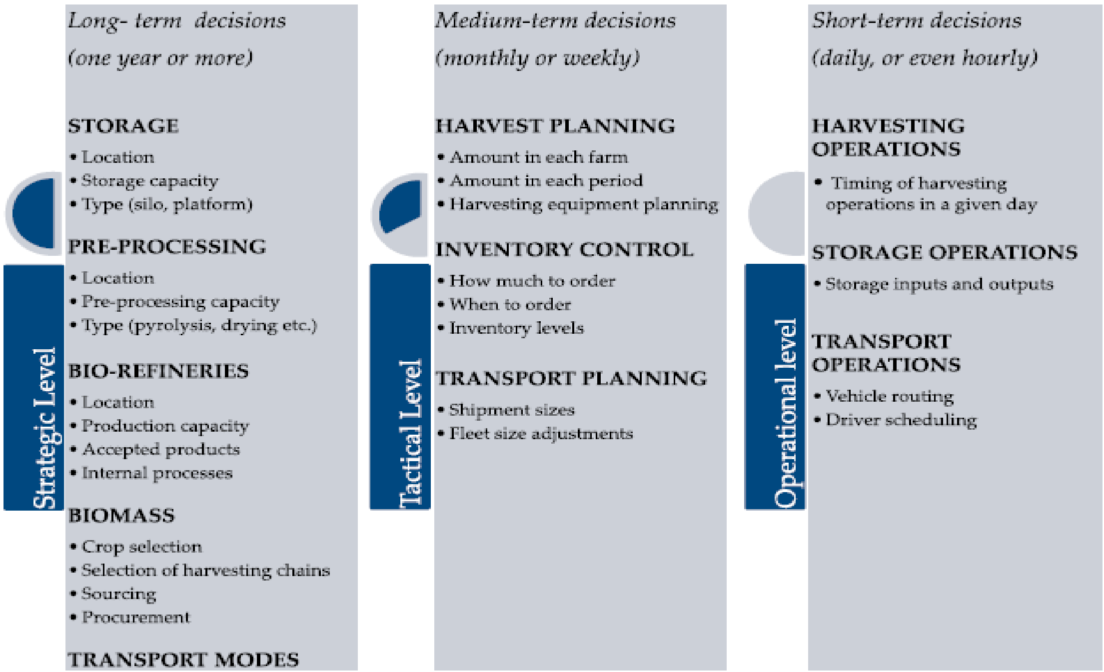

Figure 8: Decision levels in biomass supply chain

Source: (Zandi Atashbar et al., 2018)

The tactical level is the medium-term decision-making level, focused on the monthly or weekly decisions. This tactical involves how will the biomass be harvested; how much will be harvested at the various plantations depending on the fluctuating demands. The tactical level also involves how will the inventory be managed; how much biomass will be ordered and when should the biomass be ordered to maintain certain inventory levels. This level also includes how will the biomass be transported to the various processing mills and using which transportation mode. The transportation mode can either be by road, rail or sea for it to be economically viable. The transportation flow model below depicts possible locations from which the biomass can potentially be transported from.

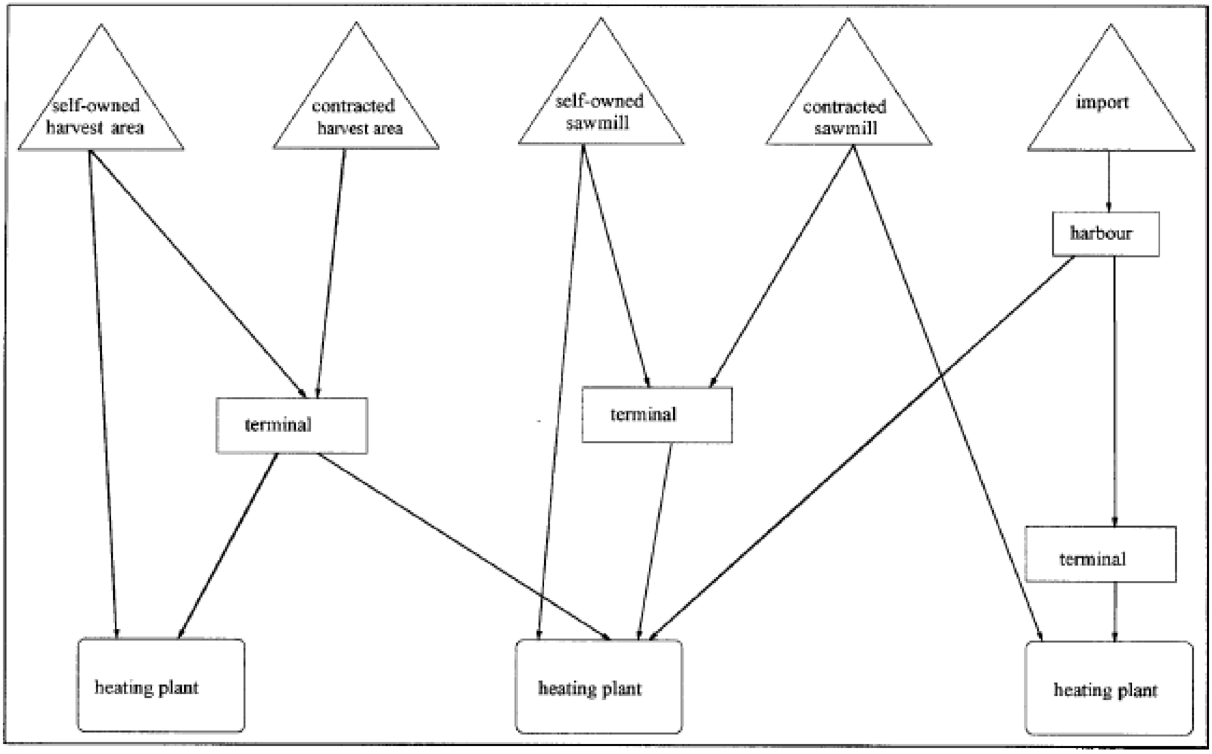

Figure 9: Transportation flow

Source: (Gunnarsson et al., 2004)

It can be seen from the schematic representation of the transportation flow above that the biomass can be sourced from various locations like self-owned harvest area, self-owned sawmills, imported, contracted harvest area or contracted sawmills. All this biomass must be sent to various terminals before it is further transported to the various sites for processing. Thus, as mentioned previously, storage plays a key role as well in the forest fuel biomass supply chain.

Lastly the operational level is the short-term decision-making level, focused on the day to day operational decisions. At this level, decision details on the daily operations are being taken, like how much should be produced on an operation line, which routes are the vehicles supposed to take to ensure they deliver the biomass in time at their various destinations (Zandi Atashbar et al., 2018).

This decision-making process enables the supply of forest fuel biomass to be established in the correct location, and use the correct processes to produce the biomass and deliver the forest fuel biomass to the processing mill in time to generate the required bioenergy to meet the market demand that fluctuates depending on the season. Thus, an efficient supply chain ensures that the customers' demands are met timeously and using the least costly manner (Ouhimmou et al., 2019). Therefore, the forest fuel biomass supply can be optimised by ensuring that the biomass supply chain model at various decision levels are investigated and incorporated in establishing the sustainable forest fuel biomass supply chain.

2.10. Pulp and Paper vs Forest Fuel Biomass Supply Chains

The supply chain of timber logs used to produce pulp and paper at the pulp or paper mills is similar to that discussed for forest fuel biomass (Flisberg et al., 2018). The timber flow starts at the forests, were trees are harvested, debarked, sorted and transported to the various terminals. From the terminals the timber is transported to the pulp and paper mills where the wood logs would be chipped to produce the pulp and paper products (Carlsson & Rönnqvist, 2005) for various customers. As with the forest fuel biomass, the timber for pulp and paper production can also be stored in the forests for a certain duration before it is transported to the terminals or pulp and paper mills, thus the storage facility and cost associated with this need to be factored in the supply chain (Bredström, Lundgren, Rönnqvist, Carlsson, & Mason, 2004).

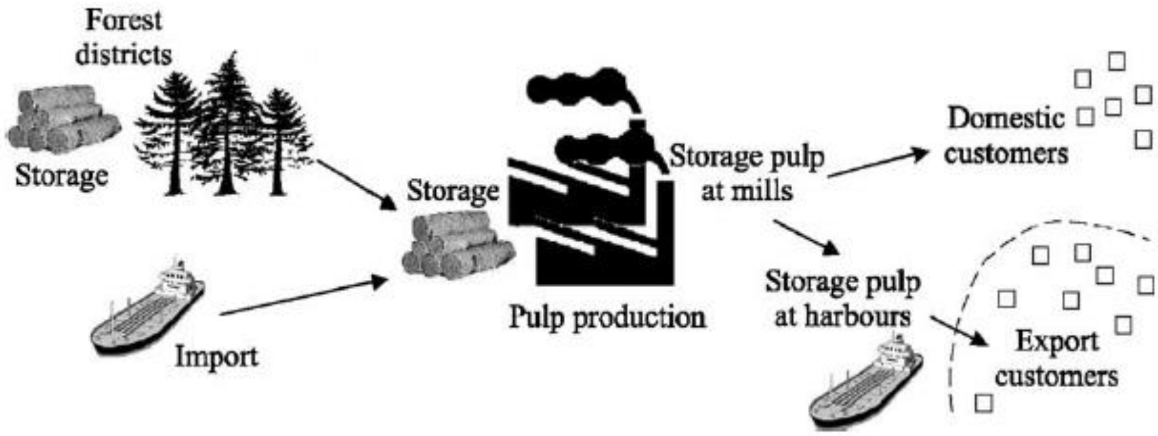

Figure 10: Pulp and Paper supply chain model

Source: (Bredström et al., 2004)

Figure 10 above depicts the supply chain of pulp and paper sector. It can be seen that it is similar to the supply chain of forest fuel biomass discussed in Section 2.5 of the report. Thus, the insights of understanding the pulp and paper supply chain can also help in understanding the challenges that could arise in establishing the forest fuel biomass supply chain.

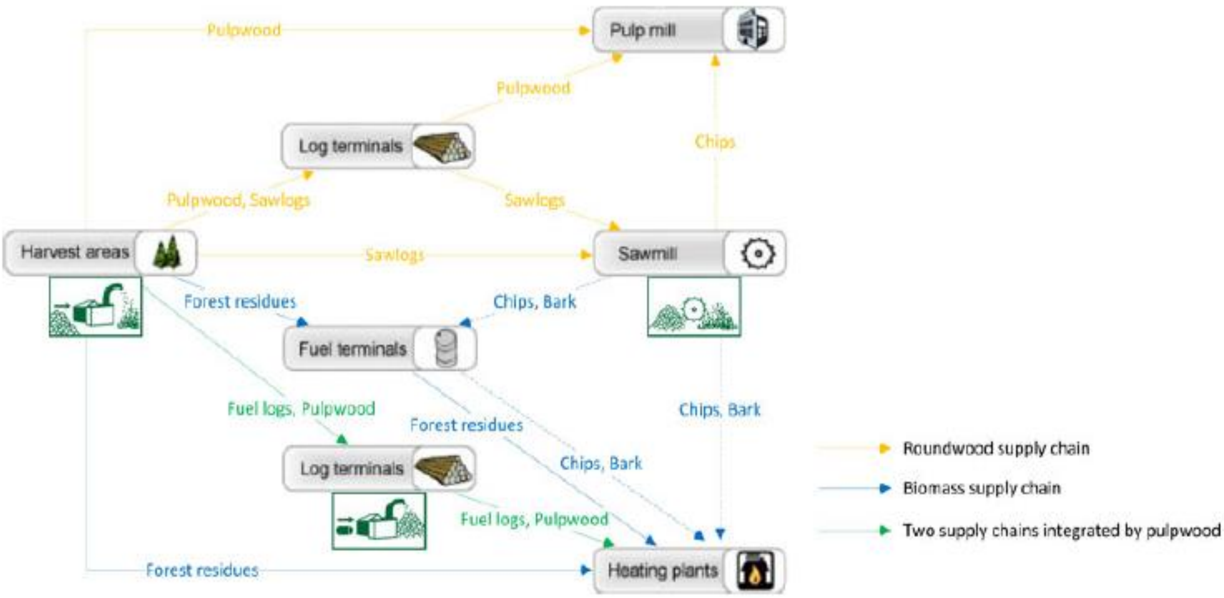

Figure 11: Integrated biomass supply chain with pulp mill supply chain

Source: (Kong, Rönnqvist, & Frisk, 2015)

From the figure above, it can be seen that the pulp production supply chain can form an integral part of the forest fuel biomass supply chain. Thus, the challenges facing the pulp and paper raw material supply chain from either private farmers or own plantations will impact the supply chain of the forest fuel biomass as well. During the harvesting season, the lower part of the trees, with lager diameters have higher value and sent to pulp and paper mills or sawmills and the remaining tree branches and the top of the trees including decayed or damaged logs are used as forest fuel biomass in as feedstock for bioenergy production (Kong et al., 2015).

2.11. Challenges in establishing and optimising forest fuel biomass supply chain

There are various challenges that arise in establishing a sustainable forest fuel biomass supply chain. One of the key challenges in establishing a sustainable forest fuel biomass is acquiring the equipment to produce the biomass in a cost-effective manner. Forest fuel biomass generally has low bulk density, and this makes it expensive when it has to be transported to production sites, therefore it needs to be pre-processed before transportation to various production sites. Forest fuel biomass is a low value high volume product. This pre-processing involves drying, chipping, bailing and compressing (Sun, Aguayo, Ramachandran, & Sarin, 2018).

The forest fuel biomass has to be dried to ensure that moisture does not add to the cost of transportation because the trucks are weighed to determine the transportation cost per mass of product and to optimise the chipping process because the biomass does not go through the chipping machines easily when it is still wet from being harvested. Then the biomass is chipped after it has been dried and compressed to increase its bulk density. This is done to ensure the transportation truck can load more mass of the forest fuel biomass per fixed volume of the truck, otherwise if the forest fuel biomass is not compressed, the volume capacity of the truck will be full, while it has loaded lower mass of forest fuel biomass (Sun et al., 2018). Thus, it will not be cost effective as the production mills pay per mass delivered and not volume.

Therefore, due to the high cost of these machines required to make the transportation of the forest fuel biomass feasible, they have to be shared between farms to lower the operational costs (Sun et al., 2018). Due to uncertainties in the weather, it is difficult to forecast the supply of forest fuel biomass. Thus, storage plays a significant role in ensuring adequate supply throughout the year to production sites to ensure sustainable supply.

Forest fire was identified to be one of the biggest risks in establishing forest fuel biomass supply chain. This is due to that one fourth or 25% of all biomass gets destroyed by forest fires before it can be collected, thus only 75% of forest fuel biomass is available for collection to be used as biomass feedstock to produce renewable energy (Lauk & Erb, 2009). Therefore, it is crucial that fire risk management is implemented when establishing a sustainable forest fuel biomass supply chain. These forest fires are either human induced or could have been nature caused like lightning strikes (Lauk & Erb, 2009).

One of the challenges that was identified in literature that hampered establishing forest fuel biomass supply was chain was openness and transparency (Mertens et al., 2019). It was found that in creating a sustainable forest fuel biomass supply chain, the entities involved had to be open and transparent with all that they have been working with to gain and create belief in the forest fuel biomass supply chain. To create belief in this supply chain, value actors or famers in this case, have to be engaged with during the process of decision making so they are part and parcel of the whole process in establishing the forest fuel biomass.

The farmers need to understand what is the end product of what they are involved in so they can support the initiative of this process and they also need to know each other so they can build trust amongst themselves as farmers to ensure they can work collectively to build this sustainable forest fuel biomass supply chain (Mertens et al., 2019). This is important as the forest fuel biomass would be collected from various farmers to ensure there is enough supply throughout the year, so they all need to know who else is part of this supply chain and they can work together sustainably.

2.12. Conclusion

This chapter has presented the literature review that was done on the establishment and sustainability of forest fuel biomass supply chain. It was identified through this research study that by developing key supply chain capabilities, organisations will ensure their supply chains are sustainable through varying financial and political environments. Therefore, a sustainable supply chain can be defined as the capability of a supply chain to meet the current needs without impacting the capability of the future generations to meet their needs (Markman & Krause, 2016). It was shown that risk management also forms a key role in establishing a sustainable supply chain.

The following chapter presents the research questions that were used for this study.

CHAPTER 3 - RESEARCH QUESTIONS

3.1. Introduction

In this chapter, a presentation of research questions that formed the basis of the study is addressed. The research questions were derived from the literature study conducted that was presented in Chapter 2. The research questions were formulated to gather insight regarding the challenges that could possibly arise when establishing and managing a forest fuel biomass supply chain. In addition to this, the research questions were formulated to guide the study of the level of understanding regarding the importance and possible uses of the forest fuel biomass left over in the plantations after harvesting the trees. This is in line with the purpose of this study which was to explore the importance of and challenges in biomass supply chain development and management in South Africa

3.2. Research Question 1

What are the possible uses of forest fuel biomass?

There are different uses for forest fuel biomass, but generally most of the biomass is left in the plantations to serve as nutrition of the soil or it gets burned to prepare for the next plantation season. The challenges and goals of each private forester need to be recognised to ensure they are met with the establishment and management of the forest fuel biomass supply chain (Mertens et al., 2019). This research question sought to gain insight in ensuring that the entities' goals would still be met with the establishment of the forest fuel biomass supply chain and to determine if they would be willing to invest in the supply chain and its establishment and management.

3.3. Research Question 2

How can the entities (biomass suppliers and customer) contribute to establishing and optimising a forest fuel biomass supply chain?

There are various ways of establishing forest fuel biomass supply chain (Zandi Atashbar et al., 2018). This research question sought to gain insight into how the private farmers and Sappi could contribute in the designing, establishing and managing of the forest fuel biomass supply chain.

3.4. Research Question 3

What challenges arise in establishing and managing a forest fuel biomass supply chain?

There are various challenges and barriers that arise when establishing and managing forest fuel biomass like transparency between all entities and ensuring they can work together to generate more value from the forest fuel biomass (Mertens et al., 2019). This question sought sort to gain insights into what the parties could perceive as the challenges to establishing and managing a sustainable biomass supply chain.

3.5. Conclusion

This chapter presented research questions that were used to form the basis of the study conducted. The answers to these research questions provide insight to how a forest fuel biomass supply chain can be established and managed in a sustainable manner catering for the needs of the role-players to help organisations move away from fossil fuel to renewable energy. The chapter that follows presents the methodology used in conducting the research.

CHAPTER 4 – RESEARCH METHODOLOGY

4.1. Introduction

This chapter presents the research methodology and design that was used in carrying out the research to answer the research questions posed in Chapter 3. The aim of this research study was to understand the challenges facing South African farmers in creating a sustainable biomass supply chain as governments are creating strategies and policies that limits the use of fossil fuel in industries and thus promoting the use of renewable energy production (Lochhead et al., 2016). This study was conducted using a qualitative research approach to determine the challenges in establishing forest fuel biomass supply chain in South Africa. The data in this research study was collected using semi-structured interviews with the private farmers, Sappi forestry management personnel and Sappi co-fired boiler operational stuff to gain insight into what challenges they face in managing their plantations and what challenges they could face in creating a forest fuel biomass supply chain that would need to be resolved to ensure the supply chain is sustainable.

4.2. Choice of methodology

The research philosophy that was followed in conducting this research study was interpretivism (Saunders & Lewis, 2018). The interviewees had their varying opinions with regards to the forest fuel biomass supply chain development depending on the perceived benefits they see in their own businesses. As a result of this, they were studied in their natural environment as different role-players, to ensure that their different interpretations of developing the forest fuel biomass supply chain is captured, and also determining their understanding of the bio-economy and the value they could generate from their waste biomass after harvesting the trees (Saunders & Lewis, 2018). The research approach that was followed in conducting this research was inductive (Saunders & Lewis, 2018). This was due to the fact that the researcher was looking at building a theory or an understanding from the interviewees' perspective of what was their perceived challenges in developing a biomass supply chain and if they knew the possible value they could generate from the biomass

(Urmetzer et al., 2020). Though a theory exists derived for a similar case, this research is aimed at building on the existing theory.

The research study was qualitative in nature and was a mono method. Qualitative research methodology elaborates or generates theories instead of testing them (Reinecke, Arnold, & Palazzo, 2016). Semi-structured interviews were conducted to determine the understanding the interviewees had with regards to the bioeconomy and development of the forest fuel biomass supply chain. The semi-structured interviews were conducted in a way that offered anonymity, so the interviewees could be open and give honest feedback without fear of what they say being made public and traced back to them (Saunders & Lewis, 2018). This research study was exploratory in nature. An exploratory research study is one that seeks to discover information about a topic or subject that is not fully understood (Taran, Boer, & Lindgren, 2015). This research study sought to determine information regarding the development of the forest fuel biomass supply chain, which currently appears to be not fully understood in the forestry sector and explored the possible challenges that may prevent its development.

A case study research strategy was followed in conducting this research study. The case study research strategy involves the investigation of certain contemporary topic in its real-life context and using different sources of evidence and posing the "how" or "why" questions (Yin, 2009). Thus, in this research study, the researcher was investigating how forest fuel biomass supply chain can be developed in the forestry sector and determine the possible challenges that may prevent or slow down its development. The research study was conducted at a specific point in time using the semi-structured interviews to collect data from the participants and thus it was cross-sectional in nature (Saunders & Lewis, 2018).

The technique for collecting data for this research study was using semi-structured interviews. The purpose of using semi-structured interviews as a method of data collection is that the participants was asked about a set of themes that have been predetermined but may vary in order to guide the interviews but also allowing the participants freedom to express their views relating to the topic being researched (Saunders & Lewis, 2018).

4.3. Population

The population identified for this research study was farmers that have forest fuel biomass left over on their plantations post harvesting, thus it is the complete set of all farmers in South Africa (Saunders & Lewis, 2018). Sappi forestry management and Sappi co-fired boiler operational stuff were also identified to form part of the population as they gave insight into the challenges, they already faced in developing the timber supply chain for pulp and paper production as it is similar to the one for forest fuel biomass supply chain and the challenges they face with combusting biomass in their co-fired boiler.

The identified population also included all farmers in the agricultural sector and farmers who plant trees and supply them to the various industries that use timber as their raw material like pulp and paper industries, mining industries and sawmills. As a country that is in its developing phase, South Africa was chosen to be a suitable location to conduct this research because of the regulations and policies that are being developed in the country to reduce the use of fossil fuel and transition industries to generate energy from renewable matter. This was seen through the establishment of carbon tax that industries have to pay depending on the amount of greenhouse gases they produce (Rebublic of South Africa, 2019).

4.4. Unit of analysis

The unit of analysis for this research study was the private farmers, Sappi forestry management team and Sappi co-fired boiler operational stuff.

4.5. Sampling method and size

The sampling method that was followed in conducting this research study was non-probability sampling because the complete population size of farmers is not known (Saunders & Lewis, 2018), thus random sampling cannot be done due to the unknown population size. The non-probability sampling technique that was followed in this research study was homogeneous purposive sampling, because the farmers that were interviewed were private farmers, and they have contracts with Sappi for supplying them with timber, they also have forest fuel biomass left over after they harvest their trees and were geographically located in South Africa in Mpumalanga Province. The Sappi forestry management and Sappi co-fired boiler operational stuff also formed part of the sample as they gave insight into how they sustain the timber supply chain for the pulp and paper production, and gave insight in to the challenges they face as it is similar to the one for forest fuel biomass supply chain and the challenges they face in combusting biomass in their co-fired boiler. The farmers were accessed through Sappi Forestry Department. The sample size was not fixed at the beginning of conducting the research interviews but was determined till saturation. Saturation was demonstrated when no new information insight was being found during the data analysis as seen on Figure 12 (Saunders & Lewis, 2018).

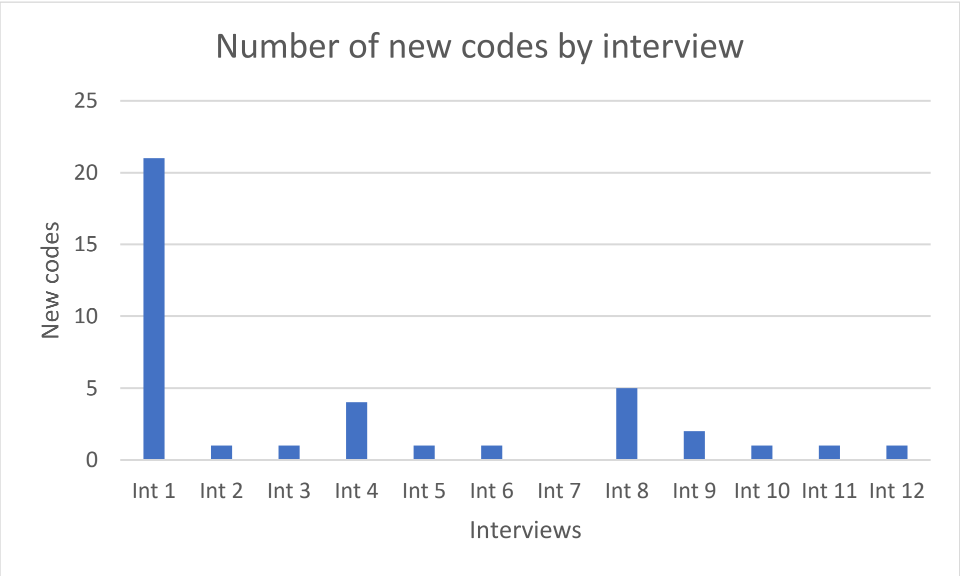

Figure 12: Number of new codes by interview

4.6. Measurement instrument

The research instrument that was utilised in conducting this research study was semi-structured interviews. The researcher ensured that before conducting the semi-structured interviews, information of the participants was acquired to ensure there was enough known about the participant before the interview, this was done to make sure the researcher was credible when interviewing the participants (Saunders & Lewis, 2018). An interview guide was developed that was utilised in guiding the interview process. The researcher made sure that the conducting of the semi-structured interviews with the participants was in their natural environment so they were comfortable to give as much information as they could.

The interview guide ensured that these main areas were covered:

- If the farmers knew what the possible uses of the biomass was that is being left on their plantations after harvesting alternative to supplying nutrients to the soil, and if they knew it can be converted into a valuable product.
- What the farmers understood regarding the supply chain and specifically forest fuel biomass supply chain.
- What the farmers thought was the main challenges that could prevent them from establishing the forest fuel biomass supply chain.
- What Sappi forestry management determined as the main challenges in establishing a sustainable timber supply chain for pulp and paper production.
- What Sappi forestry management perceived as the main challenges that could arise in establishing a sustainable forest fuel biomass supply chain.
- What Sappi forestry management and the private farmers perceived as the risks in establishing the forest fuel biomass supply chain.
- What Sappi co-fired boiler operational stuff perceived as the challenges in combusting biomass in their boiler.

The questions were open ended, to allow the participants to give their full opinions (Saunders & Lewis, 2018) and probing was done by the researcher to ensure the participants gave as much information as they could. The interview was structured firstly with an introductory part, then the two constructs and the relationship and finally anything that the participants may like to add (Saunders & Lewis, 2018). A consent form was signed and agreed to by the participants to allow for the interview to take place and that their anonymity was protected through the research study. The interview guide that was used is shown in Appendix 3.

4.7. Data collection

The data for this research study was gathered by the researcher using semi-structured interviews. The participants sampling was purposively selected to ensure homogeneity. They were private farmers that supply Sappi Ngodwana mill with timber for their pulp and paper production processes, Sappi co-fired boiler operational stuff and Sappi forestry management personnel. The private farmers were South African based in Mpumalanga Province. These interviews took a minimum of 15 minutes to maximum of 50 minutes. The data was stored on various cloud storage platform to ensure their safety keeping.

4.8. Analysis approach

The data in this research study was analysed using the conventional content analysis. This is method of data analysis was used because the existing theory is limited with regards to forest fuel biomass supply chain development and determining the challenges for implementing this supply chain since past research was mostly conducted countries outside South Africa (Hsieh, Shannon, & Shannon, 2009). The research data feedback was grouped into themes after it has been transcribed and then analysed. During the data analysis, it was also proven that saturation was reached during the interviewing process when no new insight was found when analysing the data (Saunders & Lewis, 2018). The transcribed interviews were uploaded on to ATLAS.ti for data analysis.

The table below depicts the phases that were followed in analysing the themes. Thematic analysis method was used in during the analysis of the themes, it is a method that is used to identify and analyse patterns or themes in qualitative data (Bruan & Clarke, 2006).

Table 1: Phases of thematic analysis

Sourced: (Braun & Clarke, 2006)

Phase
1. Familirise yourself with your data
2. Generate codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

4.9. Quality controls

The quality control in this research study was monitored by ensuring that the sampling criteria is appropriate, and that it has been defined clearly for the research being carried so that saturation can be proven when the data is being analysed (Morse, Barrett, Mayan, Olson, & Spiers, 2002). By doing this, the data was proven to be reliable and valid because the non-probability sampling technique followed in this research study was homogeneous purposive sampling. Validity is a system that is used to ensure that the research measures what it was intending on measuring (Saunders & Lewis, 2018). Validity was ensured using the biomass supply chain framework. The interviews were structured around this framework to ensure validity.

4.10. Limitations

The limitation to this research study was that the outcome of the research study cannot be generalised to the rest of the population but will only be applicable to the sample population that was studied because it was an explorative study in nature and qualitative research study (Taran et al., 2015). Thus, whatever was found about the forest fuel biomass supply chain development, was only applicable to the farmers that took part in the research study. This research study would then need to be done in a quantitative manner to generalise the findings to the rest of the population (Saunders & Lewis, 2018).

4.11. Ethical clearance

In ensuring that the researcher conducted the research in an ethical manner, the researcher obtained ethical clearance from the university's Ethical Clearance Committee. This was followed by ensuring that consent to conduct the interview was given to the researcher by the various people that were interviewed. To ensure anonymity, the true names of the participants in this research study were changed, thus guaranteeing anonymity of the interviewees.

4.12. Conclusion

This sectioned presented the research methodology and design followed in this research study. The research methodology, unit of analysis, sampling method and size, measurement instrument, data collection, analysis approach, quality controls, limitations and ethical clearance was outlined in detail. The following section will review the results obtained from the semi-structured interviews that were conducted based on the thematic analysis that was followed.

CHAPTER 5 - RESULTS

5.1. Introduction

This section outlines the key findings from the interviews that were conducted with the private timber farmers and Sappi Forestry management personnel in identifying the major challenges that arise in establishing a sustainable forest fuel biomass supply chain. These keys finds are aligned with the research questions outlined in Chapter 3 of this research study. The interview guide was also aligned with the research questions. The key results are also presented based on the themes that were identified during the qualitative data analysis of the interviews using the thematic data analysis process. The data was gathered to understand how private farmers can establish a sustainable forest fuel biomass supply chain because governments globally are creating strategies and policies that are forcing industries to move away from fossil fuel based energy generation to renewable source of energy production, and thus reducing their carbon foot print resulting in less environmental degradation.

This chapter start by presenting the description of the participants that took part in this research study, then followed by the presentation of the results from the qualitative analysis.

5.2. Description of participants

Table 2: Interview participants and context

Participant Pseudonym	Description
Interviewee JA	Manages timber plantation of 1765 hectares in Mpumalanga
Interviewee TH	Manages timber plantation of 800 hectares in Mpumalanga
Interviewee AN	Manages timber plantation of 500 hectors in Mpumalanga
Interviewee MB	Manages timber plantation of 13000 hectares in Mpumalanga
Interviewee HE	Manages timber plantation of 1400 hectares in Mpumalanga
Interviewee AT	Manages a plantation of 1400 hectares in Mpumalanga
Interviewee RE	Manages timber plantation in Mpumalanga
Interviewee DE	Manages timber supply chain from various Sappi plantations
Interviewee PA	Manages timber supply chain from various Sappi plantations
Interviewee LO	Sappi co-fired boiler operational stuff
Interviewee LU	Sappi co-fired boiler operational stuff
Interviewee NK	Sappi co-fired boiler operational stuff

The names of all the interviewees were changed to from their original names to ensure anonymity of the participants. As seen above, the various participants managed farms or plantations in Mpumalanga Province in South Africa of various sizes, thus supplying various quantities of timber. The other participants manage the timber supply chain for pulp and paper production process as it was discussed that it is similar to the forest fuel biomass supply chain, and the other participants run

Sappi co-fired boiler. All the participants were briefed on the purpose of this research study so they can understand what was required of them and the sessions were recorded as they were performed over the telephone.

5.3. Results: Research Question 1

What are the possible uses of forest fuel biomass?

This research question sought to gain insight on the farmers' knowledge about the uses of forest fuel biomass, what would drive them to establishing a forest fuel biomass supply chain. This research question was aimed at uncovering if the farmers were willing to establish this forest fuel biomass supply chain and if they are willing to invest in it and make it work.

5.3.1 Burning of forest fuel biomass and alternative uses

Some of the interviewees did not know what are the possible uses of forest fuel biomass that is left behind on their plantations. They indicated that most of the time they burn the forest fuel biomass to clear compartments in preparation for their next plantation season.

> Interviewee AN: "*At the moment we not mulching it, at the moment we actually burning it."*

> Interviewee AT: "*it depends on if it is early in the plantation season, they would rather burn it, because to get the planting done."*

The other interviewees indicated that some of the forest fuel biomass they use it for charcoal production and used to sell it smelters who produced silicon. Some of the interviewees were again looking for possible alternative uses for the forest fuel biomass.

> Interviewee MB: "*Charcoal is normally, the market we normally looking at. We had the packaging market where you sell four kg bags to the shops for packing charcoal. We also selling on a wholesale basis per ton to silicon smelters and also briquet."*

> Interviewee RE: "there are some people taking the stumps for charcoal, but the market is dead at the moment. it is not that good anymore."

> Interviewee JA: *"no no no we don't supply charcoal, we have no one buying it from us. Currently there is no one buying it, we have pine that is waiting for the market"*

Some of the interviewees indicated that they knew about biomass used as feedstock in the production of electricity at various multifuel boilers.

> Interviewee AT: *"The biofuel market is quite vast, and the potential is there, we can supply a lot out of South Africa out of purchased timber."*

> Interviewee MB: *"The second other thing that I normally know is that use it to make chips. But those chips they make they use it to fuel the boilers. Boilers that they use in the plant instead of using coal. Some use woodchippers to chip the biomass and grind it and fire it into the boilers."*

5.3.2. Volumes of forest fuel biomass and profitable pricings

The interviewees mentioned that there is adequate volume that could be supplied for forest fuel biomass. It is all based on the cost that it will be sold at, because it needs to be a profitable process otherwise, they will not be interested in doing it. Will this be paid per Calorific Value (CV) of the wood, which is the energy contained in the forest fuel biomass.

Interviewee JA: *“what’s left over we can be able to sell to you everything like 32 to 34 tons per hectare.”*

Interviewee AN: “It can be less than, or at least 50 tons per hectare and maybe more. *And if you take everything you should be able to supply about 2500 tons per year of biofuel.”*

“It is possible to do it. It depends how much they willing to pay.”

Interviewee AT: “*The second thing is what is your price per ton? Or you're going to pay per CV value”*

“If they do it and they don’t get anything, they will not do it if they just break even. There must be some value that they can put in their pockets afterwards.”

Interviewee HE:” *No, we not doing any, any kind of biomass. Remember there is always biomass, like your company looking to it, we could also look into it, we don't have enough, it is not viable for us to go into it. you need to have basically, waste from everywhere to make it viable.”*

Interviewee MB: “*on average in a compartment, we normally take about 80% of what you want, but then now it will also depend on the growth of the* *compartment. So, on average if a compartment is grown well, it would give us about 120 tons per hectare. So, they will take, say, 20% of that, that will be our biomass."*

It was also found as mentioned by Interviewee HE, that there is always biomass left over after harvesting, but they do not have adequate capacity to ensure there would be a sustainable supply of this biomass to be used as feedstock to a multifuel or co-fired biomass boilers.

5.3.3. Summary of the findings of research question 1

From the research interviews conducted, it was evident that in answering research question one, there are participants that are already using the forest fuel biomass for other purposes like charcoal production and also supplying to silicon smelters whilst others burned it because they had no uses for it. It was shown that they had sufficient volumes of forest fuel biomass left over on their plantations after felling the trees, which is a process of cutting down or harvesting the trees. They also indicated that if it is profitable, they are willing to establish the forest fuel biomass supply chain.

5.4. Results: Research Question 2

How can the entities (biomass suppliers and customer) contribute to establishing and optimising a forest fuel biomass supply chain?

This research question sought to gain insight into determining how the farmers could help in designing a sustainable forest fuel biomass supply chain. The key question posed was in understanding if the farmers knew about forest fuel biomass supply chain and how they think they could make it sustainable as they would be the key role-players.

5.4.1. Knowledge of forest fuel biomass supply chain and harvesting

From the interviews conducted, there were some respondents that knew of the forest fuel biomass supply chain and they were willing to share their current knowledge into ensuring that the forest fuel biomass supply chain that could be established is established in a sustainable manner. They have a harvesting plan that they follow to ensure sustainable production of timber and biomass.

> Interviewee RE: *“Every 10 years we burn, because we fell every 9 to 10 years, every rotation we burn. So, the trees grow roughly about 10 years or every 10 years we cut them and also have biomass.”*

> Interviewee JA: *“We are harvesting every month, ever since I have started working, it has been 10 years now. So, my harvesting plan is given to me for another 10 years of harvesting. Now like starting from next week we have to start replanting. So, I think it is gonna be something done every month, so every time after harvesting there will be something. It is a monthly basis thing.”*

5.4.2. Availability of forest fuel biomass

The interviewees also indicated that there is forest fuel biomass that is currently available to be utilised by the multifuel or co-fired biomass boilers. They indicated that it would be better to take the forest fuel biomass than to burn it in the various harvested compartments.

> Interviewee AN: *“It would be better to take it for biofuel than burn it.”*

> Interviewee AT: *“especially on the community farms, there is a big big big market for that.”*

"If I take in my situation, it is about 80,000 tons per annum of timber annually of which roughly on the on the biomass, maybe left behind would be about 8 to 10%, so between 6000 and 8000 tons annually. S*o, if you break it down on a monthly, you can do between 800 and 1000 tons a month of biomass."*

Interviewee HE also mentioned that although the biomass is available, to have sustainable continuous supply, they might need to investigate using the actual timber to help supplement some of the biomass that would be required to power the multifuel biomass boilers.

Interviewee HE: "*because you need massive volumes, and for me, if you want to do something like that, you will need to start taking your, your trees. If you really want to make it profitable, you will start competing with other clients, you will start to take either your timber material, that's my opinion."*

Interviewee RE mentioned that the biomass is available, it just needs to be collected and bailed up to be used at various multifuel biomass boilers.

Interviewee RE: "*the branches and stuff, are left behind. the stuff is there, it just needs to be bailed up and collected together and they can be used."*

This indicates that there is sustainable supply of forest fuel biomass that is available to be used in the production of green energy and minimising fossil fuel usage, thus resulting in low carbon footprint.

5.4.3 Summary of the findings of research question 2

Forest fuel biomass is currently available for the production of greener energy from multi fuel biomass boiler. This was proven from the interviews that were conducted in answering research question 2. Most of the biomass is left behind when timber is being harvested for pulp and paper production, and since this is already a well-established process, its timber supply chain is also sustainable. Therefore, due to the similarities between the forest fuel biomass supply chain and the timber supplied for pulp and paper supply chain, it would make the forest fuel biomass supply chain sustainable. All the information acquired with regards to the harvesting planning of timber, will be utilised for the forest fuel biomass supply chain as well because they are comparable.

5.5. Results: Research Question 3

What challenges arise in establishing and managing a forest fuel biomass supply chain?

This research question sought to gain insight on what are the barriers and challenges that could arise when the forest fuel biomass supply chain is established. There were various challenges that were identified when the research interviews were conducted that needed to be addressed to ensure that there is sustainable supply of forest fuel biomass to the various multi fuel biomass boilers.

5.5.1. Centralised location and transparency

From the interviews conducted, it was identified that for the farmers to be part of establishing a sustainable forest fuel biomass supply chain, there must be transparency between all key role-players. They indicated that if all their questions are answered and they are positive, then they would be willing to be part of this forest fuel biomass supply. They indicated that if you tell a famer what you want, they will do it for you. One of the interviewees also mentioned that they were transparent and gave incentives to the workers and community to minimise fires and it worked.

> Interviewee AT: *"if all other factors come to play and if the distance is correct, the size is correct. there is a lot of ifs. If all the ifs can be positive, then there is a lot of potential."*

> Interviewee RE: *"you give a farmer something, and he will do it for you."*

> Interviewee PA: *"yes definitely is a better relationship with the community. Plus, also for the workers with created sort of an incentive system. I would say give an example from Somhlobo trust, we said to the workers, it's about 182 workers. We said to them if you don't have a fire for the whole fire season up until the 15th of November, each employee will get the R2900 as a as a bonus so that helped a lot because all those 182 people went out to people in the communities there's peace there's no fires."*

Another key challenge that was raised was with regards to having a centralised location that farmers can bring their forest fuel biomass, and have it collected there at the depot instead of every farmer sending directly to the end-users because it will increase the transportation costs. They were willing to work together to ensure that wherever the forest fuel biomass depot is built, would not matter, if it is in favour of all of them. They could work together with the surrounding farmers and have the biomass delivered there as it would increase the volumes of biomass when collected between the various farms or plantations. There just has to be a weigh bridge to measure the load of the forest fuel biomass as it gets to the depot to ensure they are all treated fairly and in the same manner.

Interviewee MB: *"I was thinking the other day, that then we can buy from the neighbouring farmers as well and transport it."*

Interviewee AT: *"I mean, if you can create a let's say the first depot. If we can send it to the depot and not the end market. It would be near the farms, for sure there is an opportunity there."*

"So maybe for instance, if there was supposed to be let's say, at the end of the day, we see that it is feasible and economic then to incorporate other guys may be like saying if we choose a specific area to be centralised, then we can potentially incorporate other people if there are other farmers around the area. Obviously, the price will be lesser at the Depot than at the market, because you also have a lot of cost to maintain the Depot."

Interviewee RE: *"that won't be a big problem to organise something like that. we just have a weigh bridge and weigh the biomass coming in."*

Interviewee MB: *"The guys that specialises in that like saw millers, they have chips silos. So, they store them separately. So, they have a depot, where they collect all the chips and bring them there. from there they would take them to the market."*

Interviewee AN: *"that can work as well, if it is centralised location, have a chipper installed. It depends how much the chipper would cost."*

It was found that it is imperative that the whole supply chain be transparent to ensure that the farmers are treated in a similar way. Having a centralised location will help reduce the farmers' transportation costs instead of sending it out to the end-users and they can all have their product weighed as it gets to the depot and they get paid per ton of forest fuel biomass delivered.

5.5.2. Quality of the forest fuel biomass

One of the challenges highlighted that would need to be resolved is the quality of the forest fuel biomass. The famers indicated that there are various quality aspects that needs to be understood and catered for like firstly moisture. They indicated that forest fuel biomass should not have a high moisture content, because this will result in increased pre-treatment cost of removing the moisture as high moisture forest fuel biomass does not burn effectively in multifuel biomass boilers. Interviewee LO also mentioned that they battle with lots of rock that comes through the system, thus the biomass must be screened.

> Interviewee AT: *”Number one is obviously you don't want moisture in it, and it must be as dry as possible. So, moisture, moisture is a big factor.”*

> Interviewee HE: “*your dry factor or the wetness factor is important. I would say maybe dry it in the compartments, or you go and dry it out. when are you gonna take that measurement, it must be a practical thing like say you dry it for one week or two weeks, but it should be practical.”*

> Interviewee MB: “*but now there are companies that buy the chips they normally pay you more, they take the moisture content of the chips. So they pay more for dry chips, and this reduces their cost because if you bring in wet chips they have to send it through a fire to dry them, so the more dry the chips, the higher the price they will pay you for it so you get more money. Because the dry chips burn easily. So, you must stack as much as possible and as dry as possible.”*
>
> “*No, you must wait for it to dry. if you chip it before it dried, it will not work. To try and chip it when it is wet, it will not work. See the wood that is sent to Ngodwana they tell you that must always keep it in field for four to six weeks. it must not exceed six months. So, they want it dry, because the wetter the wood, the more chemicals they require to cook the wood when it has a lot of moisture.*

You must also let it dry because if it is wet, the chipping machine will not cut it properly, you will get the machine to get stuck. So, it has to dry to work.”

Interviewee LO: *“. Yeah, so we do have metal, metal detectors, which will have screens to remove the rocks, and we are picking up some of these things on the system. And then we have a shredder which will shred everything into the spec that we want to get to be when it goes to the boiler.”*

Interviewee LU: ”*it affects the efficiency on the boiler because first it has to dry off the moisture before it burns, but we don't really care about the moisture, but again in the same breath the dryer is a better.”*

Therefore, it is imperative that the forest fuel biomass is dried up before it is collected otherwise it will not be processed easily when it is still wet. High moisture content in forest fuel biomass makes the chipping process slow and could result in failure of the chipping machines as there would be lots of moisture in the biomass and the chipper blades do not work effectively when chipping wet product. Thus, the biomass should either be collected and sent to the depot where it would be dried up before sending it to the chippers of alternatively it should be left to dry up in the various compartments where it was harvested before it is collected and chipped. High impurities in the biomass can also lead to increased boiler tube leaks and equipment failures.

Interviewee NK: “*I think from an abrasion point of view, when you feed this thing to the boiler, you expose your boiler itself to stones, non-combustibles. So that's a potential of erosion on tubes and the possibility of tube leaks. Yeah, so. And I think, probably that's the biggest thing, that's the biggest risk that you're looking at.”*

5.5.3. Collection of forest fuel biomass

The collection process of forest fuel biomass was also identified as one of the challenges that arises when establishing a sustainable forest fuel biomass supply chain. This was due to that the forest fuel biomass must be collected manually after the timber for pulp and paper production and other uses has been removed. The treetops and brunches are left scattered everywhere in the plantations and thus manual labour has to go in and collect all this biomass. It is unlike timber that is easily collected by machines and stacked by the roadside, this must be done manually and gathered to either be chipped or bundled into bales.

> Interviewee AT: "*but remember if you have biomass in the plantation, it must still be extracted and be loaded. So, there is a harvesting cost and loading cost, extraction cost as well. It's gonna lie within the branches, you have to go back in after the operation is finished, stack it, and then extract it and load it."*
>
> *"It's gonna be 80% manual. The only mechanical part is the loading and the extraction."*

> Interviewee HE: "*the biggest challenge with biomass is the collection. How are you going to collect it in field? And, and then in what format? You want to put it in containers? Are you going to clean it? Because remember, depending on how you can pick it up, are you taking the soil, are you taking all the dirt. are you taking it to a central point, or you going to process it there?"*

> Interviewee MB: "*you need to to collect and collect and make stacks. and those stacks need to be taken to roadside. So now what you find that's normally happens, we normally pay our contractor about R79 per ton, that is to collect the stuff and group them to batches, and again we need to pay them R37 per ton to transport them to the roadside. So, if we take the money for the two versus the money we get back after selling this thing, it is very very minimal*

> *money. So, we basically not making that much money, so we basically just do it to clean our compartments."*

It was made clear that collecting the forest fuel biomass would be challenging, but mostly it must be economic and profitable to farmers to do it, otherwise they will not be interested in doing it.

Interviewee MB also mentioned that for the collection to be profitable and economic to the farmers, there need to be a chipper in the compartments and they chip the forest fuel biomass as they collect it to ensure they sufficiently collect enough at one time and not move around a lot to stack it by the roadside.

> Interviewee MB: "*So one other way which would make things easier is to always bring in the chipping machine. Some other guys would buy a tractor, which would have a chipping machine on the tractor that runs through the compartments. So, as they collect, they throw the biomass or things inside the chipping machine. So, it is putting the chips on the side and then it will take the chips in the roadside in a container. That is one way other than trying to pull the trees to roadside*."

Interviewee MB added to the statement by saying that it will be even more costly to pull a whole tree to the side of the road because the trees have different size, and some are smaller. The challenge comes in that the Skeeder (machine used to collect timber from the compartment) is sized to collect three tons, and with wood log, it is easy to ensure it is fully loaded at all times, but if it has pull trees as a whole, it will be difficult to ensure that it is fully loaded at all times and thus there will be significant fuel wastage with the Skeeder travelling being underloaded.

Interviewee MB: "*The challenge would be if you want to pull a whole tree to roadside, then it means you must use a Skeeder. So, a Skeeder is a very big machine. So now if the size of your trees are small, and if the Skeeder must go to road side, it must at least take about three tons to road side to make it cost effective, so if the trees are small and you cannot bundle them, you will not make much money, which means your extraction cost would go sky high. The volume that you are transporting is very small. So that's why most of the guys prefer to do it in the fields. You find what they would do is stack in filed and a tractor will come in the field and take it to the roadside. Or if they use a Skeeder, they will stack the timber into three tons and tie it with a rope and the Skeeder will take it to roadside. But if you want to pull trees then it becomes much more expensive, because you pull less volume then the cost of the fuel it won't work. The Skeeder, normally you find that it takes about 14 litres of diesel. Now the fact that you are pulling smaller trees it won't change the cost and the cost will be fixed for the fuel. But what you have taken out was very small. So now when you calculate at the end, your volume cost versus your fuel cost then you find that you have very high cost versus the volume taken out of field. So that's why whenever we do the stacking in the field, we're trying to maximise the fuel cost, that for every trip made to roadside it is done efficiently and you can benefit from it.*

Interviewee RE also supported the fact that you will need a chipper in the compartments in order to economically collect the forest fuel biomass and a baler that will ensure the forest fuel biomass is bundled properly for collection.

Interviewee RE: "*like I say when it is large bush, it is a problem to collect all these items. So, you will need a chipper for the biomass, branches and bark so it will be a big problem or challenge to do that because the logs are easy to collect but the biomass is more difficult. So, I do not know what is the cost of this chipper or you can get a bailer to collect the biomass."*

Due to the collection process being manually labour intensive, there has been injuries that occur. This was mentioned as not being good for business because you do not want to hurt people in any operation. Thus, they are looking into mechanising most of the processes to prevent manual labour as far as practically possible. Again, due to the process being manual labour intensive, most people do not want to work there, thus they have inadequate work force.

> Interviewee JA: "*So you either can get a machine, as Sappi got machines because they had problems with injuries, they encountered during the time of employing contractor to work with them. And every time it's people who are injured at work. Now they use more machines.*"
>
> *"So now what will happen is, you can employ people locally, but they do not want to work in the forests they don't want to work in the farms when we want to recruit people from the location in their farm, it becomes a problem. So, what we can do, if we work with you in this project, we have to comply. We get local and then keep those machine debarkers for the trees for Sappi we have a contractor to help with debarking."*

In comparison to the timber supply collection, it was mentioned that wet seasons poses a risk as they have to stop production since some machines could fall over due to the steep slopes they are being operated on.

> Interviewee DE: "*There's a variety of challenges. So first, firstly, like for instance, we in summer now, so the first challenge is because because of the terrain that we run in, as soon as it gets wet, we cannot access specific roads, routes or plantation so we can't supply fiber whenever it's basically wet, so the operation basically come to a complete standstill. And that's because even harvesting machines, I mean, we've got the most of machine running outside but when it does get waste, it's it's risky for for for us to actually continue running*

them because we're running very dangerous slopes. So machines might fall, they might get stuck."

5.5.4. Transportation of forest fuel biomass

Transportation of forest fuel biomass was one that almost all the people interviewed mentioned as being the biggest challenge to ensuring a sustainable biomass supply chain. The biggest challenge is that biomass is not dense like timber, so you load less mass per truck compared to when transporting timber. This makes the transportation of forest fuel biomass expensive, and thus it must be optimised to make sure it is economic. They mentioned that transportation of forest fuel biomass is the main thing that can kill this supply chain.

> Interviewee HE: "S*o for me, you need to look at all the different things, because what will kill you is the transport and, and are you putting in mulchers of whatever you do. So, for me, it's all the different things you also need to take, I always say transport is killing most of this. It is expensive, doesn't matter what form you do it in, just in my experience. Because there is no weight when transporting biomass, thus transport is expensive."*

> Interviewee JA: *"I think we will not have challenges much, except for transporting it to your place and to the place of where it is going to be bought."*

> Interviewee TH: "*The challenge I will have is the transport, you need to collect, shovel, and take to the market. who will pay for all that because it will be expensive."*

Interviewee MB mentioned that there are volume limitations before you even get to the mass limitations as the forest fuel biomass is light. So, you cannot load the correct mass that the transportation trucks are rated for, thus the fuel cost for transporting the forest fuel biomass goes up as compared to that for transporting the much heavier timber for pulp and paper production.

> Interviewee MB: *"If a timber truck is loaded with the timber that is sent to Ngodwana, it would weigh about 35 tons. But if you put in the biomass, you will not get the same 35 tons but roughly about 23 tons, so the fuel cost is the same, same driver salaries, tyres cost, so the fixed cost on the truck stays the same, but your end product is less. So, what you want to do is load more, but you cannot load more than the poles heights are covered, you cannot load more. Thus, you cannot make as much money*."

What Interviewee MB recommended was that the trucks must also be modified to suite biomass transportation. Thus, it was mentioned that rather using truck that are covered on all sides and can potentially be able to load more volume, thus more mass.

> Interviewee MB: "*There are these guys, that normally transport the wood chips. They have different trucks. So, their trucks are covered on all sides so they can stack more.*

Interviewee AT again mentioned that there are limitations to the distance that the forest fuel biomass can be transported to. Therefore, careful consideration needs to be put in when arranging for transportation of forest fuel biomass that is should not exceed specific kilometres as then it would make the whole supply chain economically unprofitable.

> Interviewee AT: "*And the main thing is the distance transported, because number one you do not get a trailer on the biomass. So, your transport is much*

more expensive. And there will be certain cut off per kilo-meter if it is viable or not."

They mentioned that the baling the biomass and compressing it, it would result in more weight being added on to the truck, thus more mass being transported. Thus, it is it imperative that the biomass is pre-processed before it sent to the end users to ensure there is maximised transportation costs.

5.5.5. Forest fuel biomass fire risk

From the interviews conducted, it was mentioned that fires can work both ways for forest fuel biomass. It was highlighted that when there are fires, it will result in more forest fuel biomass generation as most of the timber will not suite the specification for pulp and paper production. Therefore, if the fire is managed to the point where is does not consume the entire compartment, the residue can be harvested for forest fuel biomass.

Interviewee AT: *"Remember fire plays a big role, if you have a bad fire season, you have more biomass and if you have less fire seasons, then there is less biomass."*

Interviewee PA*: "there was a time where we lost about about 400 hectares in one day. And you know, in terms of the aerial support the aerial firefighting, because when the fires big with your own people on the ground, the fire trucks and the people you can't really contain it. But the flames are so high, you know, they go up. So you need the aerial support, to drop the aeroplanes to drop the water from the top just to lower the flames and then the people can get closer to the fire. So we used to spend the millions 1 million 2 million something like that."*

Fires need to be closely managed at all times because they greatly impact the supply chain for either forest fuel biomass or timber for pulp and paper production. If these fires are not closely managed, compartments can burn down to the point where nothing can be recovered.

> Interviewee MB: "*we were selling 4000 tons per month or every month, thus 48000 tons per year when you multiply by 12 months. This time around, it is has dropped so we will be sending 30,000 tons per year to Ngodwana. This is about 2500 tons per month. It is limitations caused by fires, which took place last year 2018 and 2019. Some was in 2014. So, some of the trees that burned last year and should have been harvested this year. And then some of them in 2014.*"

Therefore, fires are to be monitored at all times to ensure that this challenge or risk is minimised to prevent major losses to the supply chain, either for timber or for forest fuel biomass.

5.5.6. Summary of the findings of research question 3

From the research interviews conducted, there were several challenges that were highlighted that needed to be resolved in order to ensure a sustainable forest fuel biomass is established. The main challenges highlighted were transportation of forest fuel biomass. The challenge with transportation was because forest fuel biomass is less dense compared to timber used for pulp and paper production, the transportation cost per mass was high, and thus the biomass needed to be pre-treated to ensure it can be stacked optimally to maximise the trucks loading mass capacity. Forest fires was also highlighted as one the main challenges with getting sustainable forest fuel biomass supply, because a breakout in forest fires could potentially destroy all the possible biomass that could have been generated after felling or harvesting of the tress used as timber supply for pulp and paper production.

Forest fuel biomass collection was also identified as one of the challenges that would be encountered as it is manually intensive process and more efficient equipment is required to ensure that this process is optimised and also having a centralised location where all the farmers could take their biomass and store it there which will reduce their transportation costs. Having this centralised location will ensure a depot is built that will also be used to monitor the quality of the forest fuel biomass, like the moisture content before it is sent out the end users, so they maximise profits generated from the forest fuel biomass. It was also mentioned that as long there is transparency throughout the forest fuel biomass supply chain, from the famers, the centralised location or depot all the way to the end-users, then the famers would be in support of this because there is great value in establishing this supply chain.

5.6. Conclusion

This chapter has outlined the findings obtained when the interviews were conducted to understand if there was widespread knowledge about the uses of forest fuel biomass and if the famers would be interested in establishing such a supply chain and what challenges would arise from this supply chain. It was discovered that there are famers who are already working with the forest fuel biomass whilst others do not use it, but just burn it to clear their plantation compartments in preparation of the next planting season.

There was a general interest from the farmers to be involved in establishing this forest fuel biomass supply chain as long as it is economically viable and profitable. Therefore, the supply chain needs to be optimised at all angles to ensure there is minimal wastage and maximum optimal output. This was highlighted when they indicated the various challenges that could affect this forest fuel biomass supply chain like transportation costs, fire risks, collection efficiencies and quality of the biomass required by end-users. It was mentioned that transparency is required throughout the forest fuel biomass supply chain in order for all key role players to be supportive of it.

The following chapter will present a detailed discussion of the results and findings obtained from this chapter.

CHAPTER 6 – DISCUSSION OF RESULTS

6.1. Introduction

This chapter provides a detailed discussion of results outlined in Chapter 5. These results were obtained from conducting semi-structured interviews and the discussion of these results incorporated insights from the literature review presented in Chapter 2. These results were discussed in line with the research questions that were used to guide this research study. In line with the increased focus of governments globally driving their economies to be more environmentally friendly and minimise the use of fossil fuel to drive their economies, this study was conducted to determine the challenges that arise when establishing a sustainable forest fuel biomass supply chain, which is a more renewable source of feedstock for energy production, that will provide biomass feedstock to multi-fuel biomass boilers to generate more greener energy as compared to using the normal fossil fuel non-renewable feedstock like coal, natural gas and heavy fuel oils.

6.2. Discussion of research question 1

What are the possible uses of forest fuel biomass?

This research question was aimed at determining if the farmers knew about forest fuel biomass uses and what would drive them to establish a forest fuel biomass supply chain.

6.2.1. Burning of forest fuel biomass and alternative uses

From the literature study that was conducted, it was shown that charcoal is one of the biggest sources of energy in most African urban households to provide energy for cooking and heating up of households during the cold seasons (Zorrilla-miras et al., 2018). This charcoal is predominantly produced from timber that is harvested from plantations or biomass that is left behind in plantations after the harvesting season.

Looking at the discussions or interviews held with the farmers, they indicated that most of the biomass in their plantations is or was used in the production of charcoal. Some of them used to supply silicon smelters with the forest fuel biomass so they could produce charcoal that is used in their processes. Most of the farmers also indicated that they supplied local charcoal producers because it used to be a big market where the local communities would use the charcoal in their households for cooking. This is in line with what the literature study that was conducted indicating that charcoal is one of the biggest uses of forest fuel biomass left in plantations after harvesting.

6.2.2. Volumes of forest fuel biomass and profitable pricings

From the literature review conducted, it was established that since forest fuel biomass is a high volume low value product, it has to be priced in a manner that will be economic for the farmers to get them engage in the forest fuel biomass supply chain, otherwise if it is not profitable for them, then they will be reluctant in joining the initiative of establishing the forest fuel biomass supply chain (Sun et al., 2018).

This was further highlighted from the interviews conducted when the respondents mentioned that they are willing to get the forest fuel biomass supply chain established as long as there is something in return for them. They wanted it to be an initiative that will benefit them economically otherwise they will not support it. They indicated that the forest fuel biomass supply chain must bring in sufficient revenues for them in order to form part of it going forward.

6.2.3. Summary of the discussion for research question 1

Research question one looked in to weather the farmers knew about the uses of forest fuel biomass and what would drive them to establish the forest fuel biomass supply chain. It was discovered that the farmers would support the forest fuel biomass supply chain provided the process is economically viable for them, meaning it would be profitable and bring in extra revenues. This was supported by the literature conducted that indicated that the farmers want the biomass supply chain process to be profitable for them and it should not be something that it done with no financial benefits.

This research question also highlighted that some farmers know of alternative uses of the forest fuel biomass supply chain as they have been in business of supplying charcoal producers with the biomass to manufacture charcoal from their forest fuel biomass that is left behind after their harvesting season is completed. The charcoal alternative was also supported by the literature review that was conducted that indicated that some of the African households still heavily rely on charcoal as a source of energy for cooking meals for their families and to heat up their households during the cold seasons.

Therefore, from the sample of farmers that participated in this study, it was found that most of them knew about the uses of forest fuel biomass. Their main key item that was raised was the pricing of the biomass, that it must be economically viable as well as profitable to the farmers if they were to form part of this supply chain.

6.3. Discussion of research question 2

How can the entities (biomass suppliers and customer) contribute to establishing and optimising a forest fuel biomass supply chain?

This research question sought to determine how the farmers can play a part in establishing the forest fuel biomass supply chain and if they were willing to be key role-players in it. It also sought to uncover if the famers knew about forest fuel biomass supply chain, predominantly supplying multifuel biomass boilers to generate energy.

6.3.1. Knowledge of forest fuel biomass supply chain and harvesting

The literature study conducted for this research identified that one of the main uses of forest fuel biomass is feedstock for bioenergy production compared to the current fossil fuel feedstock being used to produce energy (Young et al., 2018). Forest fuel biomass is renewable matter as compared to the fossil fuel feedstock like coal, heavy fuel oil and natural gas that is non-renewable (Asada & Stern, 2018). Many countries are developing national energy strategies or policies that target the reduction of high dependency on energy produced from fossil fuel, and moving towards renewable energy that is produced from biomass which has less negative impact on the environment (Lochhead et al., 2016).

From the interviews conducted, it was identified that some of the farmers knew about the forest fuel biomass being used as a feedstock in the production of energy at various multifuel biomass boilers. This was in accordance to the literature study done that this forest fuel biomass can be used in the production of greener energy to move away from the fossil fuel feedstock that is predominantly being used.

From the Biomass Supply Chain Decisions Level model shown in the figure below, it can be seen that the tactical level of the decision making has to incorporate the harvesting plan of the forest fuel biomass (Zandi Atashbar et al., 2018). The harvesting plan ensures that there is continual supply of forest fuel biomass at all times of the year to the end users (Sun et al., 2018). The harvesting plan also incorporates the seasonal changes in volume requirement to the multifuel boilers, because during the colder months there is more biomass required due to the increased demand in energy usage as compared to the hotter months were there is generally lower energy usages in various households.

Thus, it is imperative to know how much biomass would be available from the various farms that would be part of the forest fuel biomass supply chain and know what would be the mitigation or risks associated with not having enough from a specific plantation and have a plan for the other farms to increase their capacities in situations where there is a farm that will not be able to meet the demand.

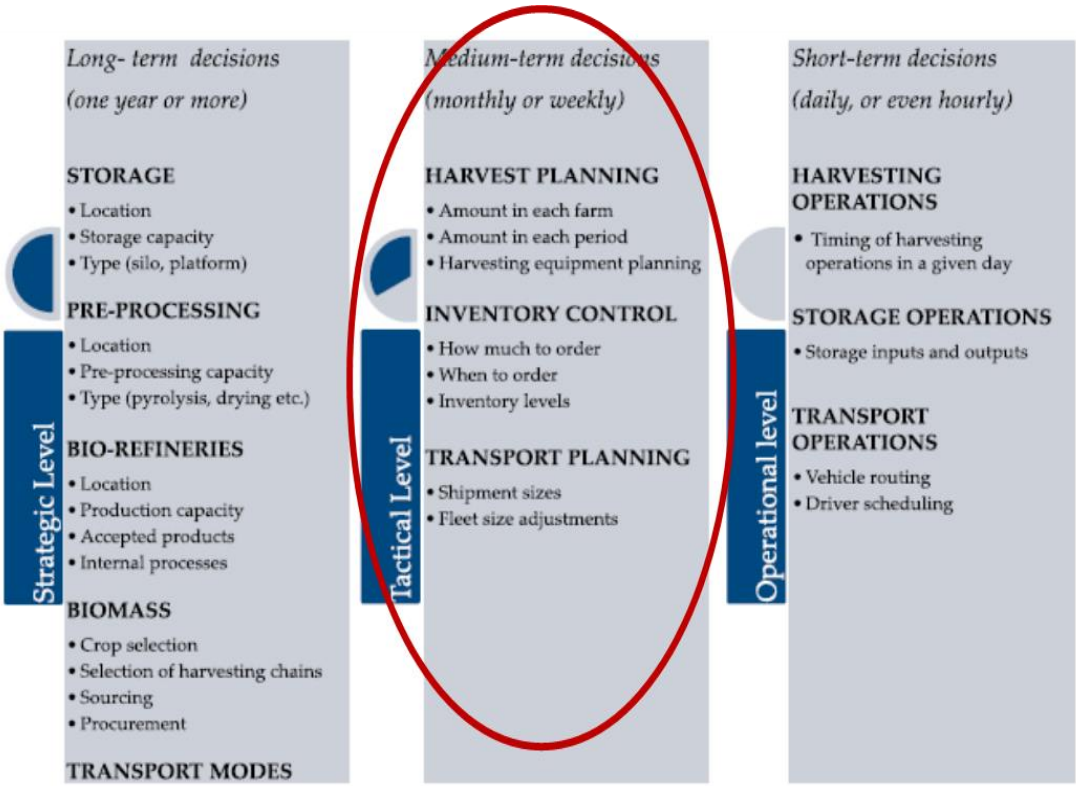

Figure 13: Harvest Planning Decision Levels in biomass supply chain

Source: (Zandi Atashbar et al., 2018)

From the responses obtained during the interviews, it was mentioned that the farmers have a harvesting plan that they need to follow. They mentioned that this was to ensure that there is continual sustainable supply of timber and forest fuel biomass to their customers. Therefore, it can be seen that it is in line with what was identified by the Biomass Supply Chain Decisions Level model that indicated that a harvesting plan needs to be in place to ensure sustainable supply of forest fuel biomass.

6.3.2. Availability of forest fuel biomass

Building on the harvesting plan discussed above that needs to be in place for a forest fuel biomass supply chain to be sustainable (Sun et al., 2018), it also shows that the biomass has to be available in large quantities for this supply chain to be sustainable. Thus, this was shown to be true when the farmers were asked about the availability of the forest fuel biomass from their plantations. The farmers mentioned that the forest fuel biomass was available to be utilised after they fell a compartment. One of the farmers also indicated that for the large amount of volume that could be required as feedstock to a multifuel biomass boiler, it should be investigated that the actual timber itself they are planting will not be used. This is provided that the price that would be paid by the multifuel biomass boiler organisations is competitive to the price that is currently being paid by other timber users like the pulp and paper industry.

Therefore, as the production of energy from forest fuel biomass increases and more feedstock is required, then this option would have to be investigated taking into consideration that this is greener energy being produced and thus by using more renewable matter in their organisations and reducing the fossil fuel feedstock, they would be reducing their carbon foot print and thus reduced carbon tax that is imposed by the government which could be increased to a point that justifies organisations to move to renewable matter being used in their processes (Rebublic of South Africa, 2019).

6.3.3. Summary of the discussion for research question 2

In unpacking research question two, it was identified that some farmers knew about the forest fuel biomass being used as feedstock to multifuel boilers that generate steam to power turbines to produce electricity. This was again supported by the literature review that was conducted indicating that governments are introducing policies that are driving organisations to move away from fossil fuel and use renewable energy like biomass to produce energy (Young et al., 2018). It was also uncovered that it is imperative for the farmers to have a harvesting plan to ensure that there would be sustainable forest fuel biomass supply throughout the year to the various multifuel boilers and incorporating the seasonal changes in volumes required (Sun et al., 2018).

With the South African government imposing carbon tax on the amount of fossil fuel an organisation uses in their processes (Rebublic of South Africa, 2019), it was mentioned that the need for the timber to also form part of the feedstock to the biomass boilers could end up being economically feasible. It could be economically feasible to use the timber as well as feedstock to the biomass boilers and not only for its current uses like for pulp and paper production because if the carbon tax becomes significantly high, it would force these organisations that are currently relying on fossil fuel feedstock to covert to renewable feedstock like biomass to generate energy and thus reduce their carbon footprint.

6.4. Discussion of research question 3

What challenges arise in establishing and managing a forest fuel biomass supply chain?

This research question identified the challenges and barriers that arises when establishing forest fuel biomass supply chain in South Africa. Some of these challenges were identified in literature and compared to what the farmers have mentioned as their main challenges in getting the forest fuel biomass supply chain established.

6.4.1. Centralised location and transparency

From the literature review conducted in this research study, it was shown that there needs to be transparency throughout the forest fuel biomass supply chain so that there is trust between the key role players in the supply chain (Mertens et al., 2019). Thus, the whole process needs to be open and all the key role-players are given fair treatment and they also need to know each other so they can work together to ensure that this forest fuel biomass supply chain is sustainable.

It is imperative that the farmers know each other and can trust each because some of the machines used in creating this forest fuel biomass supply chain may have to be shared between the farmers at a centralised location. Due to the fact that these machines require high capital investments which cannot be afforded by one single farmer, but when it is a joint group of farmers it may be feasible to have this machines acquired and utilised to enhance and optimise the efficiency of the forest fuel biomass supply chain (Sun et al., 2018).

The farmers also confirmed this to be true when they mentioned that there needed to be openness throughout the forest fuel biomass supply chain. They wanted fair and equal treatment and that everything should be standardised for all parties involved and they know upfront how the systems will work. They indicated that a centralised location would be the best way to go forward, where the forest fuel biomass would be collected from the various surrounding farms and brought to this centralised location that will be in close proximity to their farms. This centralised location would have to be fitted with a weigh bridge, so that when trucks come to deliver the forest fuel biomass, they are weighed and paid per mass of forest fuel biomass delivered.

This indicated that the farmers wanted fair treatment amongst themselves and they all understand that they are being paid and managed in the same way and it is a proven method on how this is done. They mentioned that a weigh bridge is the best way to ensure transparency with truck load deliveries because forest fuel biomass is not dense, so one truck load may vary significantly to another truck load because of how the forest fuel biomass may be loaded and stacked in the trucks.

This was again supported by the literature that was conducted that indicated that the forest fuel biomass is very light in weight, and it cannot be packed efficiently to optimise the loading of the trucks, thus if the end user or the multifuel boilers that use this forest fuel biomass as their feedstock are located far, it will not be economically feasible to send the forest fuel biomass directly from the farms to the mills, but rather it would have to be pre-treated or pre-processed to ensure maximised truck loading (Flisberg et al., 2018). Pre-processing of forest fuel biomass may involve drying, chipping, baling and compressing of the forest fuel biomass (Sun et al., 2018).

Through pre-processing the forest fuel biomass by chipping, baling and compressing, will ensure that the bulk density of the forest fuel biomass is increased and thus there will be more mass loaded on the transportation vehicles and thus improving the cost per ton of mass transported. This centralised location will be a place where the biomass is brought to further be dried up before it is chipped, and the stock inventory will also be kept here as it will serve as a depot.

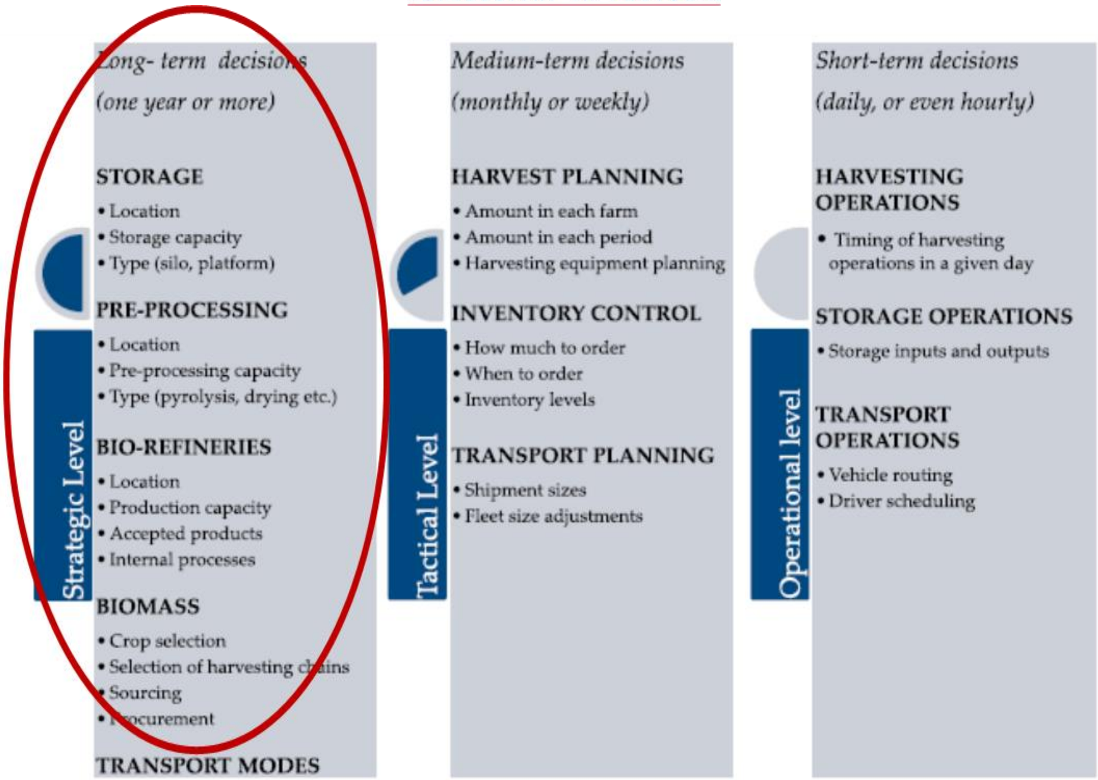

Figure 14:Storage & Pre-processing Decision Levels in biomass supply chain

Source: (Zandi Atashbar et al., 2018)

From the Biomass Supply Chain Decisions Level model depicted in the figure above, it can be seen that biomass storage facility and biomass pre-processing forms part of the strategic level in the decision-making model. Thus, it is vital that there is centralised location in the form of forest fuel biomass depot established to ensure that the pre-processing of the forest fuel biomass takes place there as well as having a forest fuel biomass storage facility. This also allows for inventory control which forms part of the tactical level in the decision-making model. Therefore, it is imperative that a centralised forest fuel biomass depot is established to ensure that these items discussed are taken care of in the supply chain design.

6.4.2. Quality of the forest fuel biomass

It was identified from the literature that the quality of the forest fuel biomass is important as the organisations that buy this forest fuel biomass incorporate the quality of the biomass. They pay for the biomass based on the energy content in the biomass which is also dependent on the moisture content of the delivered forest fuel biomass (Flisberg et al., 2018). As already discussed above, it is imperative that the quality of the forest fuel biomass is monitored and ensured that it is consistent when delivered to the end users which are the multifuel biomass boiler organisations. The quality is again monitored at the depot, which is the centralised location where the forest fuel biomass is gathered and pre-processed before it is sent to the end users.

During the pre-processing steps at the centralised location or forest fuel biomass depot, the dryness of the forest fuel biomass is monitored and ensured that it is in line with the desired end user specifications (Zandi Atashbar et al., 2018). If there is more moisture in the forest fuel biomass as it is delivered to the multifuel boiler organisations, they will have to pre-dry it first to drive out the moisture content prior to feeding it to their boilers. It is dried to allow for ease of combustion in their boilers and they can have optimised energy generation. Therefore, if there is high moisture content, the multifuel boiler organisations will pay less for the biomass as they will incur an additional cost during their pre-drying processes.

From the interviews conducted, the farmers also mentioned the quality of the biomass must be closely monitored as they have seen previously that the end users pay according to calorific value of the forest fuel biomass which is greatly impacted by the moisture content in the biomass. Thus, the higher the dryness factor, the higher the price of the forest fuel biomass when it is sent to the market. The farmers and forest managers indicated that the forest fuel biomass needs to be dried up first before it can be chipped, because chipping high moisture content forest fuel biomass or timber could damage the chipping machines and this will slow down the process, making it inefficient. Generally, they mentioned that the drying process of the forest fuel biomass is done at the harvested compartment, by leaving the forest fuel biomass for at least two weeks before collecting it.

The challenge arises when the area is continually damp due to uncontrolled weather conditions, so they may not be able to access the forest fuel biomass and chip it, thus that is where the depot can come into play, so the forest fuel biomass can still be collected whilst it is still wet and dried up at the depot prior it is chipped. This ensures that there is continual supply of forest fuel biomass and there is sufficient stock at all times and it is monitored as seen on the tactical level of the Biomass Decision Making model were forest fuel biomass inventory level has to be managed (Sun et al., 2018).

6.4.3. Collection of forest fuel biomass

With the increased demand of forest fuel biomass due to the regulations that are driving organisations to produce more greener energy, more optimised systems to collect forest fuel biomass have been developed (Gunnarsson et al., 2004). Forest fuel biomass collection is believed that it can be doubled when done efficiently (Flisberg et al., 2018). It was identified that the collection of forest fuel biomass can be optimised when the assortments are done in a specific manner where the fuel wood is stacked separately to the logging residues, and that is stacked separately to the treetops. When the collection is done in this manner, it allows the collection of the forest fuel biomass to be optimised and improved (Zandi Atashbar et al., 2018). If the chipping of the forest fuel biomass is done in the compartments as it is being collected, this will make the process of handling the forest fuel biomass more efficient, and it is just the chips container from the chipping tractor that is offloaded on the roadside when it is full (Flisberg et al., 2018).

This was further supported by the results obtained from the interviews conducted that showed that the collection of the forest fuel biomass is one of the biggest challenges. They indicated that it is easier to collect timber logs as compared to the forest fuel biomass because you can handle the timber logs much more efficiently than the forest fuel biomass. They normally stack the timber logs and a Skeeder comes in and collects them from the compartment being harvested and then stacked by the roadside where it will be taken to the various terminal points.

The challenge arises when collecting forest fuel biomass since it cannot be stacked as efficiently as the timber logs, and it is also much lighter than the timber logs. As mentioned in the results section of this report, a Skeeder machine is designed to carry a certain load of mass and it transport that to the roadside. If the Skeeder does not fully load as is in the case of moving forest fuel biomass, there will be increased cost associated with the collection of the forest fuel biomass and this will result in the process not being economically feasible. The Skeeder cannot move the same mass quantity of forest fuel biomass as compared to the timber logs due to the lower bulk density of the forest fuel biomass, thus this result in higher extraction costs of forest fuel biomass from the compartments to the roadside. One of the interviewees mentioned that the collection of forest fuel biomass by the farmers should not only be looked in a profitability manner, but that they just need to recover the costs associated with clearing the compartments as they will have to do it anyway at their own cost. Thus, they need to look at it with a broader view that it is something that must be done, and even if they break-even, it would still be fine, and it would still be beneficial for them.

6.4.4. Transportation of forest fuel biomass

From the literature study conducted, it was found that the transportation of forest fuel biomass was one of the biggest costs associated with this supply chain. The main challenge that was identified was that forest fuel biomass has low density and it cannot be stacked the same way that the timber logs can be stacked (Sun et al., 2018). This increased the cost per mass transported of forest fuel biomass compared to that of timber logs transported for the production of pulp and paper. Therefore, it was identified that for the forest fuel biomass to be transported in a cost-effective manner it had to be pre-processed (Gunnarsson et al., 2004). Pre-processing of forest fuel biomass as it was discussed in Section 6.4.1. incorporated chipping, baling and compressing the forest fuel biomass to increase its the bulk density (Sun et al., 2018).

It was also identified from the Biomass Supply Chain Decisions Level model that transportations forms a critical part of the biomass supply chain under the strategic level and so does the transport planning (Zandi Atashbar et al., 2018). This was further confirmed in the results section of this report where it was shown that the interviewees mentioned the transportation of forest fuel biomass as one of the biggest challenges. They further went on to mention that transportation was a killer for this supply chain. Therefore, it was found that it is imperative that the optimisation of the forest fuel biomass transportation be managed efficiently to ensure the process is profitable and sustainable. By compressing the forest fuel biomass as far as possible to increase its bulk density and ensuring that it is as dry as possible so there is minimal water being transported was one of the ways which was mentioned by the interviewees to optimise the transportation.

6.4.5. Forest fuel biomass fire risk

It was shown from the literature study conducted that forest fires accounted to a loss of about 25% of all biomass being destroyed in the plantations (Lauk & Erb, 2009). Therefore, this only leaves about 75% of biomass to be collected and with loses in collection and inefficiencies, this number could potentially be lower as it was discussed. From the results section, it was also identified by the interviewees that their plantations are prone to fires, thus fire management must be part of their strategy.

This was found to be a gap looking at the Biomass Supply Chain Decisions Level model shown in the literature review, that it does not incorporate general risk management associated with managing a biomass supply chain. The risk could result from natural disasters, economic disruption, political situation or labour disputes as it was shown in the literature review (Ouhimmou et al., 2019). These are what are called triggering events as discussed in the literature review (Heckmann et al., 2015), and they need to be incorporated in the Biomass Supply Chain Decisions Level model.

6.4.5. Summary of the discussion for research question 3

In unpacking research question three, it was identified that there are various challenges that impact the establishment of the forest fuel biomass supply chain. The main challenges that needed to be addressed was ensuring that there is transparency throughout the biomass supply chain so the key role-players can have confidence in the openness of the supply chain and believe in it. Having a centralised location was also identified as one of the key strategic decisions that would ensure that the supply chain is optimised so there would be minimal transportation costs and a depot were all the biomass inventory would be kept as well as being pre-processed to ensure they meet the end user's specifications and it can be chipped and baled to maximise mass loading, thus improving the transportation cost effectiveness. It was also identified that fire management is crucial, as if it is not managed, it could result in about 25% of all biomass left in the plantations being destroyed. Looking at the Biomass Supply Chain Decisions Level model, it was further identified that risk management need to be incorporated to this model to ensure mitigation plans are addressed in case there are risks that arise as a result of natural disasters, economic disruption, political situation or labour disputes.

6.5. Conclusion

This chapter has outlined the discussion of the results of this study. It was shown that there are some farmers that knew about the uses of forest fuel biomass and how it could be used instead of leaving it in the plantations after felling the trees. It was also shown that there was interest from the interviews conducted, that the farmers would be interested in establishing the forest fuel biomass supply chain, provided it is economically viable and profitable. The main challenges that were identified was that there needs to be transparency and openness through the biomass supply chain key role-players, so there is trust built amongst themselves as they would have to work together to make the forest fuel biomass supply chain sustainable and profitable. There were risks that were identified that also needed to be incorporated into the Biomass Supply Chain Decisions Level model as it does not address risk management. Risks that arise from natural disasters, economic disruption, political situation or labour disputes needs to be managed and therefore they need to be addressed on the Biomass Supply Chain Decisions Level model.

The following chapter presents the conclusions of this research study.

Chapter 7 – CONCLUSION AND RECOMMENDATIONS

7.1. Introduction

This research study was aimed at exploring the development of forest fuel biomass supply chain in South Africa. The use of fossil fuel to produce energy was found to have a negative impact on the environment and the fossil fuel itself is being overexploited and getting depleted, thus alternative fuel feedstock is required (Carraresi et al., 2018). Therefore, globally governments are developing national energy strategies or policies that target the reduction of high dependency on energy produced from fossil fuel, and moving organisations towards renewable energy that is produced from biomass which is bioenergy (Lochhead et al., 2016). Forest fuel biomass is one of these renewable matter that is being used as feedstock to power multifuel biomass boilers or co-fired boiler (Giampietro, 2019) to produce energy that has less negative impact on the environment. This exploratory study identified challenges that farmers or farmers based in South Africa face in creating a sustainable forest fuel biomass supply chain that will supply adequate forest fuel biomass to the organisations that require the forest fuel biomass to generate greener bioenergy.

7.2. Conclusion of the results by research questions

Research question 1: What are the possible uses of forest fuel biomass?

It was shown through research question one that some farmers knew what the forest fuel biomass could be used for, like in the production of charcoal, which many of them were involved in. It was shown that many households in sub-Saharan Africa, still used charcoal as a source of energy to cook for their families and also warm up their house holds during the colder moths of the year. From the sample of farmers that participated in this study, it was found that most of them knew about the uses of forest fuel biomass and their main key challenge they raised was the pricing of the biomass, that it had to be economically viable as well as profitable to them if they were to form part of this forest fuel biomass supply chain.

Research question 2: How can the entities (biomass suppliers and customer) contribute to establishing and optimising a forest fuel biomass supply chain?

It was identified through research question two that some of the farmers knew about the use of forest fuel biomass used as feedstock to multifuel biomass boilers to generate greener energy that is less harmful compared to the energy generated from fossil fuel feedstock. It was also found through unpacking this research question that it is crucial for farmers to have a harvesting plan that would ensure there is sustainable continuous supply of forest fuel biomass to the multifuel biomass boiler organisations. This was supported by the Biomass Supply Chain Decisions Level model that indicated that the harvesting plan is important as part of the tactical decision level.

Research question 3: What challenges arise in establishing and managing a forest fuel biomass supply chain?

Through unpacking research question three, it was identified that there were multiple challenges that impacted the establishment of forest fuel biomass supply chain. One of the main challenges was to ensure that there is transparency throughout the biomass supply chain so the key role-players can have confidence in the openness of the supply chain and believe in it whilst working together to make it work. Ensuring that there is a centralised location built, where all the farmers would bring their forest fuel biomass and have it pre-processed there to ensure that it meets the end-users' specification was one of the challenges that was identified and this was also highlighted on the Biomass Supply Chain Decisions Level model. Forest fire management, general biomass fire management and other risk factors that could arise from natural disasters, economic disruption, political situation or labour disputes needed to be managed. This was found to be a gap on the Biomass Supply Chain Decisions Level model that should be addressed as indicated in the following sections.

7.3. A proposed model

This section presents a prosed model that should be utilised in creating forest fuel biomass supply chain. The proposed model is built upon the model created by Nasim Zandi Atashbar, Nacima Labadie and Christian Prins. The figure below depicts the Biomass Supply Chain Decisions Level model that was created by the people mentioned above to help and align the decision-making process of forest fuel biomass supply chain. This model was created to optimise and master the complexities that come with optimising biomass supply chain (Zandi Atashbar et al., 2018).

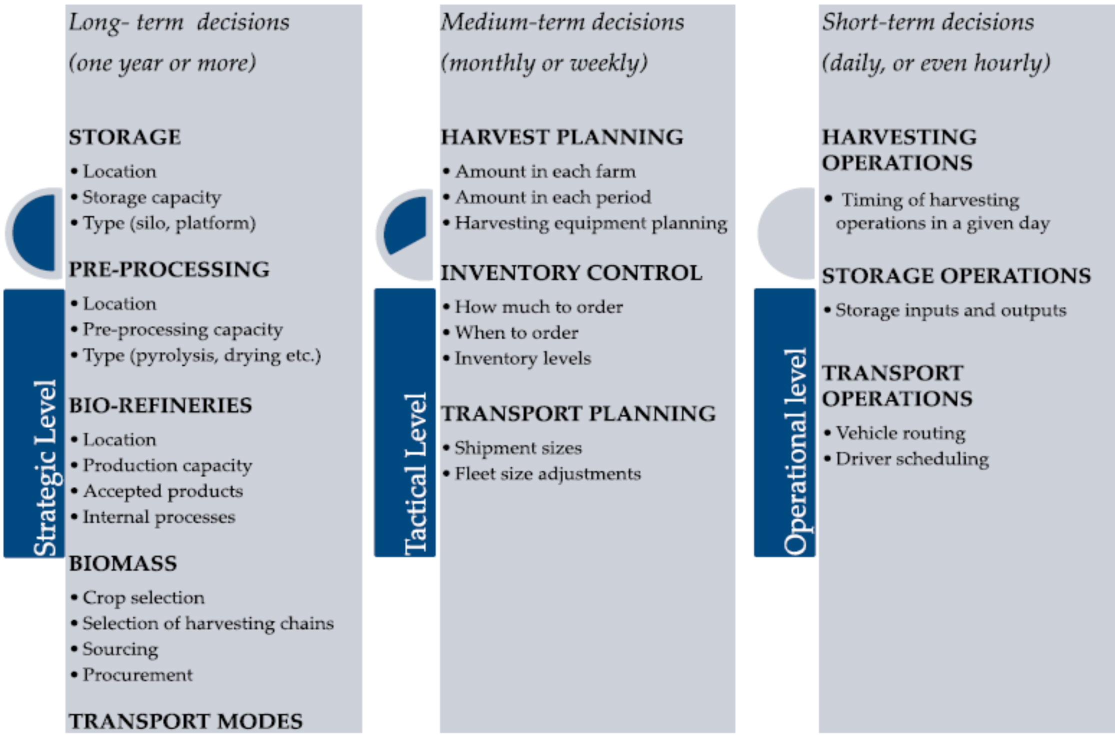

Figure 15: Discussion on Biomass Supply Chain Decisions Level model

Source: (Zandi Atashbar et al., 2018)

From this model, it can be seen that the Biomass Decision Making Level has been classified into three levels, which are the strategic level, tactical level and the operational level. As previously discussed in the literature review, the strategic level depicts decisions that needs to be taken for the long term which mostly involves financial investments and they take more than one year time frame to be executed like constructing a new factory (Sun et al., 2018). This includes the storage facilities, the location where it would be based, the capacity of the storage facilities. It also looks into the pre-processing systems; how will the biomass be pre-treated to ensure it meets the end-user's quality specifications. Lastly it looks at the transportation modes of the forest fuel biomass. Will it be transported by road, rail or water? All these decisions need to be considered before establishing a sustainable forest fuel biomass supply chain and managed accordingly.

The tactical level focuses more on the medium-term decision making of the forest fuel biomass supply chain. This looks into the harvesting planning schedule and inventory level control. This ensures that there are adequate stock levels at all times throughout the year to maintain the feedstock capacities required by the multifuel biomass boiler organisations (Zandi Atashbar et al., 2018). It again looks into the transportation planning to ensure that this is optimised and there is no unnecessary fuel wastage by taking longer routes whilst there are shorter and better routes available that could result in delayed deliveries.

The operational level of the Biomass Supply Chain Decisions Level model focuses on the daily decisions to be taken to meet the daily requirements to operate the biomass supply chain sustainably. This again looks at the daily harvesting timing to ensure they meet the daily requirements whilst managing the daily inventory stock movements.

From the results obtained from this research study, it was identified that risk management played a big role in ensuring that the forest fuel biomass supply is sustainable and can deliver the required volumes at the required times. Therefore, this was identified as the gap that needed to be incorporated to the Biomass Supply Chain Decisions Level model that was described above. Risk management was thus incorporated across all decision-making levels which are strategic, tactical and operational levels as seen on the figure below of the proposed Biomass Supply Chain Decisions Level model.

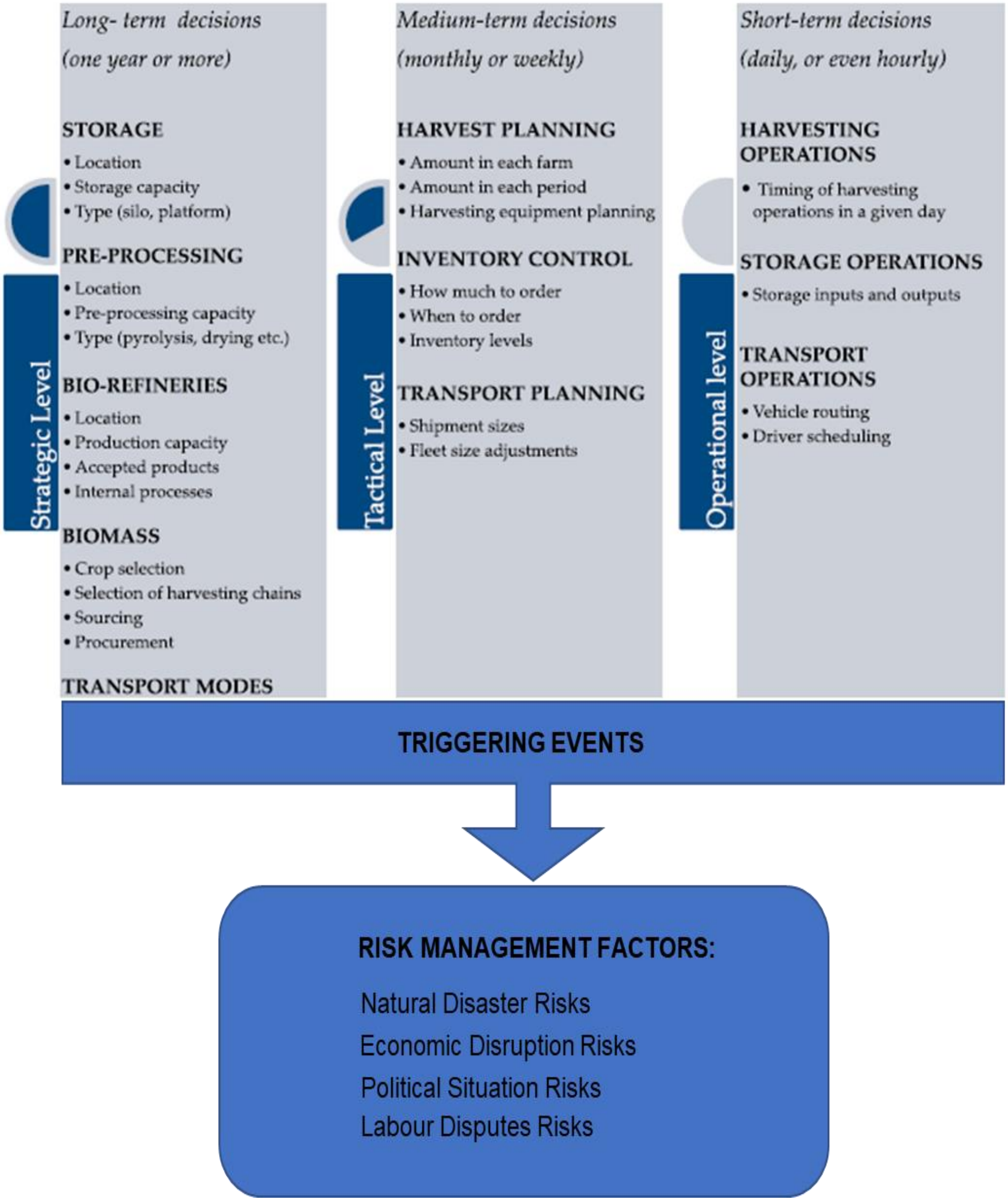

Figure 16: Proposed Biomass Supply Chain Decision Making Model

Risks needs to be managed so there could be mitigation plans that are put in place to ensure that if there are any risks that come, there is a plan to work with that will keep the forest fuel biomass supply chain functional. The risks that were identified were triggering events, which could result from natural disasters like fires and draught; economic disruptions; political situational risks and labour dispute risks.

These risks are the most common ones that were discussed by the farmers during the research study that would potentially hamper the success or functionality of the forest fuel biomass supply chain.

7.4. Implications for business

This research study has presented how imperative it is that when establishing a forest fuel biomass supply chain, there are main key factors that need to be considered and managed to ensure that supply chain is sustainable. This study has built upon the Biomass Supply Chain Decision Making model and outlined that risk management must be factored when establishing a forest fuel biomass supply chain. The risks that were identified and found to be a gap with the existing model was mostly the triggering events, which are risk that results from natural disasters, economic disruptions, political situation and labour dispute risks.

The contribution made by the researcher was in identifying the risk gap in the Biomass Supply Chain Decision making model, to indicate that if risk mitigation management is not included in using the Biomass Supply Chain Decision Making model, it would result in having a supply chain that is established but vulnerable to triggering events that were identified.

7.5. Limitations of the study

This research study was exploratory in nature, therefore limiting its generalisability of the results that were obtained during the study. Additional limitations of the study comprised:

- Due to the subjective nature of a qualitative research study, the research may be affected by the biases of the researcher.
- Due to the small size of the sample that was used in conducting the research, generalisability of the results obtained is limited to other contexts.
- Only farmers that were based in South Africa at the Mpumalanga region, Sappi Forestry management and Sappi co-fired boiler operational stuff formed part of this study.

7.6. Suggestion for future research

Future research study may need to duplicate this research in a different geographical region to determine if the same results are uncovered. It is recommended that other famers who have potential biomass residue left behind after their harvesting season apart from the ones supplying timber be used to also determine if the same results are obtained with regards to establishing a sustainable forest fuel biomass supply chain. This research study should also be repeated and validated using a quantitative research method to determine if the results obtained from this study still hold with a lager sample.

7.7. Conclusion

This research study has outlined how a sustainable forest fuel biomass supply chain should be established. By using the exploratory, qualitative interviews, it was identified that risk management should be incorporated in the Biomass Supply Chain Decision Making model. This will help put measures in place to mitigate against triggering events like natural disasters, economic disruptions, political situation and labour dispute risks. By ensuring that these risks are mitigated against, a sustainable biomass supply chain can be established that will be able to supply forest fuel biomass to all its various customers in a sustainable way throughout the year and through seasonal changes in demand. These additional triggering events where added to the existing model to summarise how they should be utilised in ensuring a sustainable forest fuel biomass supply chain is established.

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9. APPENDICES

APPENDIX 1: INFORMED CONSENT FORM

Title of proposed study:

The importance of biomass and its supply chain: challenges facing forest fuel biomass supply chains in South Africa

Researcher's name: Kabelo Lefofana

Final year student at Gordon Institute of Business Science, University of Pretoria

	Please initial	
1. I confirm that I understand what the research is about and have had an opportunity to ask questions		
2. I understand that my participation is voluntary and that I can withdraw at any time without giving reason.		
3. I agree to take part in the research.		
	Yes	No
4. I agree to my interview being audio recorded		
5. I agree to the use of anonymised quotations in the publications.		

Name of participant:…………………………….. Signature:…………………….

Researcher's name:……………………………. Signature:…………………….

Date:

(Saunders & Lewis, 2018)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

APPENDIX 2: ETHICAL CLEARANCE

Gordon Institute of Business Science
University of Pretoria

Ethical Clearance Approved

Dear Kabelo Lefofana,

Please be advised that your application for Ethical Clearance has been approved.

You are therefore allowed to continue collecting your data.

We wish you everything of the best for the rest of the project.

Ethical Clearance Form

Kind Regards

APPENDIX 3: INTERVIEW GUIDE

Establishing biomass supply chain - Challenges facing forest fuel biomass supply chain
Introduction
• Thanked the participant for attending
• Explained the purpose of the research and interview. Emphasis that the participant's own opinions were important
• Asked if the participant was willing to be interviewed and that it was their decision to be interviewed
• If they were willing, the researcher asked them to read and sign the consent form; if they not willing, the researcher thanked the participants for their time and closed the interview
Interview
1) Do you know of the possible uses of the biomass that is being left in the plantations after harvesting as alternative to supplying nutrients to the soil?
a. Probe: What are those uses?
b. Probe: What valuable product(s) can it be converted to, and give some examples you know of?
2) What do you understand regarding the supply chain and specifically forest fuel biomass supply chain?
a. Probe: Who can be supplied with the forest fuel biomass (what potential markets are there?)
b. Probe: How could those markets be supplied?

3) What do you think are the main challenges that could prevent the establishment, or sustainable operation, of forest fuel biomass supply chains?
a. Probe: Can you give some examples of these challenges? b. Probe: What are your biggest problems with the biomass distribution? c. For Sappi forestry management: what are the main challenges you encounter in ensuring a sustainable timber supply chain for pulp and paper production? d. For biomass boiler operational stuff: what are the challenges you face with combusting biomass

APPENDIX 4: ATLAS.TI CODEBOOK

<u>Individual codes</u>

○ Available biomass supply

○ Benefits of using machines for biomass collection

○ Biomass Depot

○ Biomass market

○ Biomass transportation challenge

○ Burn the biomass to clear compartments for next plantation

○ centralised location

○ Challenges with labour

○ Collection of biomass on the farm

○ Cost for biomass

○ Cover lost production from other plantations

○ Create more employment

○ Debarking

○ dry contracts with transportation

○ equipment wear

○ Fire risk

○ Fuel for machinery used

○ Future difficulty of sourcing of biomass

○ Future value of biomass

○ Harvesting frequency

○ Incentives to stop fires

- Increase company profitability
- Increase in volume of biomass required
- Industries converting to biomass
- Knowledge of biomass supply chain
- Lightning striking trees and causing them to dry up
- Looking for alternative users for biomass
- Quality of biomass
- Redress reject timber
- Residual forest fuel biomass uses
- Risk of burning biomass
- Risk of falling machines
- Size of the farm
- Sourcing of biomass
- Storage of biomass
- Strapebility issues in winter
- Timber volume supply
- Transparency
- Tree species being planted
- Uses of biomass
- Volume of biomass
- Wet terrain