MODELLING LAND-USE DECISION-MAKING IN ENCROACHED FORESTS, COPPERBELT PROVINCE, ZAMBIA

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Abstract

Natural resource management is an important issue around the world in the light of increased global population size and the subsequent demands arising from an increased need for food, clean water and other ecosystem services. This has often resulted in the encroachment of protected areas and the adoption and maintenance of unsustainable land use practices.

This study is concerned with the development of tools that will help us understand the characteristics of land use decision-making by people who illegally settle in protected areas. The study has the main aim of developing a model of local stakeholder land-use decision-making for the encroached forest areas in the Copperbelt Province of Zambia. This will allow the modelling of the stakeholder land-use practices. This will help predict their effects on the environment of the Province

Soft Systems Methodology (SSM) was used to develop a conceptual model of land use decision making in the study area and the outputs from SSM were used to develop a Belief Network (BN) model of land use decision making in the study area. Decision trees were also used to model the land use decision-making characteristics of the local stakeholders in the area.

The findings suggest that SSM is a useful tool for the modelling of the complex problem situation in the study area and the subsequent development of solutions to the problems identified through participatory approaches. The research also showed that BNs and decision trees were able to model land use decision-making by using the agricultural activity as a basis for analysis.

The findings suggest that BNs and decision trees are complementary and have the potential for addressing applications in land-use decision-making in informal settlements where available information is more likely to be scant and disparate.

Dedication

This work is dedicated to the memory of my father, Mr Henry Mulemwa Akombelwa and uncle Simasiku who taught me to never give up in whatever I do.

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Chapter 1 - Introduction

1.1 General Introduction

The state of the environment is of concern today as the world population increases. Access to natural resources such as clean water, clean air, renewable energy sources and good fertile soil for agricultural production, is now at a premium because the demand for them outstrips their natural supply (MA, 2003). A more intensive use of the Earth's resources is thus anticipated in order to accommodate future population growth and economic expansion (Lein, 1997; Liu & Taylor, 2002; UNECA, 2002). The management of the environment implies the need to involve various stakeholders in decision-making processes for the purpose of sustainable development especially in developing countries. This requires an understanding of the frameworks that guide the various stakeholder decisions with respect to land use. To model how land use changes, it is necessary to identify who makes the decisions and to model their decision-making processes. It is, therefore, important to structure predictive models at appropriate spatial and temporal scales that reflect the relationships between policy, land-management and environmental processes (Bacon et al., 2002). Three main challenges to the modelling process arise. Firstly, the problem of sparse data especially for rural areas in developing countries. Secondly, the challenge of integrating of data layers in a spatial analytical system poses a problem because of misalignment of the data sets. The third challenge is to develop an understanding of the spatial decision-making processes carried out by the stakeholders and to express the stakeholder perceptions. The use of spatial information in environmental decision-making as an aid to planning or monitoring is important given the increasing use of GIS in participatory methods for seeking solutions to environmental and social problems (Bunch & Dudycha, 2004; Carsens & van der Knaap, 2002; Harris et al., 1995; McCall, 2003).

The research project explored stakeholder spatial decision-making with respect to land use and its implications for the development of sustainable participatory management strategies. This was in light of the challenges of sparse data, data integration and to develop an understanding of, and the subsequent expression of, stakeholder perceptions with regard to land use. It used the Copperbelt Province of Zambia as a case study.

1.2 Aims and objectives of this study

This section presents the aims and objectives of the research.

1.2.1 Aim of the study

The study had the main aim of developing a model of local stakeholder land-use decision-making for the encroached forest areas in the Copperbelt Province of Zambia. This allowed the modelling of the stakeholder land-use practices to help predict their effects on the environment of the Province.

1.2.2 Objectives

To achieve the aim stated here, a number of objectives had to be satisfied. These were outlined as:

i. To develop a model of the existing land-use decision-making system using soft systems methodology (SSM).

This was done by the researcher in conjunction with all the stakeholders in the study area during the field survey. Focus group meetings were held with all stakeholder groupings together. It was expected that this would reveal the nature of the land-use decision-making process currently in use in the study area and subsequently allow problems and issues to be addressed.

ii. To develop a Belief Network (BN) model of land-use decision-making using agricultural activity as a basis for analysis.

This was done by the researcher using questionnaire and other data. Stakeholder perceptions required for this process were obtained by sampling through administration of the questionnaire. The analytical process was conducted after the SSM process. It was expected that this would examine the local stakeholder land-use decision-making process and allow the prediction of land-use decisions.

iii. To develop a Decision Tree model of land-use decision-making using agricultural activity as a basis for analysis.

This was done by the researcher using questionnaire and other data. Stakeholder information needed for this process was obtained from the questionnaire administration. This was expected to examine whether the land-use decision-making process could be automated and subsequently, if it could allow for the prediction of land-use decisions.

iv. Evaluate national policies related to the access to and usage of land by local stakeholders.

This was done by the researcher. National policy documents were consulted in conjunction with information from the focus group meetings and questionnaire. This exercise was expected to examine the role of national policies in influencing land-use decision-making.

v. To identify the relationship between the different types of tenure and the land related uses

This was done by the researcher using the questionnaire and other data. Interviews with the stakeholders were conducted and information from the focus group meetings was used to explore the trends of land tenure type and land use practices in use.

1.2.3 Research questions

The capturing, understanding and characterisation of the different perceptions of local stakeholders and their implications for the management of the environment constitutes a large part of this research. Based on the aim and objectives outlined in the preceding section, the study has two research questions:

i. Can Bayesian Belief Networks and Decision Trees be used as tools to capture and model stakeholder perceptions with respect to land-use decision making?

ii. What are the implications of the research findings for the development of participatory management strategies?

1.3 Research methodology

The general methodological approach on which this research is developed is based on the soft systems concept (Checkland & Scholes, 1999). The definition of the problem is an iterative process. This method is suited for tackling unstructured problems and allows the use of graphical modelling techniques such as Bayesian Belief Networks which can be used to examine the impacts of potential management options on an environment as a whole (Aalders, 2008; Cain et al., 1999; Lynam, et al., 2004; Marcot, 2006; Mejia, 2003; Uusitala, 2007). An approach which 'learns' the decision rules from the data using Decision Trees was applied to help with the exploration of the land-use decision-making process (Provost & Kohavi, 1998; Langley & Simon, 1995; Witten & Frank, 2005).

The data collected from individual interviews were used as input for the construction of models of stakeholder perceptions and their likely land use decisions based on the crops they grow. These resulting models were then compared to highlight trends regarding stakeholder land-use decision-making processes in the province.

1.4 Outline of thesis

Chapter 2 explores the elements and framework of decision making in the context of land use and then looks at the methods, tools and techniques that can be used to capture and model the land use decision making process.

Chapter 3 describes the methodology of carrying out the research project and gives a description of the geographical and environmental characteristics of the study area.

Chapter 4 explores the current land tenure situation in Zambia in general and of the Copperbelt Province in particular and positions it and natural resource use in a historical context and explains how it has arrived at the current situation

Chapter 5 describes the data collection process and the preliminary data processing done to reformat the data collected before analysis.

Chapter 6 looks at the development of a conceptual model and application of the soft systems methodology to the study area

Chapter 7 looks at the construction of the Belief Network model for the Copperbelt Province.

Chapter 8 focuses on the testing and validating of the Belief Network model developed using data collected from the Maposa and Chibuluma forest reserves.

Chapter 9 looks at the application of decision tree modelling techniques to land use decision-making.

Chapter 10 synthesizes the research output and discusses the relevance of the findings before concluding the thesis with suggestions for further work.

The conceptual model for the research is shown in Figure 1.1 to illustrate the various components of the study. The conceptual model has three main stages. The first stage involves the collection of data for input into a database. The second stage is the analysis of the data using three different approaches: Soft Systems Methodology (SSM), Belief Networks and Decision Tree analysis, to create three Land Use Decision Models (LUDM). The final stage is the comparison of the models for a final LUDM assessment.

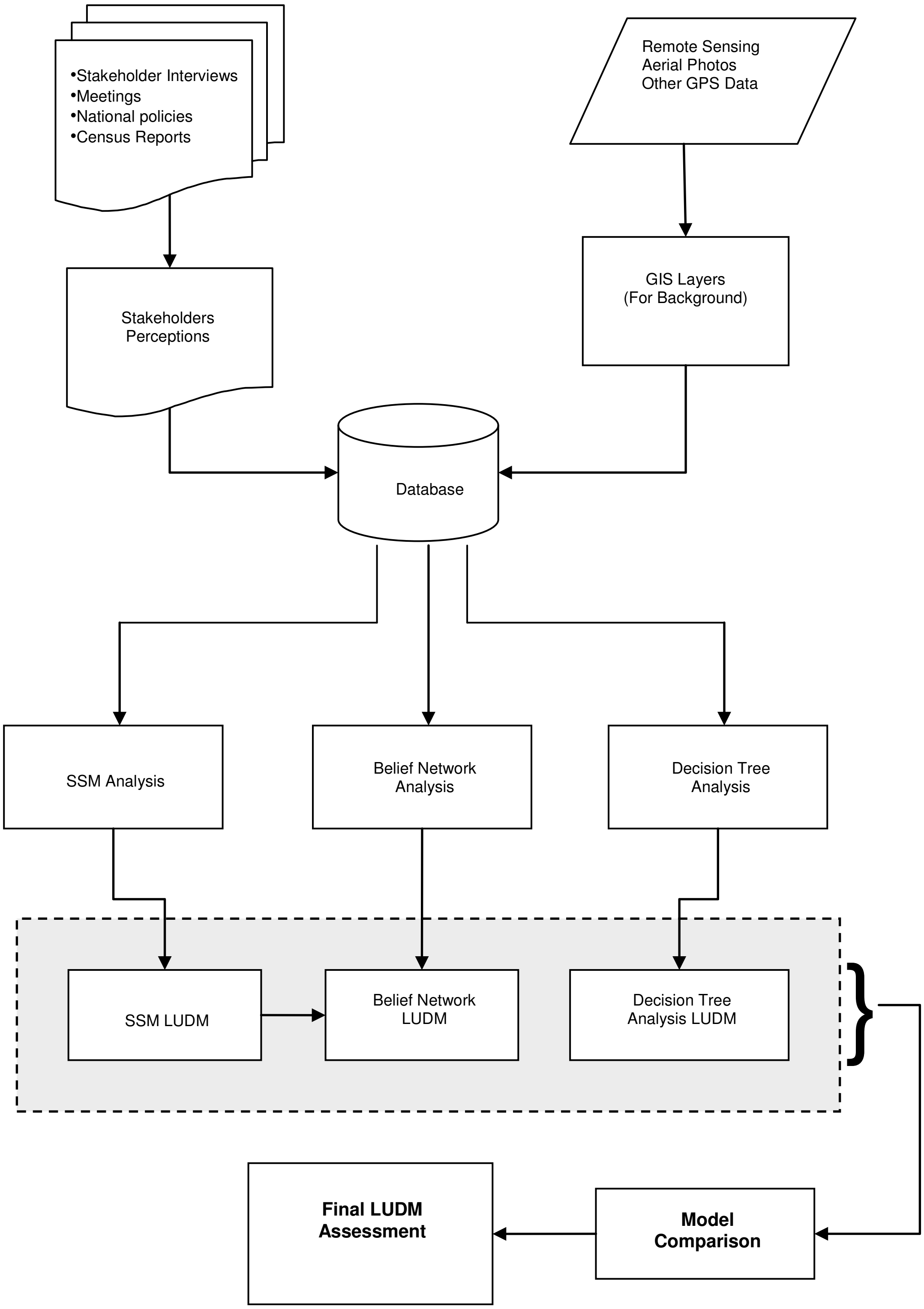

Figure 1.1: Conceptual model of research showing development of Land Use Decision Model (LUDM).

Chapter 2: Modelling Land Use Decision-Making

2.1 Introduction

This chapter addresses land use decision-making processes in the context of sustainable environmental management. It describes the elements and framework of decision-making and identifies the various approaches used in the modelling of the land use decision-making process.

2.2 Land use decision-making and natural resource management

Firstly it is necessary to define what the term land use means. It is worth noting that land use has different definitions depending on the discipline and level of analysis (Briassoulis, 1999) and this has inhibited holistic and integrated approaches to the analysis of land and its change. In reviews on the theoretical and modelling approaches of land use change, Briassoulis (1999) and Lambin et al. (2000), draw attention to the distinction between land cover and land use which are sometimes taken to be synonymous. According to the reviews, land cover describes the physical state of the land surface such as cropland, mountains, and human structures such as buildings and pavement and other aspects of the physical environment. Land use on the other hand involves the human activities directly related to land and making use of the resources or having an impact on them (Briassoulis, 1999; Lambin et al., 2000). In other words, it is the manner in which the biophysical attributes of the land are manipulated and the intent underlying the manipulation (Turner & Meyer, 1994). The importance of distinguishing between land cover and land use is made clear by Turner & Meyer (1994) who state that a single land use may correspond to a single land cover such as pastoralism to unimproved grassland while on the other hand a single land cover class could support multiple uses. An example of this is forest land cover type used for combinations of timbering, agriculture, fuelwood and recreation. This research shall take as a definition the following encompassing definition given by Aalders (2008): *"Land use is the outcome of human and biophysical processes that operate in a landscape, with regard to biophysical, socio-economic, cultural conditions and constraints, and political context."* The decision for land use change is made by individual land managers based on their responses to the conditions and constraints (Aalders, 2008). The land manager referred to here could be the landowner, employee, tenant or crofter.

Natural resource management has become a very important issue to governments in developing countries in the light of increasing global population size and the subsequent demands arising from an increased need for food, clean water and other ecosystem goods and services. This is demonstrated by the adoption of the United Nations' Millennium Development Goals (MDGs) whose target is the improvement of human well-being through the achievement of targets in 8 goals ranging from reducing poverty to ensuring sustainable environmental development by 2015. Of interest is the MDG (8) referring to ensuring sustainable development which aims to have the principles of sustainable development integrated in national and local policies to try and reverse natural resource loss (UN, 2007). Central to natural resources management is the aspect of land use decision-making. The conventional 'top-down' approach to natural resources management encourages a technical approach to problem solving that often excludes the local knowledge, preferences and values of the communities affected by the outcome (Chileshe, 2005; Groot & Maarleveld, 2000; Long & Long, 1992). Since planning is a very political process contested by different interest groups, it is essential to have a fair planning mechanism, and therefore necessary to include local perspectives into the overall planning process whether for national policy planning or for local planning (Fisher et al., 2005; MA, 2003; UNECA, 2002).

The management of natural resources has evolved considerably from the 1960's when the emphasis was on conservation only; nature was considered as the wilderness while people were considered as threats. In a review of natural resource management practices, Fisher et al., (2005) observed that in the 1960's to early 1970's, conservation practices regarded local stakeholders as 'meddlers in the natural environment'. The natural environment was often prized as being spiritually charged with the capacity to uplift the human spirit and as such required preservation (Fisher et al., 2005). Today the emphasis is on sustainable participatory management and nature is viewed in terms of biodiversity while people are considered as a resource (Fisher et al., 2005). The challenges to effective natural resource management are brought to the fore in tropical developing countries where rural communities, largely dependent on forest resources, face obstacles to development in terms of access, poverty, literacy, language and cultural barriers (Lynam et al., 2007).

The shift in emphasis from conservation to sustainable participatory management is alluded to in another context by Lynam et al. (2007) who observe that the inclusion of community perspectives in natural resource management has led to the development of participatory approaches and tools that deal with analysis, synthesis and decision-making related to natural resource management and policy. Decision-making by individuals or groups of individuals has an influence on land use and land cover change and different methods are emerging that include decision-making in land use models (Aalders, 2008; Berger & Schreinmachers, 2006; Briassoulis, 1999; Lei et al., 2005). This implies the need for an understanding of local stakeholder decision-making processes in order to allow for the prediction of stakeholder actions for effective management of the environment.

It is noted that there is an increasing need to develop management and planning options both for landscapes that are significantly altered, or under the threat of alteration, and are under increasing human pressure. These options require an effective understanding of the landscape process and decision processes operating in that landscape so as to allow the formulation of effective strategies which are both socially and economically acceptable to deal with bio-physical problems (Hobbs & Lambeck, 2002).

Before looking at land use decision-making it is necessary to address the issue of decision-making in general. The next section looks at a general description of decision-making.

2.3 Decision-making

2.3.1 What is decision-making?

A decision is defined as a choice or judgement made after thinking and talking about what is the best thing to do (Hornby, 2000). This implies a process preceding a choice or an action. Hornby (2000) further defines decision-making as *"…the process of deciding about something important, especially in a group of people or an organisation"*. This suggests that it is a reasoning process used by individuals or groups of people to arrive at a common decision. Mintzberg et al. (1976), define it as a specific commitment to action or commitment of resources. The process of deciding is then considered to be the set of actions and dynamic factors that begin with the identification of a stimulus for action ending with the specific commitment to action. In the context of natural resource management and land use it suggests a process of considering what action or set of actions that would benefit the individual or community most, given a set of prevailing environmental circumstances that limit maximisation of the benefit. Conceptualising a problem in an environmental context focuses on questions of how the environment is represented, what elements compose its structure, how those elements relate and what process or processes govern its behaviour (Harding, 1998; Lein, 1997). Clearly the decision-maker requires assistance in the decision-making process, which is in the selection and ordering of decision-relevant factors in order to ensure that a transparent, logical structure of the problem emerges. Marakas (2003) cautions, however, that the specific conditions and circumstances of the problem to be addressed ultimately influences the way in which the decision is made.

2.3.2 The elements and framework of decision-making

Since decision-making is a process, it is necessary to look at the elements of the process and see how they fit together to form a framework within which decision-making is possible. There exist several decision making models. Some of these are the Rational model, the Carnegie model, the Incrementalist model, the Unstructured model and the Garbage Can models.

Rational decision making is the systematic analysis of a problem and choice of a solution (Marakas, 2003; Over, 2004). This is essentially a two stage process: problem identification and problem solution. The rational decision model has several variations also known as Step decision models such as the 5-step and 8-step decision models. The rational decision model assumes that decision makers have the right information and ability to make correct decisions and that decision makers agree about the goals (Marakas, 2003; McGrew & Wilson, 1982).

Often, there are constraints in decision making such as limited time allowed for the decision, or limited information or resources available. Decisions made in these circumstances are thus bounded by rationality (Over, 2004; Simon, 1957). This alludes to the importance of intuitive decision making based on experience and feeling rather than logical sequential steps especially for complex multi-dimensional problems (Over, 2004; Reber, 1995). This is the Carnegie decision model. It also recognises the political process involved in decision making and arrives at a solution which satisfices (Simon, 1957; Reber,

1995) rather than optimises. The term satisfice is a combination of satisfy and suffice coined by Simon (1957) and suggests a choice between an ideal optimal solution and one that is just good enough.

The Incrementalist decision model suggests that decision makers choose alternatives close to past actions to reduce risk resulting in a sequence of incremental changes which do not benefit from an evaluation of all alternatives and selecting one (Over, 2004). This type of decision making is suitable for stable environments with predictable trends. Another type of decision model is the Unstructured decision model suited for decision making under high uncertainity such as dynamic environments (Mintzberg, et al., 1976). This approach requires re-thinking alternatives when faced with obstacles. Unstructured decision making evolves in an unpredictable manner and uses intuition that requires continuous adaptation to changing situations. The Garbage Can decision model proposes that decisions begin with the solution instead of identifying a problem. It is a highly unstructured process which relies on chance and timing (Mintzberg, et al., 1976).

Indecision can also considered to be a type of decision making. This is when a decision maker is unable to make a decision for a variety of reasons. It is also referred as decisional procrastination (Ferrari & Dovidio, 2000). Indecision becomes decision with time as the decision maker implicitly has the decision made for them by someone else (Adair, 1997). Ferrari and Dovidio (2000) argue that indecision can be attributed to individuals being systematic and strategic searching for more information about the alternatives. This is in the light of uncertainty being cited as the most important element in decision making (McGrew & Wilson, 1982).

It is clear from the foregoing that decision making is a complex process. The basic elements of decision-making have been outlined by Marakas (2003), using a five-step rational decision model. Figure 2.1 outlines the rational decision-making process.

In the five-step decision model, there are five elements that constitute the decision making process (Marakas, 2003), and these are: the stimulus, the decision maker, problem definition, alternative selection and implementation. A brief description of the process follows.

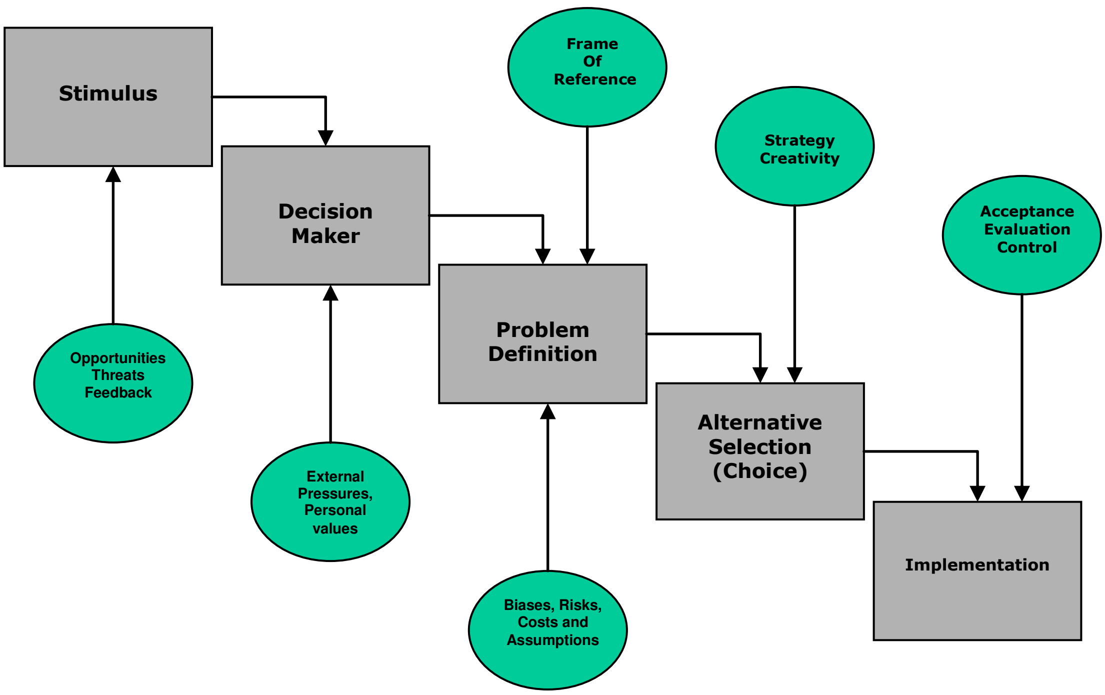

Figure 2.1: The five-step rational decision model (Marakas, 2003).

2.3.2.1 The stimulus

This is generally the first step in the decision making process and occurs when the decision maker perceives the existence of a problem or problems that require one or more decisions to be made. The onset of a stimulus acts as a trigger for the decision making process (Marakas, 2003; Mintzberg et al., 1976). A problem in the decision-making context can be considered to be the perception of a difference between the current state of a system and the desired state. Examples of system states are the availability of firewood, access to drinking water or the amount of rainfall in year. According to Marakas (2003), a variety of stimuli can cause the perception of a problem context.

2.3.2.2 The decision maker

The decision maker plays a dual role in the process: firstly, as an element in the process as shown in Figure 2.1, and secondly, as a participant, in varying degrees, in all the steps of the process (Marakas, 2003). As a step in the process, the decision maker responds to a stimulus and is acted on by external pressures and influenced by personal values in the perception of the stimulus. This then has an impact on how the decision-maker will define the problem, which is the next step. As a participant in the entire process, the decision maker will be involved in the analysis of information at all stages of the process with the ultimate generation of a final decision. There are many different types of decision makers broadly divided into two classes: individual decision makers who work alone in the decision-making process and multiple decision makers who include group and team decision makers distinguished by their mode of interaction in the decision-making process.

2.3.2.3 Problem definition

This step is critical to the successful outcome of the decision-making process (Cain, 2001; Lein, 1997; Marakas, 2003). Problems often manifest themselves as a series of symptoms indicative of the existence of an underlying problem. This requires that the careful consideration of the stimuli must be done to help define the problem before any effective investigation of possible solutions can be conducted. The formulation of a problem definition may not be straightforward especially when there are different interest groups contesting different views (McGrew & Wilson, 1982).

2.3.2.4 Alternative selection (choice)

This step, the choice phase, is the essence of the decision making process - the decision itself. The decision maker is faced with the selection of an alternative effective solution from a set of feasible options (Lein, 1997; Marakas, 2003). Quantitative models can be used to compare and evaluate the alternatives and in some cases even reduce the level of uncertainty. Making a decision can be a complex process and is governed by a number of factors: decision structure, cognitive limitations, uncertainty, and alternatives and multiple objectives.

(i) Decision structure: Decisions vary from completely structured to completely unstructured. A structured decision is one which is repetitive and routine, while an unstructured decision is one where there is no specific procedure to deal with the situation.

(ii) Cognitive limitations: This difficulty arises from the limitations of the human mind to process and store information and knowledge. The limitations of the individual decision maker can substantially increase the difficulty of making a particular decision (Marakas, 2003).

(iii) Uncertainty: There is, generally, always a degree of uncertainty in every decision-making situation. Usually the decision maker assigns some subjective probability to the expected outcome and this is based on the degree of completeness and accuracy of the information used to assign the probability. There are methods that have been developed to assist the decision maker in assigning high quality subjective probabilities to decision outcomes. The more uncertain a decision outcome is, the more difficult it is to make the decision (Bacon et al., 2002; Cain, 2001; Marakas, 2003, McGrew & Wilson, 1982).

(iv) Alternatives and multiple objectives: The reason for the decision-making process is to produce a desired outcome and to do so requires a careful examination of the possible outcomes associated with given decisions. The complexity of a particular decision can be significantly increased by the presence of multiple alternatives. This can be compounded further by the decision maker having more than one objective at a time (Marakas, 2003).

It can be seen that although, making the decision is the heart of the decision process, it has a lot of challenges associated with it, however, there are methods to help the decision-maker arrive at the best decision in the given circumstances.

2.3.2.5 Implementation

This is the ultimate step in the decision-making process. The decision process triggers actions and events focussed on implementing the solution selected to solve the problem. These actions may include creating consensus and acceptance, negotiation, strategising and intense planning (Lein, 1997; Marakas, 2003; Mintzberg et al., 1976).

2.3.3 Decision-making vs learning

The five steps describe the decision-making process generally from a rational evaluation of choices. It can be inferred from Figure 2.1 that there is learning implicit in the decision-making process. This must not be confused with making decisions. Learning is the process of the creation of knowledge through the transformation of experience by what is learned and how that learning is applied. In other words, it is the increasing of one's capacity to take effective actions (Kim, 1998). Hagmayer and Meder (2008) suggest that there is learning especially in repetitive decision-making.

Decision-making has also been described as a political process by McGrew and Wilson (1982). They argue that it introduces the elements of power, influence and interests and it is thus *"...an activity in which there are conflicting interests* at stake, as well as conflicting perceptions of the substance of the problem which requires a decision amongst a variety of actors be they individuals, *groups, organisations, or governments"* (McGrew & Wilson, 1982: 227). Human beliefs and judgements may sometimes not be fully consistent with logic, probability theory or decision theory and it is therefore important to understand under what conditions people are likely to adopt the various decision making models (Janis & Mann, 1977; Over, 2004).

2.4 Land use decision-making

Having, looked at the stages of the decision-making process, it can be deduced that land use decision-making can be considered to be the process of determining the best uses of land given the existing constraints and opportunities and choosing the optimum decision from the alternatives presented within the boundaries and constraints imposed by the problem's context. Although the key stages of the decision-making process are clearly defined, in practice they may not be so clearly defined.

Once a decision is implemented, focus is drawn to how those effects are translated though this representation. This is put succinctly by Harding (1998) who states that *"…the environmental decision*-making process begins when a person, group of people or organisation perceives and identifies a problem, risk or a need. This is the point at which a solution is sought. The process of identifying the possible solutions and then finalising which is most appropriate is the essence of any decision-*making process."*

It is often the case that different stakeholders will have competing needs hence natural resource decision-making requires a process to reconcile multiple actors (Anderson et al., 1999). Land uses change regularly and in some locations, there is a transformation in land use with a growing multi-purpose objective (Carsens & van der Knaap, 2002). If a large number of stakeholders are involved, land use problems can become complex planning problems and decisions made should be transparent to all stakeholders and, will depend on, among other things, the suitability of the land for the specific type of use (Carsens & van der Knaap, 2002). This is echoed by Lynam et al. (2007) who acknowledge that community decision-making is a political process which needs careful handling, as it can involve sensitive issues. Making environmental decisions is, therefore, a complex task which can be broadly expressed as three components (Lein, 1997):

(i) acquiring, retrieving and selecting relevant information

(ii) Structuring the decision problem to enhance visibility of the alternatives and their features

(iii) Evaluating alternatives for their relative expected attractiveness

The components outlined above are part of the five-step rational decision model (Marakas, 2003). It is clear that without the necessary information to support the decision-maker, the process can become very difficult and complicated. It is necessary to now look at how the decision-making process can be captured in order to allow for modelling of the process.

2.4.1 How do we capture the land use decision-making process?

Scientists use different methods and techniques to achieve a broad understanding of the social, economic and political dimensions of a culture (Mejia, 2003). The quantitative and qualitative data that are gathered can be translated into information that can be used to understand and explain human behaviour. The approaches are complimentary and their use depends on the research objectives, approach and preferences of the researcher (Lynam et al., 2007; Mejia, 2003). However, in the case of land use decision making, we need to look at land use change and try to get our understanding from there. There are three main generic approaches that have emerged in the study of land use change and these are the narrative approach, the agent-based approach and the systems approach (LUCC, 1999).

The narrative approach seeks depth of understanding through historical detail and interpretation. This gives a historical account of how land use has changed with time aims to give an interpretation of why the changes have taken place. The agent-based and systems approaches both rely on explicit model development and empirical testing. The agent based approach however, seeks to distil the general nature and rules of individual agents' behaviour in their decision-making. Briassoulis (1999) notes that special emphasis is given to human agents in determining land use decisions and the search for generalisation about their behaviour. The systems approach finds understanding in the organisations and institutions of society that establish the opportunities and constraints on land use decision-making. The emphasis with this approach is on the structures rather than the individual agents (LUCC, 1999).

2.4.2 Types of modelling approaches

There are a number of land use theories but the most common land use theories are based on von Thünen's agricultural land rent theory developed in 1826

(Briassoulis, 1999; Lambin et al., 2000). In the agricultural land rent theory, von Thünen (1966) prescribes the optimum distribution of rural land around a market town. Agricultural systems are found to be centred around a single 'isolated' market place in the form of land use intensity rings. Land rent is the price for the use of a piece of land or equivalently priced services yielded by land during a specific time period.

The agricultural land rent theory and its derivative theories addressed rural land uses. However, with increasing urbanisation, there was a need to develop land use theories to explain land use processes in peri-urban and urban areas. Alonso's bid-rent theory refined von Thünen's theory (Lambin et al., 2000). The bid-rent theory describes and explains the residential location behaviour of individual households as a function of distance to the Central Business District (CBD) of the city as a solution of an economic equilibrium for the market space (Alonso, 1964). Lambin et al. (2000) observe that optimisation models have been widely used and that they suffer from limitations such as the non-optimal behaviour of people due to differences in values, attitudes and cultures and the somewhat arbitrary definition of objective functions in the models. They further observe that at an aggregated level, these limitations are insignificant but become more important with the change in observation scale.

Another theory that has been used to describe land use change in urban areas is the Rent-gap theory formulated by Smith (1979). This theory explains urban gentrification which denotes the socio-cultural changes in an area resulting from the informal economic eviction of lower income residents by the wealthier through increased rentals, property prices and taxes. It has been argued by Clark (1988, 1995) that it is a political economic theory of uneven development on the urban scale tied to the societal relations and power struggles involved in the creation and capture of values in the built environment.

In the generic approaches described above, there are various types of models that have been developed to model land use change. Most of these models use drivers of change to simulate the spatial nature of land use and the economic rationale for the use. Many of the models are statistically based and these are divided broadly into statistical and econometric models, optimisation models and integrated models.

Statistical models use quantitative data to quantify the strength of different drivers of change using linear or logistic regression techniques. These statistical models generally use regional data. These have recently begun to use parcel level data (Veldkamp & Lambin, 2001; Lei, 2005). Econometric models on the other hand describe land use change in the context of economic, transportation and market factors that influence development patterns in various land use related sectors (Bockstael, 1996).

Optimization models are exclusively oriented towards producing solutions which optimise certain objectives defined by users or decision-makers (Briassoulis, 1999). They are best suited for decision support. Integrated models are mostly large scale models whose spatial coverage is related to the purpose, focus and other design characteristics.

Other approaches are the Cellular automata approach used to parameterise land use rules to determine whether a cell will undergo land use transition (Clarke et al., 1997; White & Engelen, 2000). Multicriteria evaluation (MCE) models have been developed. They model spatial relationships of interacting variables (Pontius, 2002). Agent based methods that simulate land use change by using agents that own single cells within a grid are also being used. Land use change in this modelling approach can be simulated by using the agent to agent interaction combined with the agent to environment interaction (Aalders, 2008; Lei et al., 2005).

Another approach that has been used to explore and understand land use change is to use Bayesian modelling. This approach utilises complex probabilistic reasoning by representing the structure of an argument in an intuitive graphical format (Aalders, 2008). This has two approaches: the hierarchical simulation based approach and the Bayesian Belief Network (BBN) approach (Uusitalo, 2007). The hierarchical modelling approach is best suited for cases with abundant knowledge of interactions between model variables while for the BBN approach, the probability distributions are generally expressed in discrete form. BBNs can use limited disparate information sources and have the potential to use both qualitative and quantitative information (Castelletti & Soncini-Sessa, 2007; Uusitalo, 2007; Cain, 2001).

Aalders (2008) observes that a variety of modelling techniques have explored the application of Bayesian methods in relation to land use (Stassopoulou et al., 1998; Marcot et al., 2001). Some of the methodologies used have developed land use models in a purely biophysical context (Aspinall, 1992) while others have illustrated the use of participatory modelling methods with BBNs (Bacon et al., 2002; Lynam et al, 2004; Lynam et al., 2007).

Another approach that can be used to model decision-making is Decision Trees. This essentially a non-parametric classifier that does not make any statistical assumptions about the data and builds a tree-like structure consisting of a root node and a number of internal nodes followed by a set of terminal nodes. This approach generates decision trees which are easily understood and are compatible with human reasoning (Provost & Kohavi, 1998; Witten & Frank, 2005; Quinlan, 1992). The 'extraction of knowledge' using decision trees is an automated process. This has resulted in numerous applications of the technique, ranging from finance to medicine and the environment.

Although BBNs and decision trees have been applied in participatory methods, there are no studies which indicate their application to informal settlements. This presents a knowledge gap which needs to be looked into in relation to the understanding of how people living in informal settlements make their land use decisions. This shall form the basis for the formulation of the research questions for this study. An informal settlement for the purpose of this study is an illegal settlement which has been developed without any legal claims to the land and also without planning permission from the relevant authorities concerned. Informal settlements are also known as ‘squatter settlements’ and are built on invaded land on the urban periphery and generally house poor populations (Payne, 1977; Willis, 2009).

2.5 Summary

This chapter has looked at land-use decision-making and the components in the decision-making processes. The chapter addressed the need for natural resource management and the role of land use decision-making in the management of the environment and stated the need to develop a method to understand and capture decision-making in this context.

The elements and framework of decision-making in general were then presented together with the various decision-making models such as the rational decision model, the Carnegie decision model and the unstructured decision models. An examination of the general decision making process was done using the five-step rational model to illustrate the various aspects that form the decision-making process. The role that uncertainty plays in, and the political nature of decision-making were also examined.

The application of decision-making in land use processes was also addressed together with the types of modelling approaches used in modelling land use decision-making. It was observed that most of the modelling approaches are based on von Thünen’s agricultural land rent theory and have been adapted to suit different conditions.

The chapter concludes by identifying and exploring the application of BBN and decision trees as approaches for modelling land use decision-making in informal settlements.

Chapter 3: Land use research methods and study area

3.1 Introduction

There is an increasing demand for science-based environmental decision-making at the local, regional, national and international levels (Gutrich et al., 2005). This chapter presents a review of land-use in the province along with a description of local climatic and socio-economic conditions. It shows how this region is a good example of a landscape undergoing unprecedented environmental and socio-economic change where different actors with different interests converge and where the capturing, understanding and characterisation of stakeholders' perceptions about the land-use decision-making process using various tools and techniques may be applied for the purpose of environmental management.

3.2 Land-use and the problem of deforestation

During recent decades, tropical deforestation has resulted in the conversion of millions of hectares of forest to other uses such as agriculture, pasture, industrial, residential and the production of wastelands. It is estimated that between 1980 and 1990, about 10% of the almost 2 billion hectares of tropical forest were converted to other land-uses (Barraclough & Ghimire, 2000). The factors that drive changes in land-use are varied but are largely human induced and can be divided broadly into two categories: those that have direct and measurable effects such as demographic, economic and technological changes, and those that are hard to measure but have fundamental effects such as political and institutional changes in society expressed in terms of values and attitudes and perceptions. The latter have an effect on patterns of resource use (FAO, 2003a). This is echoed by Geist & Lambin (2002) in a landmark global study to examine the causes and drivers of tropical deforestation. Their comprehensive review of tropical deforestation showed that it is driven by identifiable regional patterns of causal factor synergies of which the most prominent are economic factors, institutions, national policies and remote influences driving agricultural expansion, wood extraction and infrastructure extension. Barraclough & Ghimire (2000) show this, in an earlier analytical case study of deforestation in five countries – Brazil, Guatemala, Cameroon, Malaysia and China where they found that public policy had an important role in influencing the direction that the usage of natural resources took.

Africa is still largely an agrarian economy and its economic performance is linked to the agricultural sector. In 2000, the agricultural sector accounted for about 70% of total employment and 20% of exports and produced about 66% of raw materials used in its industries (FAO, 2003a). A direct effect of agricultural production on forestry is how future increases in agricultural production are to be achieved. Past increases in production have come about mainly by bringing more land under cultivation. Limited industrialization means continued dependence on land. With increasing population and failing extractive and manufacturing industries, subsistence cultivation is likely to expand with adverse impacts on forest and woodlands. If no significant improvements in technological efficiency in agriculture are achieved, then forest clearing will remain an important option for agricultural expansion

(Barraclough & Ghimire, 2000; FAO, 2003a, b). The biggest challenge to Africa's environment is the reconciliation of its development needs with the sustainable management of its natural resources (NEPAD, 2003).

Globally, the rate of deforestation has decreased in the 10 year period 1990 to 2000 although it continues at an alarming rate in some countries (FAO, 2010). Africa and South America recorded the highest net annual loss of forest during this period. Zambia experienced a deforestation rate of 3.2% during the same period and a rate of 3.3% for the period 2000 to 2010 (FAO, 2010).

Forest cover in the Southern African region in 2000 was estimated to be about 31% of the total land area. The distribution of forest cover varied from country to country with Angola having the most cover and Lesotho being the least forested country with less than 1% forest coverage (FAO, 2003b). The forest cover for Zambia is currently estimated at 67% of the total land area (FAO, 2010).

The 10 year period up to 2000 saw an alarming rate of deforestation in the Southern African region accounting for up to 31% of the annual continental forest cover loss. This amounted to about 851,000 ha per year (FAO, 2003b). The reasons for deforestation are attributed to agricultural expansion and an increased demand for forest products such as charcoal. This is of particular importance close to urban areas. The reasons remain valid across Africa (FAO, 2003b).

Since ecosystems do not follow political boundaries, the management of the environment is beginning to move towards joint cooperative efforts as evidenced by the adoption of international conventions by African countries both individually and collectively, through regional bodies, as well as through the newly formed continental body, the African Union (AU). The New Partnership for Africa's Development (NEPAD), is a new initiative of the AU. Working through such organisations can help deal with environmental problems that occur over political boundaries.

3.3 Stakeholders and Land-use Decision-making

In order to understand how stakeholder decisions shape future uses of the land, it is necessary to understand spatial decision-making. There is a need to develop tools that assess future scenarios and their potential consequences within the context of sustainable development. It is now increasingly recognised that problems currently confronting our societies lie at the interface between people and the environment and that the causes and solutions to these problems lie with the activities of people, and therefore, a major part of moving towards application and action for sustainable development should be the inclusion of stakeholders in the determination of what needs to be done and how (Baginetas, 2005; GRZ, 1994; Guy & Kibert, 1998; Haines-Young, 2000). The inclusion of local stakeholders in the identification and solution of environmental problems suggests a need to develop tools to express and represent stakeholder perceptions and subsequent decision-making with respect to land-use.

The Millennium Ecosystem Assessment (MA) carried out by the Millennium Assessment Board found that human well-being and progress toward sustainable development are vitally important in improving the management of the Earth's ecosystems (MA, 2003). The project observed that human actions are diminishing the capability of many ecosystems to provide food and clean water; hence sound policy and management interventions are required to reverse ecosystem degradation. A key factor identified in the MA is knowing when and how to intervene and this requires a sound understanding of both the ecological systems and social systems involved (MA, 2003).

The role of decision makers to affect ecosystems, ecosystem services and human well-being is recognised by the MA. It identifies three levels at which decisions are made, i.e.:

1. Individuals and small groups at the local level who directly alter some part of the ecosystem
2. Public and private decision makers at the municipal, provincial, and national levels
3. Public and private decision makers at the international level

Adams (2001:261) alludes to the multi-layered system of decision-making. He observed that deforestation is the result of structures and decisions by actors at a range of levels. It is the intention of this research project to focus primarily on the first level of decision makers, the individuals and small groups of farmers, and to some extent the second level of decision makers, i.e. local authorities and central government.

Adams (2001:267) further observes that small-scale farmers have long been regarded as ignorant, uneducated and destructive forest clearance villains by government forestry departments. Citing an instance of this in south-east Nigeria where small scale farmers have been the agents of significant forest cover loss, he argues that forest farmers have a very clear understanding of the ecology of fallow plots, are aware of the economic and ecological options of cropping systems, and of the implications of the total loss of forest cover. It was also argued that the decisions of forest farmers at the local household level are entirely rational and are influenced by institutional and economic factors as evidenced in Madagascar where the suppression of shifting cultivation by the colonial state removed indigenous institutions that regulated how and where forests could be cleared (Adams, 2001; Agarwal et al., 2005; Geist & Lambin, 2002). This presents a need to study and understand the processes that the local stakeholders use in arriving at their land-use choices.

The foregoing assumes that the decisions that local stakeholders make are rational and utilise all available information. This may not always be the case because people will tend to make choices based on their most important current needs rather than through a rational process (Simon, 1957; Reber, 1995). This means that they will make choices that satisfice rather than optimise. The decision maker will have a choice between an ideal optimal solution and one that just is good enough, that is, one that satisfices given the prevailing circumstances.

3.4 The need for a sustainable approach

Adams (2001) argues that culture, society economy and environment are complex and changing continually and that development that is based on programmes and policies that are conceived and imposed within institutions distanced from those they affect is unlikely to be able to cope with these changes effectively, or to meet human needs. He further argues that better environmental and developmental planning is both needed and possible and that sustainable development is the beginning of a process not the end. It is a statement of intent not a route map. This resonates with Haines-Young (2000) who suggests that the goal for sustainable environmental management is not to seek a steady state, but rather a sustainable trajectory for our ecosystems and landscapes, because of constantly changing social, economic and environmental circumstances. Haines-Young (2000) further emphasises that it is the character of change that is the issue and urges the examination of how change processes maintain or enhance the physical and ecological functions that generate the goods and services that we value. However, central to these processes is the involvement of local stakeholders who should not be considered as the problem but as the solution since they are the agents who modify landscape elements to suit their needs (Haines-Young, 2000; Kristensen et al., 2001).

In discussing decision making with relation to policy, it is important to understand what policy is. Simply put, a policy is a plan of action to guide decisions and actions (Winter, 1996). Policy is not easy to define but can be viewed as a dynamic process rather than a single action, decision or piece of legislation. It is best seen as a network of decisions and actions that take place over a period of time (Winter, 1996). The policy process includes the identification of different alternatives, and choosing among them on the basis of the impact they will have. Policies in short can be understood as political, management, financial, and administrative mechanisms arranged to reach explicit goals. In the context of decision making for environmental management, policy is best considered as a dynamic process with a cycle as defined by (Winter, 1996). The cycle consists of the following: agenda setting, policy formation, decision making, policy implementation and policy evaluation.

Land-use and the access to fuelwood for energy are key factors that affect the sustainable management of resources in Africa. The development of a process and tools that will allow local stakeholders to participate in decision-making concerning resource use in the context of the land and forestry policies is essential.

Encroachment into reserved forests for agriculture and settlement is a problem that keeps recurring in Southern Africa. In Eastern Zimbabwe, local inhabitants settled in forest reserves for pasture, agriculture and settlement (Katerere et al., 1993; Nhira & Fortmann, 1993). The locals initially perceived the forest reserves as ‘spare land’ but with increasing population, the forests were encroached. In Kenya, similar trends have been observed and this has been attributed to the need for rich agricultural soils and increased demand for charcoal and fuelwood (Omosa, 1998). The problem of encroachment of forests has been reported in Zambia particularly in the Central Province (Chidumayo & Chidumayo, 1984; Kajoba & Chidumayo, 1999; Nkomeshya, 1998; Serenje et al., 1994; Zimba, 2004) and lately in the Copperbelt Province (Chileshe, 2001; Njovu et al., 2004; Nkomeshya, 1996; PFAP, 1996). Remotely sensed imagery has shown increased land cover clearance in protected areas (Chidumayo, 1989).

3.5 Tools for participatory modelling of land-use decision-making

In order to address the need to adopt a sustainable approach to the management of natural resources, it was necessary to look at the tools that could be used for this purpose. This section looks at the tools that were used in the research.

In a study to evaluate tools for participatory decision making, Lynam et al. (2007), identified several tools and tested them for their capabilities, products and flexibility of use with regard natural resource use decision making. The tools included among them Pebble Distribution, Bayesian Networks, Participatory Mapping, the 4R’s, Venn diagrams, Spider diagrams and Future Scenarios. It was found that Bayesian networks lent themselves well to most of the tests to which such tools were subjected compared to the other tools. Bayesian Networks were well suited for group or individual usage and their outputs were easy to comprehend. Furthermore, they could be applied either at local village level or at higher levels.

In an assessment of tools to help with the generation of Decision Support Systems (DSS) for application in water resources management, Cain (2001), looked at six tools which included Bayesian Networks, Influence Diagrams, Decision Trees, Mathematical Modelling, Multi-Criteria Analysis (MCA), and Spread Sheets. Cain assessed the tools using three criteria. These are:

(i), how well the tool represented the internal workings of the environment to be managed at an optimal level;

(ii) Secondly, how well the tool communicated the reasons underlying decisions, in other words the representation of the decision process;

(iii) Lastly, the ability to explicitly represent uncertainty in the DSS.

Based on these criteria, it was found by Cain (2001) that although all the tools could handle complexity and uncertainty, most of the methods such as MCA were not flexible in terms of updating uncertainty. Others such as spreadsheets though easily accessible, had the drawback of models not being easily understood since the model dynamics were hidden in the mathematical formulae underlying each cell. However, Bayesian Networks proved both flexible and easy to use with regard to the three criteria. They handled changes in uncertainty well and had an easily understandable visual presentation. Bayesian Networks have been described briefly in section 3.5.6 outlining their main elements and application and their underlying theory discussed in detail in Chapter 7.

There are several other tools that could be used to facilitate the modelling of land use decision-making. A comprehensive range of tools was proposed by van der Vorst et al., (1999) for environmental management enquiry. Table 3.1 outlines the tools and techniques that have been considered for use in this investigation.

Table 3.1: Tools for environmental management enquiry (adapted from van der Vorst et al., 1999)

Tool	Technique	Approach	Data type (Predominant type)	Assumptions in capturing decision-making
Interviews / Questionnaires	Participant observation	Ethnographic	Qualitative	Local stakeholders are best in describing their own situation
Group Meetings	Collaborative	Negotiation	Qualitative	Optimal solution is through consensus building
SSM	Root definitions	Soft systems	Qualitative	It helps clarify purpose of a system.
GIS / Remote Sensing / Photogrametry	Mapping	Hard systems	Quantitative	Allow the integration of spatial and non-spatial data sets for multidisciplinary approach to understanding spatial decisions.
Belief Networks	Mathematical	Systemic	Quantitative and Qualitative	Allows modelling of decision-making process
Decision Trees	Mathematical	Systemic	Quantitative and Qualitative	Allows modelling of decision-making process

3.5.1 Personal interviews

Personal interviews are part of a group of techniques forming the ‘Ethnographic’ method of investigation (Chambers, 1994a). This is a process of describing a culture from the perspective of those living in it. Within this is contained the Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal

(PRA) methods. A distinction is drawn between RRA and PRA (Chambers, 1994b). Chambers points out that RRA is the collection of data by outsiders who then take it away for analysis while PRA involves outsiders as mere facilitators for local people to conduct their own analysis, plan and take action (Chambers, 1994b).

In this sense, it can be understood that RRA is extractive and PRA is participatory. The application of either technique depends on the specific situation for gathering data, which will allow the understanding of the functioning of the community groups, and importantly, how they will respond to change (Chileshe, 2005).

Within the technique of interviews there are formal interviews, semi-structured interviews and group interviews. Semi-structured interviews were used in this investigation and they were targeted at government and local authority representatives as well as representatives of non-governmental organisations who were identified to have an interest in the management of the environment in the Copperbelt Province of Zambia to obtain their views on the management of the case study areas and beyond. The reason semi-structured interviews were used was to allow for a free flowing conversation covering all relevant topics.

3.5.2 Questionnaire survey

Questionnaire surveys are also part of the ethnographic method of investigation alluded to by Chambers (1994a). In a strict sense, a questionnaire is a structured interview in that each respondent is asked a series of questions according to a prepared and fixed interviewing schedule, the questionnaire (Brace, 2004). It serves as an 'aide memoir' to the interviewer and provides consistency in the way in which interviews are conducted and data recorded to facilitate analysis (Hague et al., 2004).

There are three types of questionnaire that can be used to carry out a survey and these are the behavioural type of questionnaire, the attitudinal type questionnaire and the classification type questionnaire (Brace, 2004; Hague et al., 2004). The behavioural type of questionnaire aims to obtain factual information about the respondent and is largely used for awareness surveys. The attitudinal questionnaire aims to find out what people think about things and these are used for satisfaction surveys. Classification types of questionnaires are used for grouping respondents and can be used in all types of surveys.

All the types of questionnaire can be of the structured format, the semi-structured format or the unstructured format. The structured format is based on prompted responses from coded questions (closed questions). These are quicker to administer and analyse. The semi-structured format uses a mixture of closed and open questions which allow for greater free responses usually collected as given. These are difficult to evaluate and need the classification of responses before statistical analysis. The unstructured format on the other hand is based on free ranging questions following a topic. The order of questions will differ from respondent to respondent (Hague et al., 2004).

The approach used in the research was to use the attitudinal and classification surveys together and the format of the questionnaire was of the semi-structured type in order to assess the beliefs and opinions of the local stakeholders.

3.5.3 Group meetings

Group meetings were conducted after administration of the questionnaire. These were designed to supplement the questionnaire survey and to bring out any other information that could not be captured by use of the questionnaire. SSM was then used to explore the problem situation, develop root definitions, and eventually to construct conceptual models that highlight important issues. The group meetings were used as a type of PRA method where local stakeholders in the community were encouraged to discuss and debate among themselves and propose solutions.

This type of participation is in line with partnership as defined by Arnstein (1969) who identified and outlined several degrees of participation by citizens in community decision-making. Eight levels of participation grouped into 3 general types of participation as illustrated in Figure 3.1 were identified (Arnstein, 1969).

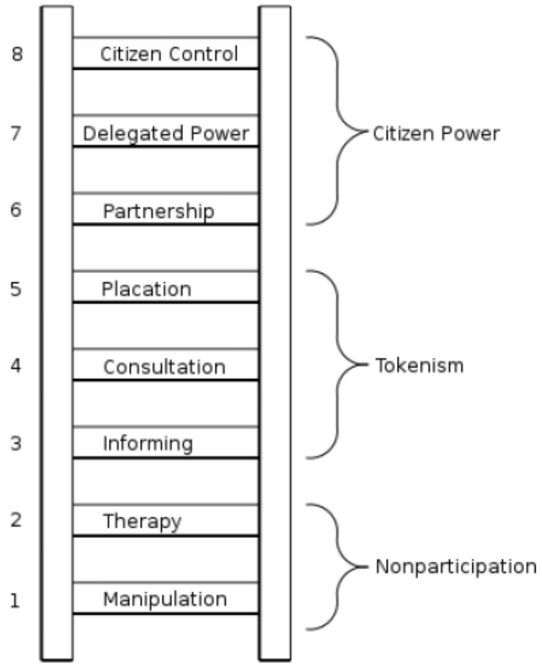

Figure 3.1: The eight rungs of the ladder of citizen participation (Arnstein, 1969)

Non-participation is the lowest degree of participation and does not allow any real participation in decision-making at all for ordinary citizens. Tokenism on the other hand allows the ordinary citizens to hear and be heard without the right to decide for themselves. Further up the ladder from *'partnership'* onwards, there are increasing degrees of decision-making that range from entering into negotiations to full managerial power of deciding (Arnstein, 1969; Lowndes et al., 2001).

The PRA technique has been used in natural resource and wildlife management in Africa (Cinderby, 1999; Harris et al., 1995; Turyatunga, 2004). The technique was applied in a study to incorporate local stakeholder perceptions into the rural land reform process in the Kiepersol region of Transvaal in South Africa (Harris et al., 1995). In Uganda, Turyatunga (2004) applied the PRA technique in the participatory mapping of natural resources in the Nyantonzi Parish of Masindi District. The data collected were used for subsequent input into the Parish Environmental action plan. In Namibia, the technique was used to generate maps of local resource use perceptions for the development of local resource use maps to highlight areas of possible conflict on resource use between villages (Cinderby, 1999).

The purpose of group meetings in the research was to supplement the questionnaire survey and to bring out any other information that could not be captured by use of the questionnaire while encouraging wider participation and community engagement in identifying problems and proposing solutions to them.

3.5.4 Soft systems methodology

With growing awareness of the environmental consequences of changes in land management, it is necessary to model changes in land use that reflect the complex relationships between policy, land-management and environmental processes (Bacon et al., 2002). To help address the complex process of land use decision-making, an approach, which includes stakeholders and is participatory and iterative, was identified for application in the research.

The soft systems approach is well suited to resolving ill-structured problems. It is considered to be a methodology for analysing and modelling complex systems that integrate technology and human groups. The process of identifying stakeholders is an important stage in the use of SSM.

SSM is a process of enquiry and utilises a seven stage process (Checkland & Scholes, 1999; Clayton & Radcliffe, 1996; Wilson, 2001) and is discussed in detail in Chapter 6. The seven step process is identified as:

i) Reviewing the unstructured problem situation
ii) Clarifying and expressing the problem situation
iii) Defining the relevant systems and subsystems, whether these are formal or informal
iv) Building conceptual models, scenarios and analogies
v) Comparing these models with the expressed situation
vi) Effecting such changes as are currently both feasible and desirable
vii) Taking action to improve the problem situation

The use of SSM to define a problem situation is akin to the third step identified by Marakas (2003) in the five step rational decision-making process. The participatory application of SSM was used in the research project to define the problem situation in the modelling of the decision-making processes. Being an iterative process, SSM has the potential to be used for the identification of areas where improvements are required (Bunch & Dudycha, 2004; Checkland & Scholes, 1999; Wilson, 2001). This is important in order to understand the decisions that are made by the stakeholders. The application of SSM in the study is addressed in detail in Chapter 6.

3.5.5 GIS, remote sensing and photogrammetry

This section addresses the use of Geographic Information Systems (GIS) and photogrammetry in the context of sustainable environmental management and specifically the representation of future conditions in land use decision-making.

The applications of GIS are many and varied. In a review on the application of GIS to land-use suitability analysis, Malczewski (2004) provides a comprehensive review on the applications of GIS. The applications of GIS, according to Malczewski (2004), range from ecological and agricultural decision-making, to landscape evaluation and planning, environmental impact assessment, regional planning and geological applications. In this research, GIS was used as a platform for the spatial representation of land-use trends and also as a platform on which remote sensing and other data could be integrated.

Photogrammetry is a specialised branch of remote sensing which uses photographic technology and images for the data acquisition and information extraction phases instead and the sensors are normally cameras on board aircraft (Wolf & Dewitt, 2000). This was used in conjunction with the remote sensing imagery to identify the study area.

It has been suggested by McCloy (2006: 23) that there is a need to understand and mimic environmental processes by way of models for effective natural resource management. McCloy (2006:23) further provides a justification for the use of remote sensing in natural resource management arguing that the data have the following characteristics:

- spatially extensive, temporarily rich and cheap to obtain;
- cheap robust methods for data extraction;
- have capacity to be integrated with other information sets

3.5.6 Bayesian belief networks

A Bayesian Belief Network is a graphical system for reasoning with probabilities using Bayes' Theorem (Drudzel & van der Gaag, 2000). They are also known as belief networks, causal networks, or qualitative Markov networks (Varis, 1997). Since Bayesian Belief Networks are interchangeably called Bayesian Networks and Belief Networks (Uusitalo, 2007; Jensen, 1996; Varis, 1997), for the purpose of clarity, they shall hence forth be called Belief Networks and will be denoted by the abbreviation BN.

They are used to estimate the posterior probability of an event given observations of the current state of the system and are composed of three elements, the ontological, qualitative and quantitative components (Castelletti & Soncini-Sessa, 2007; Cain, 2001).

- The ontological component is represented by a set of variables also known as nodes that can take on different values also known as states which could either be discrete or continuous.
- The qualitative component is represented by a graphical structure composed of nodes with directed links representing causal influences between parent and child variables.
- The quantitative component is represented by Conditional Probability Tables (CPT) which quantify the effects of causal variables.

A BN is able to update the posterior probabilities of the variables using the probabilistic information of the CPT and the dependency information of the causal structure by applying Bayes' Theorem. A key characteristic of a BN is the principle of networking nodes representing conditional, locally updated probabilities (Pearl, 1988; Varis, 1997). The usefulness of BNs is in their capacity to proceed not only from cause to consequence but also deduce the probabilities of different causes given the consequences (Uusitalo, 2007). Table 3.2 outlines the differences in the philosophies of Bayesian and Frequentist (classical) statistics as reviewed comprehensibly by Ellison (2004).

From Table 3.2, it can be understood that for the frequentist approach, probability is an intrinsic property whereas for the Bayesian approach, it is a degree of belief of the individual.

Table 3.2: Table showing some aspects of frequentist vs Bayesian philosophies based on Ellison (2004)

Frequentist	Bayesian
Defines probability in terms of long run relative frequencies	Defines probability as an individual's degree of belief
Uses only sample data	Uses prior knowledge along with sample data
Considers model parameters as estimates of fixed 'true' quantities	Treats model parameters as random variables
Estimates the probability of data having occurred given a hypothesis	Provides a quantitative measure of the probability being true in light of available data

Importantly though, the frequentist approach uses only sample data whereas the Bayesian approach incorporates prior knowledge together with the sample data. This allows the use of previous experience to help in the estimation of probabilities. This property is useful in the context of this research as it permits the combination of sampled data with information from records and other sources to be combined in order to help improve the estimation of the probabilities of certain events and ultimately, the understanding of the decision-making process currently under investigation.

3.5.7 Decision trees

A decision tree is a predictive model that uses a tree-like graph to model the outcomes of sequential tests (Quinlan, 1992). Decision tree techniques follow a top-down induction strategy to build tree-like sequential graph models that have branches, nodes and leaves that can be easily translated into a set of mutually exclusive decision rules (Witten & Frank, 2005: 105).

The basic structure of a decision tree consists of a root node, a number of internal nodes and a set of terminal nodes. Each leaf node of the tree corresponds to a rule while a branch represents the conjunctions of the features that led to the classification (Witten & Frank, 2005; Quinlan, 1992). A decision tree can be used to classify a case by starting at the root of the tree and moving through it until a terminal node is encountered.

Decision trees are able to handle data in the form of continuous and categorical variables and ancillary or missing data. This supports their use in environmental management applications and especially for land cover classifications from remotely sensed data (Brown de Colstoun & Walthall, 2006; Garofalakis et al., 2003; Pal, 2006; McCarty et al., 2007; Otukei & Blaschke, 2010; Witten & Frank, 2005). Though they have not been applied to land-use decision-making analysis before, decision trees were tested for their possible application to land-use decision making in this research. They are discussed in detail in Chapter 9.

3.6 Choice of BNs as platform for land-use decision modelling

BNs are a tool which will be examined for application in this research. It is necessary to have a brief look at their theoretical background. BNs have been applied in many different fields to address a great variety of problems. These include medical diagnosis (Nikovski, 2000), artificial intelligence (van Tol & AbouRizk, 2006), fishery (Varis, 1997; Woodberry, 2003), ecology and natural resource management (Cain, 2001; Ellison, 2004; Marcot et al., 2001), landscape assessment (Lynam et al., 2004) and land-use change (Bacon et al., 2002).

BNs were linked to GIS by Stassopoulou et al., (1998) to assess the likelihood of natural regeneration of burnt forests in Greece. Bayesian techniques coupled with GIS were applied to build alternative forest plans in Finland (Kangas et al., 2000), while Bayesian regression techniques were used to estimate deforestation in Madagascar (Agarwal et al., 2005). Cain (2001) shows an example of the development process of constructing an operational BN. He applied it to water resources management in developing countries. A woodland landscape assessment to help in the development of the management plan for the Gorongosa National Park in Mozambique was carried out by Lynam et al., (2004). They used a combination of participatory techniques, Bayesian modelling and GIS to help understand the importance of the landscape to local communities. Bacon et al., (2002) on the other hand employed Bayesian techniques to understand the factors that might influence land managers to change land-use from farming to forestry in the marginal uplands of the UK.

The power and appeal of BNs lies in their ability to present a visual summary of expert knowledge or opinion about some subject and offering an efficient and principled approach to problem solving (Cowell et al., 1999; Heckerman, 1995). Based on this and the findings of the assessments by Cain (2001) and Lynam et al., (2007), BNs were adopted as a platform for decision modelling for this research project. They are discussed in detail in Chapters 7 and 8.

3.7 Selection of Study Area

The high rate of deforestation in Zambia over a relatively short period of time cited by the United Nations (UNECA, 2002) motivated the choice of study area. The area chosen for study is the Copperbelt Province and specifically the Maposa Local Forest and Chibuluma National Forest. The selection of these forests is because they lie within the catchment area of the headwaters of the Kafue River. The apparent rapid deforestation observed over a 14-year period presents an opportunity to study and understand the land-use change processes that have taken place. This should be taken in the light of new copper mines that have opened in the North-Western Province adjacent to the Copperbelt

Province. The North-Western Province may become the focus of industrial activity in the future. It is therefore important to understand and model decision-making with regard to land-use in the Copperbelt Province as it could have possible implications on the management strategies that may need to be employed in the North-Western Province. Furthermore, it is representative of change that has taken place in several countries across Africa such as Kenya (Omosa, 1998) and Zimbabwe (Mushove, 1994).

The problem of deforestation in the Central and Southern Provinces is well documented (Chidumayo & Chidumayo, 1984; Kajoba & Chidumayo, 1999; Serenje et al., 1994) and is witnessed by increased settlement in protected forest reserve areas and their subsequent depletion. Past studies on the problem in the Copperbelt Province have focussed on assessments of the extent of depletion of the forest reserves (Njovu et al., 2004; Nkomeshya, 1996, 1998; Nswana, 1996; PFAP, 1996; Zimba, 2004). That part of the decision-making process which drives deforestation activities has not been addressed. Adams (2001) warns that in rural areas with restricted access to land coupled with increasing population pressure whose sustenance is based on the continuous cropping of nutrient-demanding annual crops like maize, it is possible to have economic and ecological collapse as almost happened in the Bwiindi area in Uganda in 1991 when government intervention put a stop to the intensive agricultural expansion.

3.8 Socio-economic context

This section briefly addresses the socio-economic context firstly from the perspective of the study area in general and secondly from the perspective of the effects of the Structural Adjustment Programme (SAP) adopted by the government from the World Bank.

3.8.1 Economic change in the Copperbelt Province

The Copperbelt Province is the industrial centre of Zambia. It is home to the copper mining industry, which has provided the economic lifeline of the country from the 1950's to date. Copper accounted for about 80% of export earnings per annum in the 1990's (ZANA, 2004). The economic boom of the sixties and early seventies due to high copper prices was stalled by nationalisation of the strategic industries. The reversal of Zambia's economic fortunes was made worse by the world oil crisis of the 1970's. The government borrowed heavily from the World Bank to support agricultural subsidies and to sustain the ageing infrastructure especially the loss-making parastatal mines. This left the country saddled with heavy foreign debt (Roth, 1995).

The copper mines were nationalised in the 1970's following the adoption of a one party socialist state. The change back to multi-party democracy in 1991 resulted in the privatisation of state enterprises including the copper mining conglomerate, ZCCM, in the Copperbelt Province (Palmer, 1997). The new government was eager to reverse the dire economic situation with the promise of aid from the World Bank and development from potential investors. The aid was, however, conditional and one of the main demands by the World Bank was that the economy had to be opened up to free market forces and all state enterprises had to be privatised. Massive job losses followed nationwide and this was acute in the Copperbelt Province as most industries based in the province relied on the copper mines for business. The World Bank also pushed for land reform because the existing legislation at that time was perceived to be an obstacle to increased agricultural production (Palmer, 1997). The government tried to diversify the main economic activity from mining, to a stronger focus on agriculture and encouraged people to take up farming especially in the Copperbelt Province. This inevitably led to an increase in demand for agricultural land. The effect of privatisation coupled with government emphasis on agriculture posed a threat to the environment of the Copperbelt Province because of the increased exploitation of the forests in that region for new agricultural development and also for timber and the production of charcoal (Chileshe, 2001; FAO, 2003b; Ferguson, 1999; Kajoba & Chidumayo, 1999; Serenje et al., 1994).

A rapid change in the landscape of the Copperbelt Province of Zambia especially around the vicinity of the seven mining towns namely Ndola, Luanshya, Kitwe, Mufulira, Chingola, Chililabombwe and Kalulushi was observed. The change largely involved the clearance of forest and could be attributed to a number of factors such as clearance for charcoal production or clearance for subsistence agriculture. This change took place during a period of economic and policy transition in Zambia.

3.8.2 SAP and its effects in Zambia

Zambia was the richest country in sub-Saharan Africa at independence in 1964 relying on exports of copper which were fetching high prices on the international market (World Bank, 2001). This however changed quickly in the 1970's when copper prices fell and oil prices shot up. The Zambian government borrowed heavily from the World Bank and by 1991 when there was a change of government, the economic conditions were dire (AFRODAD, 2007). The new government in a bid to re-orient from the socialist past into a new economic direction, negotiated for the SAP from the World Bank in 1992. The conditions for the 1992 SAP were very strict and far reaching and these were:

- Privatisation of state enterprises
- Liberalisation of the economy
- Removal of subsidies
- Removal of price controls and introduction of cost sharing for education, health and other social services
- Restructuring of the civil service
- Macro-economic reforms
- Monetary and fiscal reforms

The SAP was implemented without regard to prevailing social and economic conditions. Taking into account that in 1992, state owned enterprises accounted for 80% of the economic activity, this resulted in a volatile economic situation with increased unemployment and poverty levels reaching as high as 85% (AFRODAD, 2007).

The consequences of the 1992 SAP were extreme poverty, capital flight, unemployment, illiteracy and a reduced life expectancy compounded by an increased prevalence of HIV. The impacts of the SAP are still being felt. In fact the World Bank (2001) has acknowledged that despite pressing ahead with implementation, the national and social context of the SAP did not favour the sustainability of the reforms. The World Bank together with the Zambian government failed to recognise the risk of failure of the reforms due to lack of attention paid to the protection of vulnerable groups (World Bank, 2001). A selection of some indicators of the effects of the 1992 SAP are shown in Table 3.3. The World Bank and the Zambian government have since entered into other agreements designed to alleviate the effects of the SAP and stimulate economic growth and social improvement such as the Poverty Reduction Strategy Paper (PRSP) of 2004. It is estimated that poverty levels are now at 68% and life expectancy is about 45years which is below the average of 52 years for sub-Saharan Africa (World Bank, 2009).

Table 3.3: Socio-economic indicators for Zambia – 1990 to 2009 (World Bank, 2009)

	1990	2000	2009
Unemployment (%)	65	81	-
Forest area (% of total land)	66	60	56
Trade (% of GDP)	73	66	61
HIV Prevalance (% of population)	8.9	15.5	15.2
Agriculture (% of GDP)	17.4	21.1	21.2
Manufacturing (% of GDP)	32.7	13.0	11.6

3.9 Physical, climatic and environmental characteristics

3.9.1 Location and boundaries

The Copperbelt Province is one of nine provincial administrative regions in Zambia. It is situated in central Zambia and to the north borders the mineral rich Katanga Province of Democratic Republic of Congo. To the east and south is the Central Province, to the west it is bordered by the North-western Province. The Copperbelt Province has seven towns whose economic mainstay is copper mining. Two sites in the Copperbelt Province showing accelerated land cover change were selected for this study: the Chibuluma local forest in Kalulushi District and the Maposa local forest in Luanshya District. Both sites exhibited types and levels of land cover changes that were typical of the general change in large parts of the Copperbelt Province. The Chibuluma forest lies 5km west of Kalulushi town and has an area of about 15 km^2. The Maposa local forest lies between three towns. It is situated 10 km north of Luanshya, 20 km south east of Kitwe and is about 22km west of Ndola along the highway connecting Ndola and Kitwe. Maposa local forest is about 29 km^2 in extent. Figure 3.2 shows the location of the study area and the administrative provinces in Zambia.

The close proximity of the forest areas to urban centres makes them vulnerable to encroachment especially given the socio-economic changes outlined in section 3.7. This is assumed to impact negatively on the management of the forest areas and thus provides an interesting aspect to the land-use decision-making process.

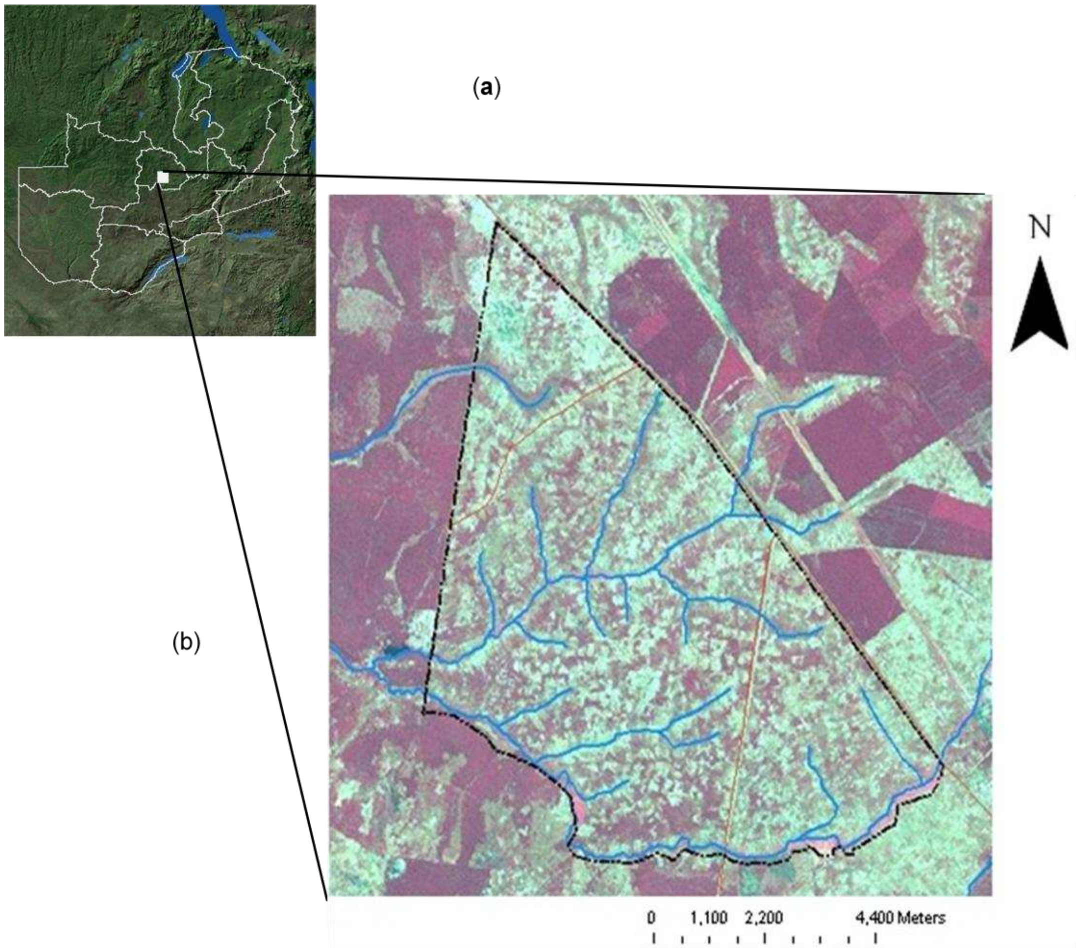

Figure 3.2: Location of study area.
(a) Map of provinces in Zambia
(b) The forest shown with bounded lines is the Maposa local forest. The dark patches to the west of the forest represent commercial farming land whilst those to the north east represent commercial Eucalyptus plantations. The light patches in the forest area represent cleared land without tree cover. The streams that drain the forest area are shown in blue.

3.9.2 Biodiversity

The Copperbelt Province is situated in the Miombo woodland eco-region, a sub-category of the Savannah woodland. The Miombo woodland eco-region is one of 16 ecosystems in Zambia and is the predominant vegetation type consisting largely of open forest (ECZ, 2001). This eco-region covers an estimated 3 million km^2 and spans seven countries: Angola, Democratic Republic of Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe.

The extent of the Miombo eco-region in central and Southern Africa is shown in Figure 3.3. It is described and mapped as the largest vegetation unit in the Zambezian centre of endemism (McClanahan & Young, 1996). In Zambia the Miombo eco-region covers approximately 294,480 km^2, which is about 40% of the total land area (ECZ, 2001). The Miombo eco-region is part of the Global 200, a global ranked list of the earth's most biologically outstanding terrestrial, freshwater and marine habitats for critical biodiversity conservation at a global scale as defined by the World Wildlife Fund for Nature (WWF). The WWF has identified 867 eco-regions and selected 232 eco-regions to form the Global 200. The Miombo eco-region is ranked 88th in the Global 200 ranking (Olson & Dinerstein, 1998; WWF, 2005). The dominant tree species in the Miombo eco-region belongs to the family Leguminoseae, sub-family Caesalpinoideae.

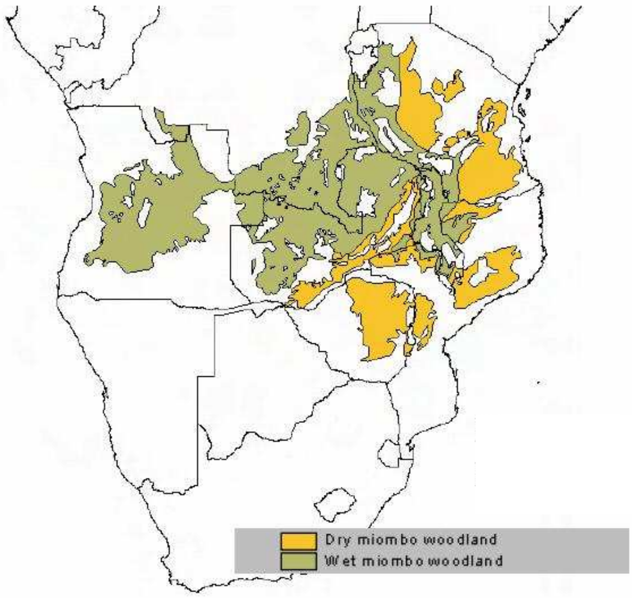

Figure 3.3: The Miombo eco-region in Central and Southern Africa (Desanker, 2002). Map not to scale showing two types of Miombo woodland and the countries it spans.

The dominant tree genus that forms the typical Miombo woodland is Brachystegia from within the sub-family Caesalpinoideae (Chidumayo & Kwibisa, 2003; McClanahan & Young, 1996).

The Miombo eco-region illustrated in Figure 3.3 spans seven countries in Southern Africa with an estimated combined population of 80 million people in the region that it covers, with the majority living in rural areas (WWF, 2005). The livelihood strategies in the eco-region are characterised by pastoralism and 'slash and burn' shifting cultivation. The traditional use of fire in preparing land for cultivation and pasture management in addition to natural fire has produced a fire adapted or fire dependant eco-region (Chidumayo & Kwibisa, 2003). The eco-region has a significant number of protected areas, but it is not clear if these by themselves are sufficient to maintain the essential ecological processes and functions for that region (WWF, 2005).

Biodiversity is important in the Copperbelt Province for a number of reasons. Firstly it is important for the livelihood of the majority of people who depend on locally available natural resources for food and shelter. Secondly, these natural resources are sometimes commercially exploited at household, community and national level. Thirdly, biological resources are often used for the preparation of herbal medicines (ECZ, 2001). Biodiversity in Zambia is threatened by a number of factors. Pollution from the mining industry is a major problem as is the threat caused by the rapid subsistence agricultural expansion into the forests reserves. The Environmental Council of Zambia (ECZ) cites land-use conflicts, human settlements, climate change, pollution, over-exploitation of resources and a lack of knowledge about biodiversity as being some of the most critical factors affecting biodiversity reduction in Zambia today. It calls for a concerted effort to redress the imbalance and highlights the need for a national strategy to achieve the required reductions (ECZ, 2001). The production of charcoal and clearing of land for agricultural purposes in the protected areas identified as threats to biodiversity conservation require further exploration through examination of the land-use decision-making process.

3.9.3 Drainage

Settlement of people in rural areas is affected by the need for access to water for domestic and sometimes agricultural usage. It is necessary therefore to look at the supply and access to water. Zambia has two major river basins into which all rivers discharge: the Zambezi River basin discharging south-east to the Indian Ocean and the Congo River basin which discharges to the north-west into the Atlantic Ocean. There are seven main river sub-basins in Zambia. The Kafue River sub-basin is part of the Zambezi River basin. The Kafue River, a major tributary of the Zambezi River forms the Kafue River sub-basin. This extends from the Copperbelt Province into the Central Province and Southern Province areas. The headwaters of the Kafue River are estimated to be about 154,000km^2 in extent. This sub-basin occupies some 22,400km^2 of the Copperbelt Province. The Kafue River sub-basin is part of the Miombo eco-region. The Kafue River drains 20% of Zambia and is an important source of food and water for 40% of its population. Its flow sustains hydroelectric power generation, three national parks of important ecological and economic value.

The river also drains two major wetlands: the Lukanga swamps, a large wetland in the Central Province, and the Kafue Flats in the Southern Province. It also supports agricultural uses downstream (WWF, 2005).

The Maposa local forest area is drained by several streams and is bounded to the south by the Maposa stream. Most of the streams in the forest discharge into the Maposa stream which in turn discharges into the Kafue River. The Chibuluma local forest is drained by the perennial Kalisha stream that dries out in the dry season. The Kalisha stream flows into an underground river system within the Chibuluma local forest.

The drainage of the forest areas is a factor that affects access to water in the encroached forest areas and is therefore another aspect of the land-use decision-making process that requires to be addressed.

3.9.4 Soils and Geology

There are four agro-ecological zones in Zambia. These are shown in Figure 3.4 and are classified according to the physical and climatic characteristics that determine the soil types. The Copperbelt Province lies in Zone 3 with a small part of its southern area in Zone 2 (ECZ, 2001). A brief description of the Zones as defined by the ECZ follows.

Agro-ecological Zone 1 (Luangwa-Zambezi River Valley Zone) covers the country’s major valleys in the southern extremes of the country and experiences the harshest climatic conditions. It has four soil types: loamy and clay soil, reddish coarse sandy soils, poorly drained sandy soils and shallow and gravel soils in rolling to hilly areas including escarpments. These are generally of low acidity and are of limited depth making them unsuitable for cultivation. This zone has a low annual rainfall of less than 800mm.

Agro-ecological Zone 2a (Central, southern and Eastern Plateau) covers the Sandveld plateau of Central, Eastern, Lusaka and Southern provinces. This zone has four soil types: moderately leached clayey soils, slightly leached clayey soils. The soils are of moderate acidity. This zone has an annual rainfall ranging from 800 to 1000mm. The soils in this agro-ecological zone are most suited for agriculture and have the most commercialised agricultural production especially for cash crops such as maize and cotton. This renders this zone most prone to environmental degradation due to agriculture (ECZ, 2001).

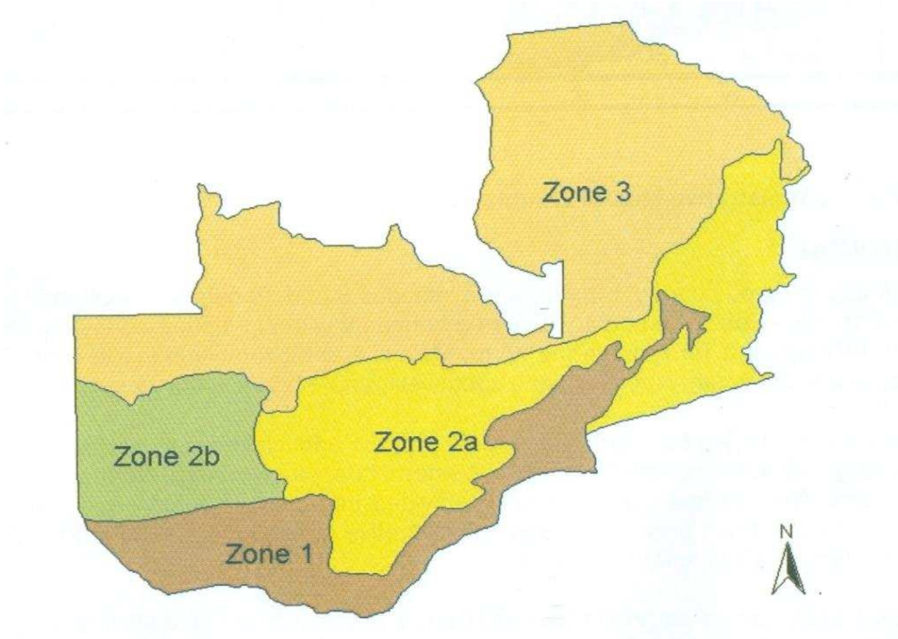

Figure 3.4: Agro-ecological zones in Zambia (ECZ, 2001). The four agro-ecological zones characterise the main agro-ecological regions in Zambia based on soil types and rainfall.

Agro-ecological Zone 2b (Western semi-arid Plains) covers the Kalahari sand plateau and Zambezi flood plain of the Western Province. This zone has two soil types: coarse sandy loamy soils in large valley wetlands and sandy soils on the Kalahari sand. The soils are of moderate acidity. This zone has low annual rainfall. The soils in Zone 2b and the low rainfall render this zone to have a low agricultural potential (ECZ, 2001).

Agro-ecological Zone 3 (Northern, North-western) is the largest zone in Zambia. It covers the northern regions of the country and extends over Northern, Luapula, Copperbelt and North-western Provinces. It is part of the Central African Plateau. This zone has six soil types. The soil types comprise red to brown clayey soils, shallow and gravel soils in rolling hilly areas, red clayey soils, poorly drained flood plain soils, coarse sandy soils in pan wetlands on Kalahari sand and rift valley soils. The soils in this zone have strong acidity and are highly leached. The annual rainfall in this zone is around 1000mm. Zone 3 is dominated by subsistence agriculture characterised mainly by maize and cassava production. However, it is the ‘slash and burn’ methods of agriculture that predominate in this region especially in the Northern and Luapula provinces where this is practised extensively and the methods have impacted negatively on the environment. This is compounded by the poor leached nature of the soils that has rendered the soils in Zone 3 largely unsuitable for commercial agricultural production. However, about 49% of Zambia’s natural forests are located in this zone (ECZ, 2001).

The Copperbelt Province is in Zone 3 which experiences high levels of rainfall. It has a mean annual rainfall of about 1200mm (Archer, 1971; Chileshe, 2005; ECZ, 2001). The province has a gently undulating terrain with an average altitude of 1200m above sea level. The occurrence of copper ores in the province is of economic importance and the ores are generally found deep underground. These are underground sulphide ores that resulted from the heavy leaching of surface oxide ores. The ore formations are mainly argillites and micaceous dolomites locally mineralised to a copper ore grade of between 3 to 4% copper. The underground sulphide ores are richer than the surface oxide ores (Hywel-Davies, 1971).

The high rainfall and gently undulating terrain coupled with good drainage in the forest areas of the Copperbelt Province make them susceptible to subsistence agriculture which is characterised by the production of maize, the staple food crop. It has been suggested from the foregoing that subsistence agriculture is common in ecological Zone 3 and that it might impact negatively on the management of the forest areas. Increased subsistence agricultural activity is assumed to have a negative impact on the land-use decision-making process, therefore the effects of such land use practices need to be addressed.

3.10 Land-use

The Copperbelt Province is a mining province and the industrial centre of Zambia. All the urban centres in the province developed around the mining industry and its attendant service industry. During the last census carried out in 2000, 18% of the country’s population was estimated to live in the Copperbelt

Province (CSO, 2003). The rural parts of the province are sparsely populated and largely consist of forest estates and villages whose inhabitants practice subsistence farming. The privatisation of the mines in the 1990's resulted in job losses in the mines and a coincident increase in settlement, both legal and illegal, in the rural areas of the province especially in the forests close to the mining towns (Chileshe, 2005; Ferguson, 1999; Hansungule et al., 1998; Palmer, 2001). Conversion of forests for subsistence agricultural and the production of charcoal to meet cheap energy demands in the towns have resulted in increased exploitation of natural resources as well as increased clearing of land cover. This has negatively affected the state of the environment in the Copperbelt Province (ECZ, 2001) and has attracted the attention of the WWF who are concerned with the management of the Miombo ecosystem as a whole and the Kafue River sub-basin in particular (WWF, 2005).

Figure 3.5 shows the general land usage in Zambia in the early 1970's. When compared to the land cover map of 2005 in Figure 3.6, it can be inferred that land uses have remained largely unchanged. The urban centres in the Copperbelt region are still showing on the land cover map of 2005.

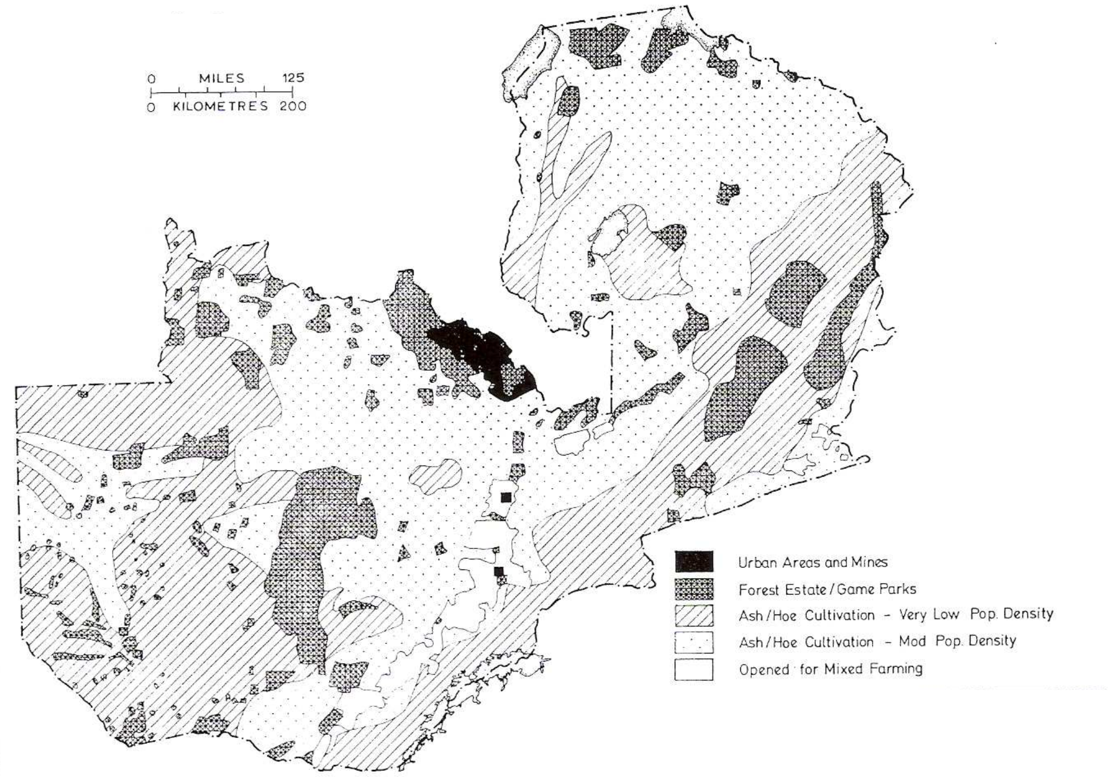

Figure 3.5: Land-use in Zambia in 1971. (Hywel-Davies, 1971)

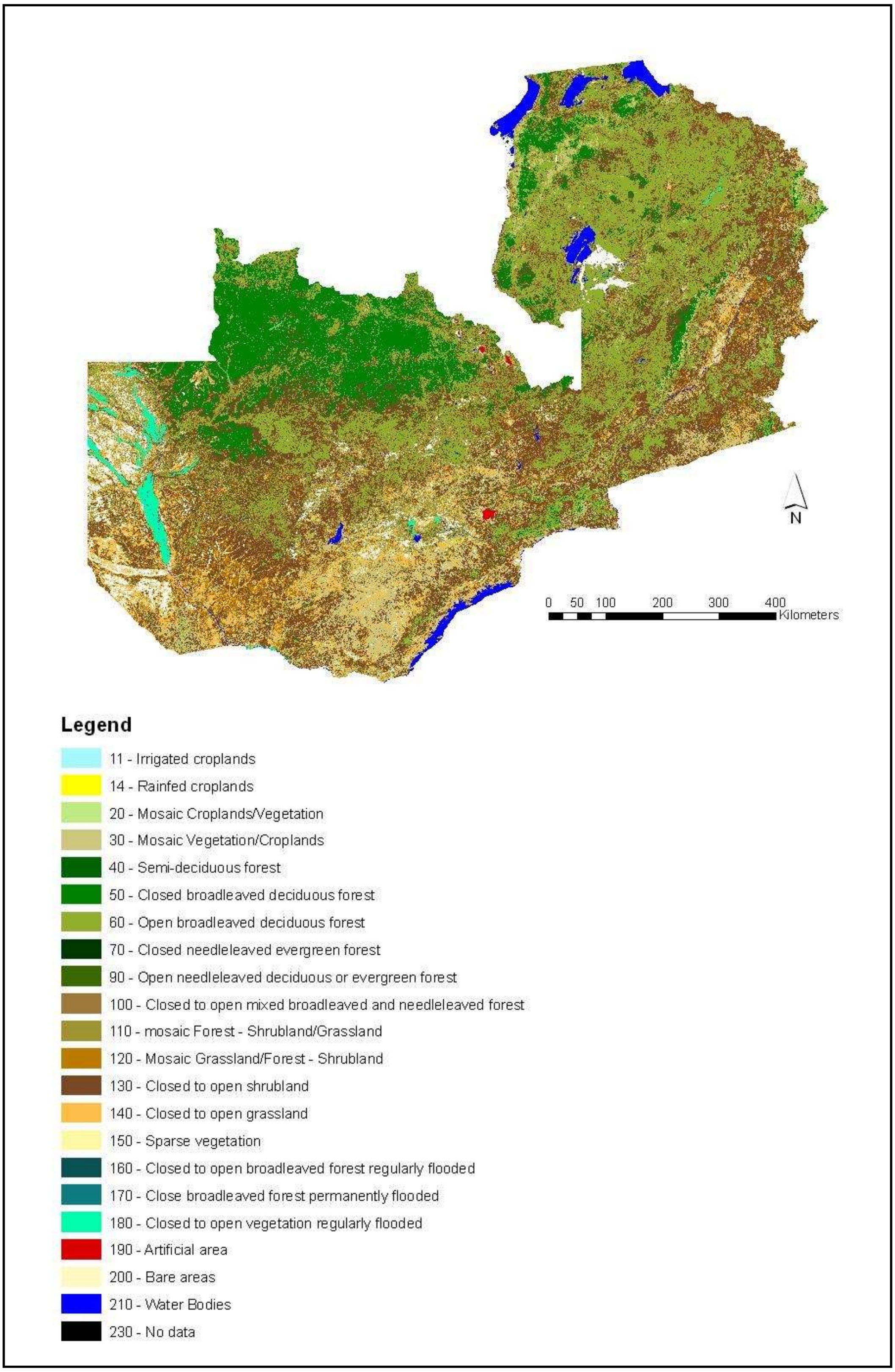

Figure 3.6: Land cover map of Zambia in 2005 (FAO, 2009). The urban centres in the Copperbelt Province are shown on the map but the most prominent urban area is the capital, Lusaka. The Copperbelt urban centres are surrounded by mixed forest types suggesting agriculture around the urban areas.

The major change seems to be the expansion of the urban area around Lusaka, the capital city, which is prominent on the 2005 land cover map. In order to sustainably manage the environment, it is important to get local stakeholders involved in the decision-making process and to do so, their land-use decisions need to be characterised in relation to their land tenure.

3.11 Summary

This chapter has described the geographical and environmental characteristics of the Copperbelt Province in general and especially that it is undergoing unprecedented environmental and socio-economic change. A review of land-use in the province was presented along with a description of local climatic and socio-economic conditions. It has described the methods to be used in this research and has identified BNs as a potential tool for the analysis of land-use decision-making. This chapter has also discussed the current land-use situation in Zambia in general and of the Copperbelt Province in particular

Chapter 4: Land Use and Land Tenure in Zambia – A Historical Perspective

4.1 Introduction

The challenge of environmental degradation is critical in many developing countries today and this has resulted in a need to understand the determinants of land use (Barraclough & Ghimire, 2000; Geist & Lambin, 2002; MA, 2003; Nelson & Geoghegan, 2002; UN, 2007; UNECA, 2002). To understand and model land use decisions of local stakeholders, it is important to understand the type of tenure that governs their ownership of the land. Land tenure institutions determine the rights and obligations of different social actors such as individuals, clans, local communities and the state in access to land, water, forests and other natural resources (Barraclough & Ghimire, 2000; Toulmin & Quan, 2000). The type of land tenure influences the decision making of the local stakeholders and ultimately their usage of the natural resources around them. There is an increasing demand for science-based environmental decision-making at the local, regional, national and international levels (Gutrich et al., 2005).

This chapter carries out a review of land tenure in the province, explores the current land tenure situation in Zambia in general and of the Copperbelt Province in particular, and positions land tenure and natural resource use in a historical context and explains how it has arrived at the current state.

To understand and model local stakeholder perceptions of land use allocation and decision-making in the Copperbelt Province, it is important to understand the type of tenure that influences land use choices. This review will next look at how the land tenure practices have developed to produce the current situation in Africa in general and in Zambia in particular.

4.2 Land Tenure in Africa

Land tenure in Africa is a complex mix of customary and colonial influences compounded with changing socio-economic situations. There are efforts to address theses issues through land reforms across the continent in order to ensure equitable and sustainable access to and usage of land and natural resources (Delville, 2000; McAuslan, 2000; Okoth-Ogendo, 2000). The following sections will look at how land tenure has evolved in Africa from colonial times to date in broad terms with an emphasis on British colonial approaches.

4.2.1 The colonial approach to land tenure in Africa

In West and Central Africa, the main colonial governments were the French and the British. In French speaking West Africa, land tenure was influenced by the coexistence of several systems, that is customary systems, Islamic religious influences and the French Code Civil (Delville, 2000). These systems were largely carried over with minor modifications after independence. This has resulted in a legal pluralism with a high degree of uncertainty about land-rights leading to conflicts for which many different arbitration bodies exist. Currently there are land law reforms in most French-speaking West African countries to harmonise customary land rights with statutory land laws (Delville, 2000). The next section will look at the approach adopted in British colonies since Zambia was a British colony.

4.2.2 The colonial approach to land tenure in British Colonies in Africa

British colonial expansion in East, West and Southern Africa relied on establishing legal mechanisms through which English-derived land law could be applied (Chileshe, 2005). The general phases used in imposing English Land Law in Africa are identified by (Chileshe, 2005) and these are: acquisition, destruction, reconstruction, substitution and integration.

Central to establishing legal mechanisms was the *'Reception Clause'* which according to McAuslan (2000) established that from a specified date, the common law, the doctrines of equity and statutes of general application applying in England on that date, would also apply in the particular country named in the reception clause. The Jurisdiction Act of 1890 was believed under Imperial Law to bestow the power of control and disposition over unoccupied land in British Protectorates to the British Crown and was used as a legal foundation for the application of English Land Law in Commonwealth Africa (McAuslan, 2000; Okoth-Ogendo, 2000).

The Acquisition Phase involved appropriation of all land in the territory and making it available for allocation to supporters of the new authorities. Thus British colonial authorities assumed full rights of jurisdiction over all land. The

Destruction Phase involved denial of the rules and practices governing land rights of native Africans. This meant that the colonial authorities set aside Customary Law in relation to vacant and unoccupied lands, allowing the colonialists to claim them, to enact land laws that in effect put in place a dual system of tenure consisting of two categories of land: Crown Land and Customary Land. Crown Land was set aside for allocation to colonial settlers while Customary Land was set aside for native Africans governed under Customary Law (McAuslan, 2000; Okoth-Ogendo, 2000).

The Reconstruction Phase saw the colonial authorities adapt Customary Law to become part of the colonial administrative rule by imposing administrative controls on the operation of Customary Tenure. This involved, in some cases, the introduction of some doctrines unknown to Customary Tenure as being part of the system. According to Okoth-Ogendo (2000), colonial administrators held the view that Customary Tenure would 'wither away' as western civilisation took root in the social relations of native African people. This had the profound effect of promoting the dual tenure system. This is the dominant approach to land tenure in English speaking Africa (Chileshe, 2005; McAuslan, 2000; Okoth-Ogendo, 2000)

The Substitution Phase constituted the promotion of increased security of tenure for the colonialists through the conversion of indigenous tenure to tenure based on Freehold. The most comprehensive exercise of tenure conversion has been carried out in Kenya from 1954 to date. This laid down procedures for the conversion of Customary Tenure into individual Freeholds.

The desire to replace Customary Tenure has influenced land policies and laws in other countries such as Zambia and Malawi (Chileshe, 2005; McAuslan, 2000; Okoth-Ogendo, 2000). It must be noted that this was a period when most African countries were on the verge of attaining independence from Britain.

The Integration Phase represents attempts to develop a new common land law for a particular country, derived from different parts of the existing laws, that was to be applied to all land and all people. This was typically after independence for most countries e.g. the Lands (Conversion of Titles) Act of 1975 in Zambia, the Tribal Land Act of 1968 in Botswana and the Land Reform Programme of South Africa after the renunciation of apartheid in 1994.

Chileshe (2005) observes that reception clauses have survived constitutional changes in most of English speaking Africa since independence with the implication that English Land Law continues to influence decisions on the development of national land law and policies and practices today. He concludes that it is clear that the colonial history of African countries cannot be separated from present land policy issues.

4.3 Land tenure in Zambia

Three distinct phases encompass the history of land tenure in Zambia. These are the Colonial era, the post-independence one party socialist era and the current multi-party democracy situation. Each phase has been guided by different political ideologies and has resulted in the enactment of divergent policies on land tenure. The following sections will explore the land tenure approach in Zambia adopted by the both colonial and the post-colonial governments and thus set the context for the current land tenure situation.

4.3.1 Land Tenure Approach during the Colonial Era in Zambia (1924 – 1964)

Most of present-day Zambia was settled by the 18th century. The settlers comprised tribes migrating from the Luba-Lunda Empire in the north, in present day DRC, and tribes from the south fleeing from Shaka Zulu's wrath. Land holding and transactions involving land were controlled by the various local customs (Mulolwa, 2002). By the 1890's, the British South Africa Company (BSAC), a mineral exploration and mining company owned by Cecil Rhodes, held administrative rights for areas under concession from local chiefs. BSAC administered North Eastern Rhodesia (NER) and North Western Rhodesia (NWR). The British monarch had indirect control over these two protectorates. The monarch passed laws for British colonies and protectorates which did not have a local legislature. These laws were passed through the Privy Council and were known as Orders-in-Council (Mvunga, 1980). In 1899, an Order-in-Council confirmed the protectorate status of NER. BSAC later secured concessions in NWR from King Lewanika of the Lozi and this eventually led to an Order-in-Council in 1911 which amalgamated NER and NWR into a single protectorate called Northern Rhodesia (Chileshe, 2005; Mulolwa, 2002; Mvunga, 1980).

BSAC began assigning land for European settlement. This largely involved the setting aside of land free from African occupation. This was done in the belief that an influx of Europeans settlers would occur. Reserves were created for the natives in the concession areas although they had no legal basis. BSAC intended to free up land for their settlers (Mvunga, 1980).

In 1924, the Colonial Office took over the administration of Northern Rhodesian from BSAC and a governor was appointed to administer Northern Rhodesia Protectorate. BSAC were allowed to keep the rights to minerals while the land was handed over to the Crown. This was formalised by the 1928 Order-in-Council which allocated mineral ownership to BSAC and only allowed the native inhabitants surface rights for the land. The Order-in-Council established the dual system of land tenure in the territory consisting of Crown Land and Native Reserves. Land rights of indigenous people living in reserves were governed under Customary Law while English Land Law was applied to Crown Land. All land was vested in the Secretary of State for the Colonies and administered by the Governor of Northern Rhodesia. This implied that the Crown could assign land to intending European settlers through the granting of Leasehold or Freehold estates (Mvunga, 1980).

The policy of granting Freehold estates to settlers was changed in the 1930's in favour of granting Leaseholds. The adequacy of the native reserves as regards sustainability of the native population became an issue of concern during the 1930's as the reserves were becoming overpopulated, and overstocked with cattle, with successively poor crop harvests and deteriorating soil conditions. Meanwhile, the tracts of Crown Land set aside for the anticipated settler influx were largely unoccupied. They became known as the *'silent lands'*. This compelled the Northern Rhodesia government to consider setting aside more land for the native Africans in order to relieve pressure in the native reserves. This resulted in the 1942 Northern Rhodesia government policy of creating a new land category called the Native Trust Lands. These lands could be assigned for a limited time from Crown Land to individual Africans or Europeans but this could only be done in cases where it was shown it could benefit Africans through livestock and cropping, and that it was not required for the direct occupation of Africans (Mvunga, 1980). This led to the appointment of two Commissions in 1942 to carve out Native Trust lands from Crown Land along the line of rail which runs from north to south. In the Copperbelt Province, government administrators requested that that the Copperbelt Province be reserved for the development of the mining industry and forestry reserves (Mvunga, 1980). The Native Trust Land Order-in-Council effected the policy in 1947. The country now had three categories of land namely Crown Land, NativeReserves and Native Trust Land.

The European settlers were not happy with the policy of only granting Leasehold estates and argued for it to be reversed claiming that Leasehold did not provide security of tenure compatible with permanent settlement. Their demand was successful. The Crown Grant Ordinance, No. 3 of 1960, allowed for the conversion of Leasehold Tenure into Freehold Tenure (Mvunga, 1980). In this way the policy of land reservation based on race discrimination and in favour of the economic interests of European settlers was entrenched in Northern Rhodesia up to independence in 1964 (Chileshe, 2005).

4.3.2 Land Tenure Approach during the Post-independence Era in Zambia

This era comprises two main phases, the period just after independence from 1964 to 1975, and the period from the 1975 Land Reforms up to 1991.

4.3.2.1 The Early Independence Period: 1964 – 1975

Zambia attained independence on 24th October 1964. The Zambia Independence Order, 1964, which provided for the establishment of the new republic recognised estates, rights and interests in land as created in the various Orders-in-Council. This meant that the categories of land remained the same. All land was now vested in the President of Zambia and the land categories were renamed as follows: Crown Land became State Land, Native Reserves became known as Reserves and Native Trust Land became Trust Land (Chileshe, 2005; Mulolwa, 2002; Mvunga, 1980). This period did not witness fundamental changes to the land tenure system. This was typical for most African countries after independence (Chileshe, 2005; Delville, 2000; McAuslan, 2000).

4.3.2.2 The Land Reforms: 1975 - 1991

In 1972, Zambia was converted to a one-party socialist state by way of a referendum. This paved the way for radical changes in land ownership. New land reform measures were introduced through the Land (Conversion of Titles) Act, 1975. All land was nationalised and all land held under Freehold Title was converted to Leasehold Title with 99 years duration. All commercial farms were included and unutilised tracts of land were taken over by the state. Undeveloped land had no value and could therefore not be sold anymore. Only the structures on land had any value.

The 1975 Land Reforms were a departure from the colonial land policy although the categories of land tenure remained the same. The reforms were prompted by the increasing phenomenon of 'absentee landlords', that is vacant undeveloped land which was held on Freehold Title. Due to the demand for land, this led to speculation in prices of land resulting in exorbitant prices for sales of vacant land. This was against the socialist philosophy of Humanism, which was the guiding philosophy of the ruling UNIP party at the time (Mvunga, 1982). The philosophy of Humanism was abandoned in 1991.

The 1975 Land (Conversion of Titles) Act sought to make more land available for agriculture by reclaiming all unutilised land under Freehold Title.

4.3.3 The Current Multi-Party Democracy Situation: 1991 and Beyond

In 1990, the political situation in Zambia reverted back to multi-party politics with the amendment of the constitution. This saw the exit from office of the UNIP party and the ascendancy to power of the MMD party. With this change of government came inevitable changes to various policies and related laws. In addition to the change to a multi-party political system in 1991, there was a desire by the government to speed up economic development. The government embarked on aggressive donor funded policy reform exercises aimed at freeing up Customary Land and Trust Land for private investment through Leasehold Title. The government had targeted an increase in State Land from 6% to 20% (Roth, 1995). This was intended to ease the artificial land shortage especially along the line of rail where most towns are situated.

Figure 4.1 illustrates the distribution of the land categories after independence in Zambia. It has been estimated that after independence, State Land was only about 6% of the total land area, while Trust Land occupied 60% and Reserves occupied 34% (Mulolwa, 2002). By 1991 it was estimated that State Land had increased up to 10% while the combined land area for the other two categories of land reduced to 90% (Chileshe, 2005). State Land is mainly confined to urban areas. The land distribution presented in Figure 4.1 shows how difficult it is for the government to allocate major development plans throughout the country as only about 10% of the total land area is under state control. The MMD government set out to effect a land policy that would embrace private ownership of land in a free market economic environment (Chileshe, 2005). Thus in 1994, the Lands Bill was introduced in Parliament.

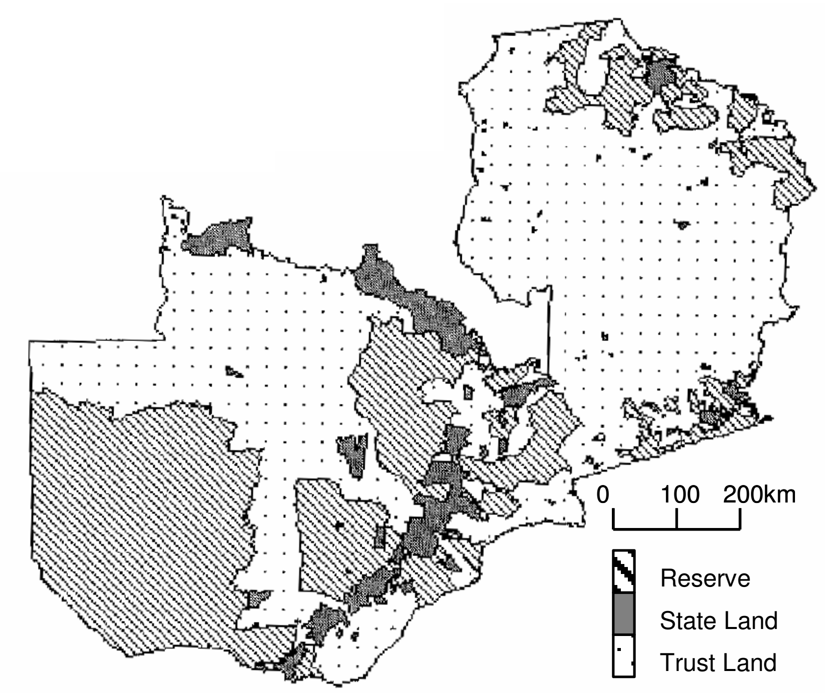

Figure 4.1: Land tenure distribution in Zambia in 1991. (Mulolwa, 2002)

The 1994 Lands Bill was not enacted into law but it sought to enact radical changes to the existing Land Law of the time. It sought to repeal and replace the Land (Conversion of Titles) Act, 1975. The Bill proposed to repeal the colonial categorisation of land. The categories of Reserves and Trust Land were to be replaced with a single category designated as Customary Land. The category of State Land would remain with 99-year Leasehold Tenure. The Bill proposed to re-attach value to undeveloped land. The forces of supply and demand would determine the value of land. It also proposed the setting up of a Lands Tribunal to settle any land disputes.

Controversially though, it intended to allow anyone holding Customary Tenure to convert it to Leasehold Tenure not exceeding 99 years. This was met with fierce resistance from opposition members of parliament and from traditional rulers who felt that their authority would be diminished if people could have Leasehold Tenure in their kingdoms. The government argued that Customary Tenure is not secure compared to Statutory Land Tenure and suggested that villagers with Leasehold Tenure could use it as collateral to secure credit for investment on their farms (Chileshe, 2005). The Bill was withdrawn from Parliament in 1994.

In 1995, under pressure from the World Bank, the government passed a hastily prepared Land Act in parliament despite two years of fierce resistance from local chiefs and opposition parties in parliament. The 1995 Land Act was a modification of the 1994 Lands Bill which was withdrawn from Parliament in 1994. In order to reassure traditional leaders of their power over Customary Land, the Act maintains that the President, in whom all land is vested, shall not assign land governed under Customary Tenure without consulting the chief. Leasehold Title could now be held in Customary Land with the consent of chiefs.

A major weakness of the 1995 Land Act is that it lacked the support of stakeholders. It was never gazetted before it became law and there was no policy document to support it. To redress the situation, there is currently in place a process of consultation to replace the 1995 Land Act. The Draft Land Policy 2002 (GRZ, 2002) has been widely circulated and is currently the subject of intense debate (Hanyona, 2005; Muyakwa et al., 2003). The 1995 Land Act has caused a lot of misunderstanding and confrontation between chiefs and their subjects (Mupuchi, 2005), between chiefs and the government

(Post, 2002; TOZ, 2003a, b; ZANA, 2004) and also between chiefs and settlers who have settled in the chiefs' areas (Post, 2002).

4.4 Land Tenure and Forestry in the Copperbelt Province Zambia

The Forestry Department was first established in 1947. This was based on the Forest Policy of 1941. Previously forest officers were part of the Department of Agriculture. The Forestry Department was tasked to place under permanent government control all forest areas needed to protect land against desiccation and erosion and to maintain the flow of rivers. The department was also mandated to reserve sufficient forest land to supply the forest produce required for domestic, agricultural and industrial use on a sustained basis without making revenue the first consideration and to spread an understanding of the value of forests to the population.

Some 25,000 km^2 or 5% of the country had been established as forest by the end of 1958. In the Copperbelt Province, a large timber concession had been set up to meet the demands of the mining industry for pit props and firewood. There was also, an increasing demand from Africans working in the mines for charcoal for domestic use. Charcoal was considered more economical to use, and is cheaper and less bulky than firewood to move to the growing centres of population around the mines (Palmer, 2001). It is noted that by 1967, about 30% of the Copperbelt Province comprised Forest Reserves and Protected Areas (Palmer, 2001).

During the 1960's organised charcoal burning associations were allowed to operate in the forests by the Forestry Department. There were also a small number of people who operated without permission on a part-time basis cutting timber. They occupied illegal squatter camps in the forests or alternated between temporary shelters in the forests and permanent homes elsewhere. Others were involved in unauthorised cultivation especially in areas adjacent to the mining towns (Palmer, 2001).

The Forest Policy of 1941 was first revised in 1965 after independence as it was found to be a constraint to effective management and utilisation of the forest resource. The power to declare Forest Reserves and Protected Forest Areas was at the time given to the Minister in charge of natural resources (Chileshe, 2001).

The Forest Act of 1947 was repealed and replaced by the Forest Act of 1973 which was itself based on the 1965 Forest Policy. This instituted the Forest Department as the sole actor in the sector in that sector of government. This policy was a centralised and restrictive one, which vested all control, ownership, planning and management in central government through the Forestry Department. Local chiefs no longer had a say on how to utilize natural resources in their vicinity once they were declared as Forest Reserves or Protected Forest Areas.

This shift in the management system from being local-people-oriented to the concentration of all power in central government resulted in increased rates of encroachment and degradation of protected forests and failed to provide an environment for sustainable forestry development (Chileshe, 2001; CONASA, 2002). Arising out of a poor economic environment and an apparent shortage of urban land, the late 1980's saw an intensification of the process for retired or retrenched miners and others to leave the urban areas and head for the forests to engage in charcoal burning which guaranteed a relatively quick and secure means of making money (Palmer, 2001). These settlers were initially recognised by Forestry Department staff who licensed them to cut a given number of trees within a given period in order to thin the forests and to prevent them from catching fire in the hot dry season. Most of the settlers chose to stay permanently and turned to agriculture at which point they became illegal squatters since farming is not permitted in forest areas (Hansungule et al., 1998). It is estimated by Palmer (2001), that by 1998, thousands of people were illegally settled in forest areas in the Copperbelt Province. No accurate figures have been recorded to date about the number of people illegally settled in the forest reserves. Considerable pressure had built up to have some of the forest areas de-gazetted to make land available for farming. Although the settlers were considered illegal by the Forestry Department, they were offered advice and support by agricultural extension staff from the Ministry of Agriculture thereby creating a conflict between two government departments (Hansungule et al., 1998; Palmer, 2001). This was a setback in terms of preventing further encroachment on to the forest reserves. Similar trends of encroachment were observed in Kenya in the forests surrounding Nairobi. In that case encroachment into the forests for farming increased and pressure was put on the government to convert the forest land to agricultural land (Omosa, 1998).

In eastern Zimbabwe, there was encroachment into the forests neighbouring village settlements (Katerere et al., 1993; Nhira & Fortmann, 1993). In all these cases, the forests were perceived as spare land by the locals who needed land to carry out small-scale agricultural production (Katerere et al., 1993; Nhira & Fortmann, 1993; Omosa, 1998; Palmer, 2001).

The conflict between government departments on the best approach to managing the forest reserves is of concern. This is compounded by political influence. Hansungule et al,. (1998) observe that so often, illegal settlers use membership of the ruling party as security to enable them continue occupying the forests illegally with a view to legalising their tenure. They are viewed as potential voters by politicians aspiring to be elected to Parliament. The creation of polling districts by the Electoral Commission in areas settled illegally reflects an implicit acknowledgment of tenure by the government. The polling districts reflect where people actually live and not where they are supposed to live (Palmer, 2001).

Deforestation is widespread in Zambia and it is not only agriculture and charcoal production that are destroying the forests; poorly controlled commercial exploitation of timber is also a major cause of deforestation in its Western, Eastern and Southern Provinces. The local communities do not benefit from these activities given that there are no timber processing industries in those areas. It is estimated that 95% of rural households in the country depend on firewood and 90% of urban households depend on charcoal (Chidumayo & Chidumayo, 1984; Chileshe, 2001; Serenje et al., 1994; WRM,

2001) This demand is not expected to drop. Wood accounts for 71% of the total energy consumption and constitutes 2.3% of the GDP (World Bank, 2001).

The government formulated a new National Forest Policy in 1998 that seeks to take care of the interests of all stakeholders whilst at the same time recognising the need for broad-based participatory approaches to forestry development. It brings on board the concept of decentralisation and is based on the principles of Agenda 21. The 1998 Forest Policy addresses four main areas of concern: resource management and development, resource utilisation, capacity building and gender equity. The implementation of the 1998 National Forest Policy and the manner in which local stakeholders perceive the participatory processes therein needs to be considered.

4.5 Summary of Land Tenure History in Zambia

The preceding discussion shows that land policies and laws in Zambia have been influenced by historical political processes. They have followed similar trends to those of other English-speaking African countries from the onset of colonialisation. The colonial administration had two interest groups to deal with, the European settlers and the indigenous Africans. The European settlers were assured of land for their settlement, farming and mineral exploitation through the land reservation policies which excluded African occupation on land with fertile soils or in areas believed to have mineral deposits. This was pursued through a dual system of tenure governed by colonial and customary laws.

The dual system of tenure, i.e. State Land and Customary Land has been adopted and modified after independence in a lot of African countries. This has also been maintained in Zambia even though the legislation pertaining to the assignment and disposal of land has changed several times. The colonial assumption that Customary Law is inferior to Statutory Law still persists today and can be seen through the legal provisions allowing the conversion of Customary Tenure to Leasehold Tenure as a way of acquiring security to obtain credit.

This chapter has shown that social, economic and political factors have influenced the restructuring of the land tenure system in Zambia from the colonial era to date. The ruling party's political ideology has been a major factor in the changing of land policies. This is relevant to the research questions since local stakeholders have to engage with these factors in the process of land use decision making.

The policies relating to forestry have also been considered briefly with an emphasis on the relationship between the development of the mining industry and the resulting settlement trends that have evolved in the Copperbelt Province. There has been an unprecedented level of encroachment into the forest reserves resulting in the environmental degradation of the forest reserves which constitute a significant part of the land area of the province. Although the effects of the degradation are not immediately being felt, it is necessary to understand the consequences of continuing on such a path. This is where science-based environmental decision-making can help stakeholders plan the sustainable use of natural resources (Gutrich et al., 2005). To do this, it is necessary to capture, understand and model the decision making processes of local stakeholders and use that to develop perceptions that may help inform the development of strategies to manage natural resources in a sustainable manner.

The chapter has shown that the Copperbelt Province is not unique in experiencing accelerated land cover loss due to encroachment of forests for agriculture, settlement and for the purpose of charcoal burning to meet the ever increasing demand for cheap energy in the towns. These trends are not restricted to Zambia but do occur in other countries as well such as Kenya and Zimbabwe. The development of methods to help understand and characterise local stakeholder decision making with respect to land use practices in informal settlements will be useful for the sustainable management of the environment.

The effect of changes in land tenure practices in Customary Land in Zambia has been addressed by Chileshe (2005). He found that land tenure reform must aim to secure land rights for individuals and households to ensure sustainable livelihoods through guaranteed access to and control of the usage of natural resources. This requires community participation in the planning and making of decisions for sustainable environmental management. This study intends to address the implications of land tenure practices in informal settlements encroaching into protected areas. The next chapter reviews the methods for incorporating local stakeholder knowledge, preferences and values into decision making in the use of natural resources.

Chapter 5: An overview of the methods and techniques applied in the study.

5.1 Introduction

This chapter uses the concepts addressed in Chapter 3 to describe the methodology for carrying out the research with an emphasis on the questionnaire survey and the preparation of the spatial database. All the various aspects of the methodology have the purpose of providing information that will help model the decision-making process and ultimately help in the prediction of future directions in land use. The research approach is described. This also includes a description of the application of the research techniques defined in Chapter 3.

5.2 Research approach

The research used a combination of tools and methodologies to study the problem of land use decision-making and to develop conceptual models that would lead to the eventual development of a BN and decision tree models to simulate the land-use decision-making process carried out by local stakeholders. The research used a combination of natural science and social science research methods. The methods used were meant to serve complementary purposes to investigate rural land use decision-making in the Copperbelt Province of Zambia. The social science methods were used to capture the local stakeholders' perceptions about the environment they live in and their participation in its management in order to understand their decision-making processes in the face of change affecting their environment. The natural science methods were used to assess the physical changes in land cover and other factors that impact on the land use decision-making process. In this sense, the research approach used is eclectic.

5.3 The Land Use Decision-Modelling Procedure

After looking at the general definition of decision-making in the context of land use and having examined the decision making processes and the tools to capture the process, a general procedure to carry out the process of representing the land use decision-making in the Copperbelt Province was developed. The procedure consisted of the following stages:

(i) Identification of stakeholders – this stage used personal interviews with local authorities, central government and NGOs. Background information and literature from various sources were also used in this process.

Four main groups of stakeholders involved in the activities in the forest areas were identified from background literature. Institutional stakeholders were selected on the basis of their involvement in the forest areas and local stakeholders on the basis of their availability to participate.

The Provincial Forestry Office was selected to represent central government. Interviews were conducted at the Provincial Forestry Office in Ndola with the Deputy Provincial Forestry Officer.

The Local Authorities were represented by Kalulushi and Luanshya District Councils because of the location of the pilot and main study areas. Luanshya District Council did not avail themselves for the study despite the Maposa Forest being located in Luanshya District. However, Kalulushi District Council was available for the survey. The interviews were conducted at the Council offices at the Civic Centre in Kalulushi with the Director of Planning.

For the NGOs, only Bridge International was active in the Maposa forest study area and they were willing to participate in the study. They were interviewed at their offices in Ndola. They also provided contact with the chairman of the local lands advocacy committee from the Maposa Forest whom they worked with in the area.

The selection of local stakeholders for interview was random and based on their availability. Village leaders in various parts of the forest area were approached and requested for permission to conduct house to house interviews in their villages. Some village leaders agreed but others did not citing the need to consult their local MP. Others simply did not make themselves available. For the village leaders who gave permission, one week notice was given for them to inform community members before the questionnaire interviews were conducted in their villages. Only adult community members heading households were interviewed at their houses and there was no gender restriction.

(ii) **Identification of stimuli** – this stage involved the use of personal interviews, group meetings and administration of the questionnaire. Remote sensing, photogrammetry and GIS were also applied.

(iii) **Definition of the problem situation** – this stage involved the application of SSM to define the problem situation and subsequently develop a conceptual model of the land-use decision-making in the study area. It mainly utilised outcomes of the focus group meetings.

(iv) **Development of BN models** – BNs were constructed with the help of outputs from SSM and used in this stage to create a choice space for the decision-maker.

(v) **Decision tree model of land use decision-making** – The machine learning approach utilising decision trees was used during this stage to develop a model representing the land use decision-making in and around the study areas. This is to be used for comparison with the BN land use decision model.

5.4 Questionnaire survey

This section looks at the process that was used to collect data from local and institutional stakeholders using the questionnaire interview approach. This approach was adopted because it could provide research objective-related information present in the minds of interviewees and not existing in formal literature and records as suggested by Magee (1973). Two questionnaires were developed, each aimed at a specific group of stakeholders. The first questionnaire was aimed at institutional stakeholders identified to have an interest in the management of the environment in the Copperbelt Province. The second questionnaire was aimed at local stakeholders living within the case study areas.

Two case study areas have been identified; the preliminary study area which was used as a pilot study in the Chibuluma National Forest in Kalulushi District and the main study area, the Maposa Local Forest in Luanshya District. In the preliminary case study area of Kalulushi, one assistant was recruited to help with guiding the researcher to contacts in the field set up in conjunction with the local authority, the Kalulushi Municipal Council. In the main study area, Maposa Local Forest, two assistants were recruited: a local who had contacts with local village leaders within the area and the other assistant to help with entering the questionnaire responses into a digital database after collection of field data and to occasionally assist with field data collection. In all cases, the assistants had a minimum of a school certificate and were competent in English and Bemba, the dominant language spoken in the Copperbelt Province.

5.4.1 Institutional questionnaire

The questionnaire used in this phase tried to capture the perceptions of institutional stakeholders and to help understand their contribution to the land use decision-making process in the Copperbelt Province. This questionnaire focussed mainly on their involvement in the management of the environment in the study areas and their contribution to the policy development process generally. A sample of the questionnaire form used in the survey is attached in Appendix A.1. To maintain confidentiality, only the names of organisations of the respondents and their job title abbreviations have been recorded in this text.

5.4.2 Local stakeholder questionnaire

This phase of the investigation involved the administration of a questionnaire to a sample of household heads in the case study areas. The questionnaire was administered to individual respondents chosen at random in the villages within the case study areas. The questionnaire was intended to be administered to respondents selected at random in the Maposa Forest covering as much of the forest area as possible. It was designed to reveal trends and common patterns in the case study areas in respect of land use decision-making and this considered land tenure security, land use preferences, policy awareness and perceptions of environmental management in the area. However, access to the villages was limited because permission was not granted to conduct interviews in parts of the Maposa Forest.

The questionnaire was designed to be administered in an interview format and respondents could provide their own answers that were later coded. The names of the respondents were not recorded for confidentiality. Another important aspect of the questionnaire survey was that the land holdings surveyed had their positions marked in space by way of GPS coordinates. Therefore, the data collected had a spatial component. However, because of the suspicions of the local stakeholders, it was not possible to measure the extents of their field sizes. A sample of the questionnaire form used in the survey is attached in Appendix A.2. After collection, the responses were entered into an Excel spreadsheet before being coded in readiness for preliminary statistical analysis.

The questionnaire data were classified in line with Dey's approach (Kitchin & Tate, 2000). A code book was developed for classifying the responses into codes so that similar groups of answers could be classified. The code book utilised is given in Appendix A.3. The responses were coded for processing in SPSS and a preliminary descriptive statistical analysis done. Each of the data headings was given a unique code heading and each response type was given a unique number code under that heading. These were then entered into SPSS for a categorical analysis of the data. The results are attached in Appendix A.4.

A sample of part of the questionnaire input after data collection from the field and entry into an Excel spreadsheet is shown in Table 5.1. The same sample is depicted in Table 5.2 after the coding of data items in preparation for input into SPSS. The sample table is illustrated with coded headings and ready for processing in SPSS in Table 5.3. A total of 404 questionnaires were administered in the Maposa forest study area and 12 questionnaires were administered in the Kalulushi pilot study area.

Table 5.1: Sample questionnaire input table

Ref NO.	Grp	Date of Survey	Position C/H/OS/OT	Village	Tribe	Rainfall H/M/L	No. of Fields
1	1	12/08/2005	OT	MUPUNDU	NAMWANGA	H	1
2	1	12/08/2005	OS	KABE	TUMBUKA	H	1
3	1	12/08/2005	OT	TWASHUKA	BEMBA	M	1
4	2	12/08/2005	OS	TWIKATANE	TUMBUKA	M	5
5	2	12/08/2005	OT	BUTUNGWA	MAMBWE	M	1

Table 5.2: Sample questionnaire table after coding of data items

Ref NO.	Grp	Date of Survey	Position C/H/OS/OT	Village	Tribe	Rainfall H/M/L	No. of Fields
1	1	12/08/2005	4	1	3	3	1
2	1	12/08/2005	3	2	4	3	1
3	1	12/08/2005	4	1	2	2	1
4	2	12/08/2005	3	5	4	2	5
5	2	12/08/2005	4	4	5	2	1

Table 5.3: Sample questionnaire table after final coding of headings

ID	Grp	STATUS	VILLAGE	TRIBE	RAIN	FIELDS	PROX_F	H_ACQ	DOA
1	1	4	1	3	3	1	1	3	2000
2	1	3	2	4	3	1	1	3	1991
3	1	4	1	2	2	1	1	2	2000
4	2	3	5	4	2	5	3	5	2004
5	2	4	4	5	2	1	1	3	1987

For input into NETICA, the tables were re-coded further to correspond to the variable states defined at each of the nodes. This is shown in Table 5.4.

Table 5.4: Sample table for input into NETICA (Showing only members in group 1)

IDnum	Grp	Status in Village	Rainfall	Land Use Restrictions	Land Policy	Forestry Policy	Income
1	1	Comm_Member	Increased	Yes	Yes	No	Insufficient
2	1	Ordinary_Mem	Increased	No	Yes	Yes	Insufficient
3	1	Comm_Member	Unchanged	No	Yes	Yes	Insufficient
6	1	Ordinary_Mem	Increased	No	Yes	Yes	Insufficient
7	1	Comm_Member	Increased	No	Yes	Yes	Insufficient
13	1	Comm_Member	Unchanged	No	No	Yes	Insufficient

The variables used in the development of the BN were all based on the coded categorical data obtained from the questionnaire interview. For measures of distance, respondents were given sample distances to places they were familiar with in order to obtain the categories Far, Near and Very Near. The estimated distances were measured using the odometer of the van the researcher was using. This approach has not been used elsewhere but was made necessary since the distance measures would have had no consistent meaning. The distance estimates were as follows:

Very Near (VN): upto 500m

Near (N): between 500m and 1km

Far (F): more than 1km

As for rainfall, the indicators of change in rainfall were taken to mean the following:

- **Increased – an increase in rainfall over a 10 year period**
- **Unchanged – no change in rainfall over a 10 year period**
- **Decreased – a decrease in rainfall over a 10 year period.**

These measures were necessary to maintain consistency of meaning from one respondent to the next by giving them a system of reference.

5.5 Personal interviews

To supplement the data collected using the questionnaire, personal interviews were chosen as a complementary method for the institutional stakeholder category of respondents. A tentative list of informants was constructed to determine the list of those to be interviewed. These were drawn from the local authority and central government as well as from Non-governmental organisations (NGOs) working with the local stakeholders in the area. Not all members of the list responded positively. The researcher asked the respondents who agreed to meet him, to recommend other subjects who could be interviewed. This is a process known as the snowballing technique identified by Black (1993).

At the beginning of each interview, after formal introductions, the informants were briefed about the research, its objectives and issues to be discussed. They were informed about the objectives of the interview and the reason for seeking their views (Kitchin & Tate, 2000). They were assured of confidentiality of all information delivered by them and that the data obtained were to be used solely for research purposes. The interviews used a mix of the structured open ended technique and the interview guide approach (Kitchin & Tate, 2000). The interviews did have a prescribed set of questions to follow, but the sequence and wording of questions were changed to avoid the setting in of disinterest. Some questions were eliminated if it was found they were not relevant to the informant. The interviews covered the main topics of interest and generally lasted for about 30 minutes. The proceedings were recorded on audio tape and transcribed later. This is one of the techniques identified by Kitchin & Tate (2000) that could be used to record the interviews. The others are note taking and video recording. Audio recording was found to be most suitable as note taking could not offer the detail offered by audio recording because of the speed with which respondents spoke (Valentine, 1997). In all cases, consent was obtained from interviewees before being taped. In total, three personal interviews were conducted.

5.6 Group meetings

This was the preferred method to supplement the questionnaire data collection process for the local stakeholder interviews. These were held with the intention of encouraging debate amongst the local stakeholders on what was perceived to be a problem in their environment and for them to suggest a solution to the perceived problem.

Fontana & Grey (2005) do not recommend this method for interviewing beginners like the researcher because of the need for very high interviewing skills and the prevalent problem of finding a suitable time and place for all those who are willing to participate in the interview. However, this was the only way that was feasible to the researcher as this paved the way for the application of SSM. A notification of the meeting was agreed with the relevant village leader well in advance and they would generally mobilise their colleagues. However, not all appointments were successful as some village leaders were not interested and so access to their areas was not possible without their permission.

In this investigation, the researcher guided the proceedings of the meeting by presenting a problem to the meeting to stimulate discussion for the identification of the problem situation by local stakeholders themselves. They were then divided into discussion groups and the views of each group were later presented and a debate followed after which a synthesis of views charting the way forward was put together. The synthesised views would serve as input for the development of conceptual models later. The proceedings of the meetings were captured on audiotape and then transcribed later.

Two meetings were arranged in the Maposa study area and one meeting was organised in the Kalulushi study area. The group meetings were open to all stakeholders available to attend from within a range of selected villages in the area. They were encouraged to freely debate issues and to facilitate this, village leaders were encouraged not to lead the discussion groups and instead the groups nominated someone else to lead. All data collected at group meetings did not have any coordinate information attached to it.

The meetings were arranged after the completion of the questionnaire administration phase. The administration of the questionnaire helped to prepare the local stakeholders for the meetings in a way because by the time they came for the meeting they would have engaged with the issues to be debated.

5.7 Development of the digital spatial database

Spatial data were collected in the study areas to allow for the creation of a digital spatial database that would be used for the subsequent modelling to help identify areas most likely to be susceptible to the risk of degradation. Spatial data collection involved the collection of GPS data for field survey points, and the acquisition of satellite images, aerial photographs, maps and other GIS data for the Copperbelt province relevant to the study. This would form the base layer on which any spatial analysis would be incorporated. The next stage will now look at the pre-processing of data for digital images.

5.7.1 Satellite image processing

Two Landsat scenes covering Path 172 and Row 69 in the World Reference System were downloaded from the Centre for Global Change and Earth Observations at Michigan University. A third image covering the same scene from an intermediate date was ordered from the Satellite Applications Centre (SAC) in South Africa. The scene from the SAC was a Landsat 5TM image acquired on 02/05/1995 while the others, are a Landsat 5TM image acquired on 02/06/1989 and a Landsat 7ETM image acquired on 13/05/2002.

The images were selected so that they cover, approximately, the same month in the year. Two images were acquired in May while one was acquired in June. This is the cool dry season after the rains when the harvests have been collected after drying the crops in the fields.

5.7.2 Radiometric, atmospheric and geometric corrections

The images have to be corrected for atmospheric, radiometric and geometric errors before any measurements or interpretation can be made from them (Lillesand et al., 2004; Mather, 2004). Correction for radiometric and atmospheric errors requires the conversion of the digital numbers (DN) of the image pixels to radiance values and then finally to reflectance values. The reflectance values are what the sensors actually measure in space. The corrections were done using ERDAS Imagine software using the following formulae and the results are in Appendix D:

Radiance calculation (DN number to Radiance)

The spectral radiance is given by

$$L_\lambda = \left[\frac{Lmax_\lambda - Lmin_\lambda}{Q_{cal_{max}}}\right] Q_{cal} + Lmin_\lambda \qquad 5.1$$

where

$Lmax_\lambda$ = DN 255 (Spectral radiance scaled to Q_{calmax})

$Lmin_\lambda$ = DN 0 (Spectral radiance scaled to Q_{calmin})

$Q_{cal_{max}}$ = Maximum quantized calibrated pixel value

Q_{cal} = DN quantized calibrated pixel value

Reflectance calculation (Radiance to Reflectance)

Planetary reflectance

$$\rho_P = \frac{\pi L_\lambda d^2}{ESUN_\lambda \cos\theta_s} \qquad 5.2$$

where

ρ_P - unitless planetary reflectance

L_λ - spectral radiance at sensor aperture

d - earth – sun distance in astronomical units

θ_s - solar zenith angle in degrees

The reflectance value is useful for comparison of multi-temporal images with different solar zenith angles and possibly irradiance inputs (Mather, 2004). Equations 5.1 and 5.2 are then applied on all the spectral bands except the thermal band for each image to give a new raster image with reflectance values.

The geometric corrections were then applied using the corrected GPS points and the images were ready for use in classification and interpretation. The corrected images over the Maposa local forest showing the forest boundary, streams and roads are depicted in Figures 5.1, 5.2 and 5.3(a) showing the progressive change in land cover. The GPS survey points shown in Figure 5.3(b) are overlayed on the image from 2002 of the Maposa forest.

Figure 5.4 illustrates the position of transects derived from the field study area. A photo-mosaic of the area was constructed from a set of aerial photos obtained from another survey taken in June 1993 to depict the extent of clearance in the forest area. The aerial photos were used for the identification of features on the ground. The photo-mosaic is depicted in Figure 5.5. It was constructed using the LEICA Photogrammetric Suite, LPS.

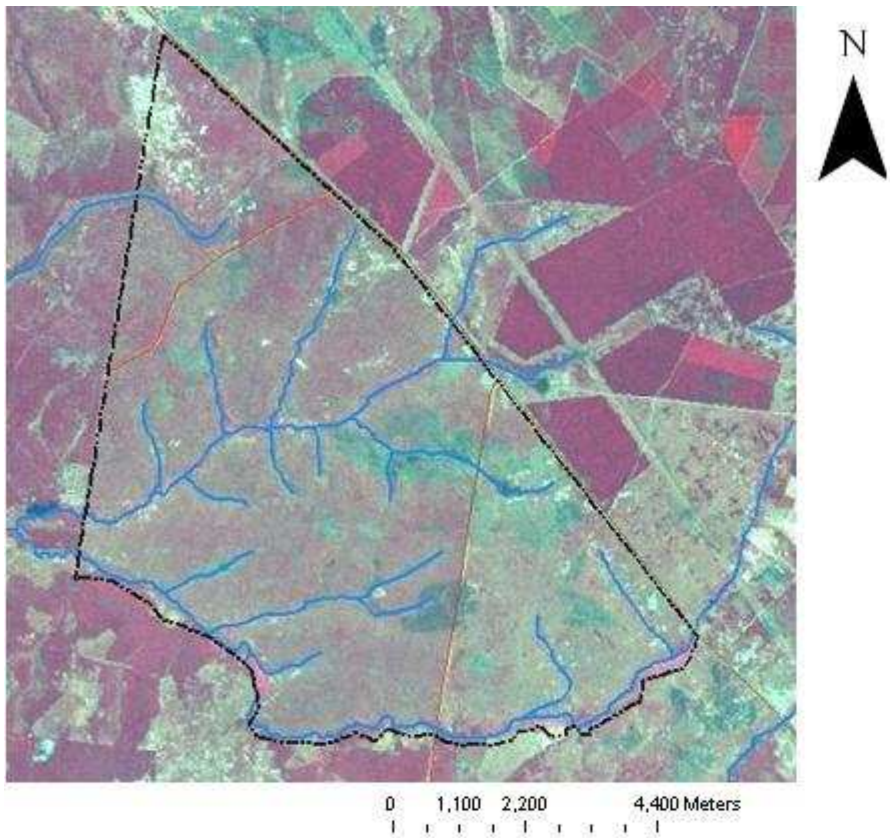

Figure 5.1: Maposa local forest 1989. The area enclosed in the boundary depicts relatively undisturbed natural forest vegetation. The dark areas in the top right of the image represent commercial Eucalyptus plantations.

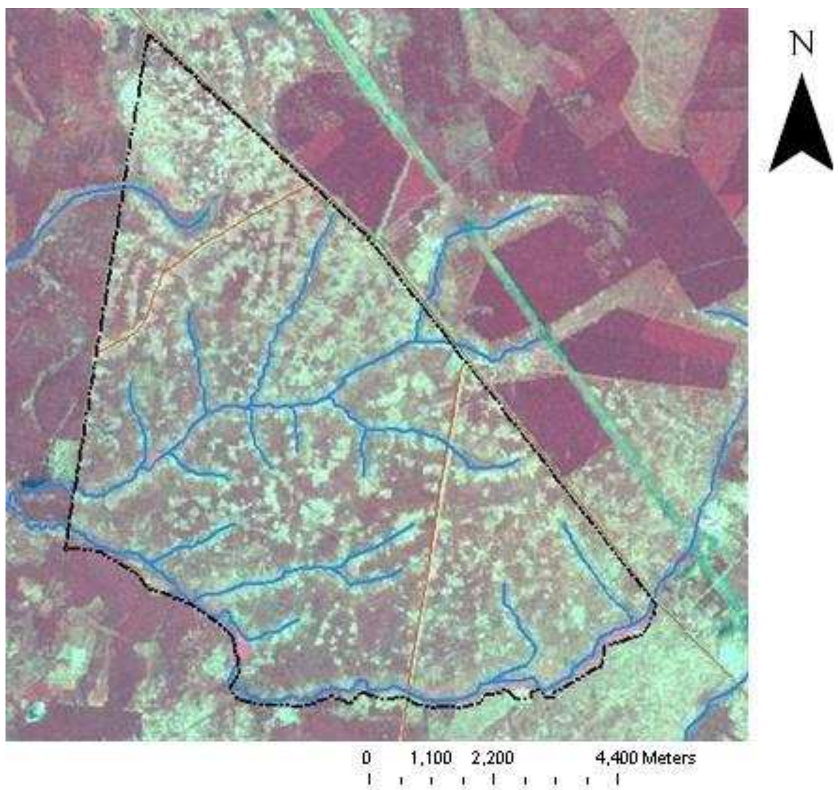

Figure 5.2: Maposa local forest 1995. Lighter patches represent forest clearance.

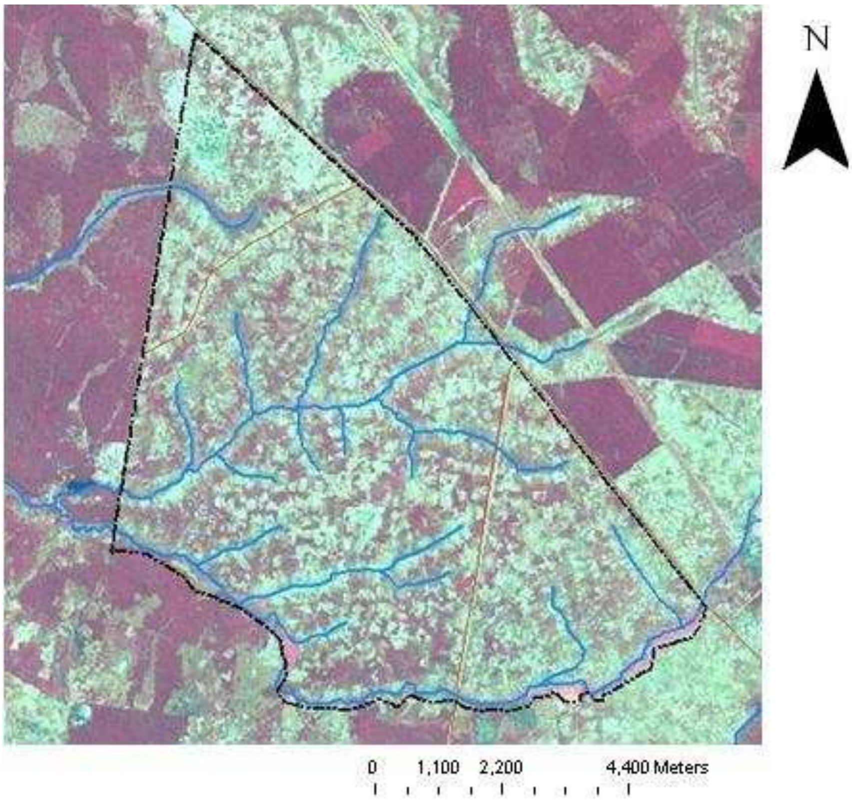

Figure 5.3(a): Maposa local forest 2002. Intensification of forest clearance.

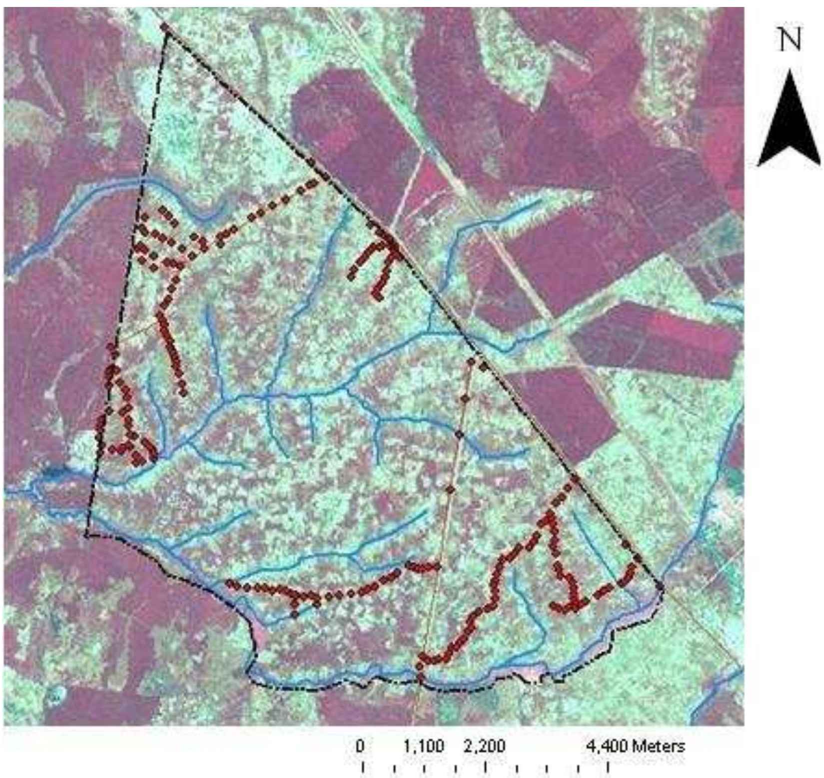

Figure 5.3(b): Maposa local forest 2002 showing GPS survey points

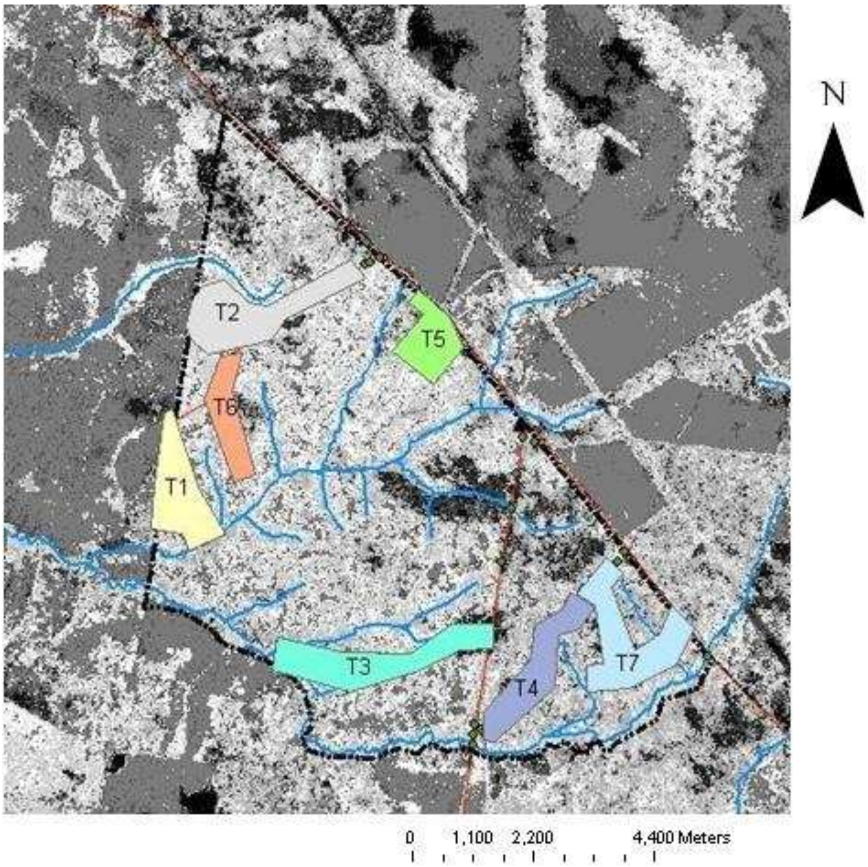

Figure 5.4: Transects showing areas surveyed in the Maposa forest area. The shapes labelled T1 to T7 show the areas where questionnaires were administered in the Maposa Local Forest.

5.8 Development of BN and Decision Tree models

The process of developing the BN model preceded analysis of the model behaviour. This was done before comparison with the Decision Tree and SSM models. This is discussed in detail in Chapter 7.

The modelling and testing of the decision tree is discussed extensively in Chapter 9. The resulting Decision Tree model of the decision-making process was used for comparison with the BN and SSM models.

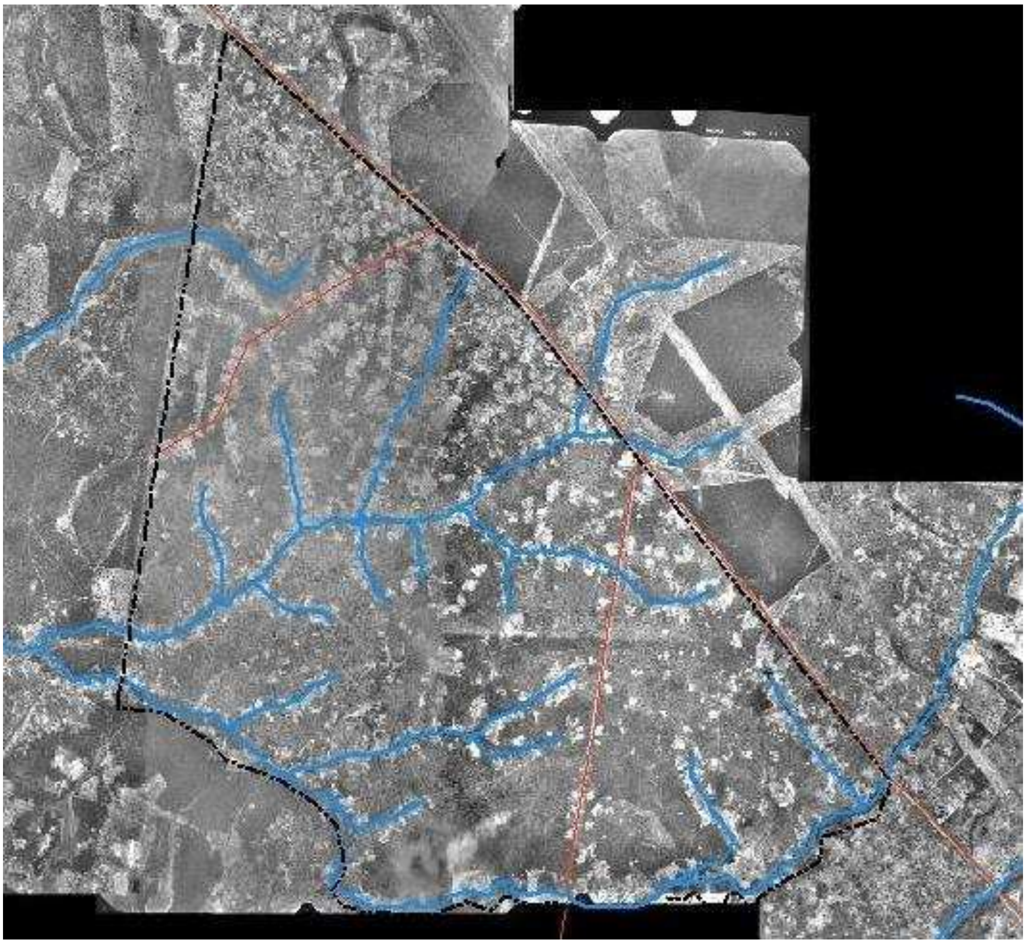

Figure 5.5: Photo-mosaic of Maposa local forest in June 1993 with river and road overlay from GIS.

5.9 Summary

The chapter has outlined the methodology that was undertaken in the research and the techniques employed. The challenges and limitations encountered during the field work were also outlined in the chapter.

Chapter 6: Soft Systems Methodology and land-use decision-making

6.1 Introduction

This chapter looks at the theory and application of Soft Systems Methodology (SSM) in the development of a conceptual model to help understand land-use decision-making in the encroached protected forest areas Copperbelt Province of Zambia. The chapter addresses the stages involved in the development of the conceptual model and then use the information collected to develop a conceptual model in the context of the situation in the protected forests in the Copperbelt Province.

6.2 Soft systems methodology

Human requirements and capabilities determine land use. To model how land use changes, requires information that clarifies the human decision-making process (Bacon et al., 2002). With growing awareness of the environmental consequences of changes in land management, it is necessary to model changes in land use that reflect the complex relationships between policy, land-management and environmental processes (Bacon et al., 2002). To help address the complex process of land use decision-making, an approach, which includes stakeholders and is participatory and iterative, was identified for application in the research. This is the Soft Systems Methodology (SSM). It has its roots in Systems Analysis and Systems Engineering (Bergvall-Kareborn et al, 2004; Checkland & Scholes, 1999; Wilson, 2001)

The main use of SSM is to analyse highly complex and messy areas of real world activity by deriving useful models of purposeful activity in any system to help structure that complexity. This technique places special emphasis on people's perceptions, together with their experience and knowledge. According to Checkland & Scholes (1999) and Wilson (2001), SSM focuses on the following:

- representation of divergent views about the definition of the problem;
- encapsulation of problems that originate from poorly defined situations;
- resolving complex unstructured problems.

In addition, SSM supports the identification of issues from which alternative solutions that can improve the systems functionality can be made. The models that are developed are not descriptions of reality but are descriptions of ways of thinking about reality (Checkland & Scholes, 1999; Wilson, 2001). This means that the models developed are actually concepts or intellectual constructs (Wilson, 2001). This therefore requires the use of a modelling language to describe the constructs. This is achieved by applying the sophistication of the English language. By using verbs in the imperative, the constructs can be represented in the form of an instruction to do something. Therefore, SSM models represent a description of what has to be done as a set of interlinked instructions to achieve some prescribed purpose. Defining the purpose is therefore an important stage in the SSM process.

6.3 Basic principles of SSM

The soft systems approach was developed as a technique to manage the human aspects of organisational systems (Mejia, 2003). Soft systems thinking should be regarded as a contribution to problem solving rather than a goal oriented methodology (Clayton & Radcliffe, 1996). It is well suited to ill-structured problems and is considered to be a methodology for analysing and modelling complex systems that integrate technology and human groups. The SSM process also involves another important stage of identifying stakeholders. SSM is defined by Checkland & Scholes (1999: 28) who cite von Bulow (1989) as follows:

"SSM is a methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never-ending. The learning takes place through the iterative process of using systems concepts to reflect upon and debate perceptions of the real world, and again reflecting on the happenings using systems concepts. The reflection and debate is structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problem situation rather than as accounts of it. It is taken as a given that no objective and complete account of a problem situation can *be provided."*

SSM is a process of enquiry and utilises a seven stage process (Bergvall-Kareborn et al, 2004; Checkland & Scholes, 1999; Clayton & Radcliffe, 1996; Wilson, 2001) which can be represented as shown in Figure 6.1 and tabulated in Table 6.1.

Stages 1 and 2 represent the identification and representation of the problem situation in terms of a 'Rich Picture'. This is a representation of the problem situation typically in the form of an abstract drawing showing all current processes and key people relevant to the system.

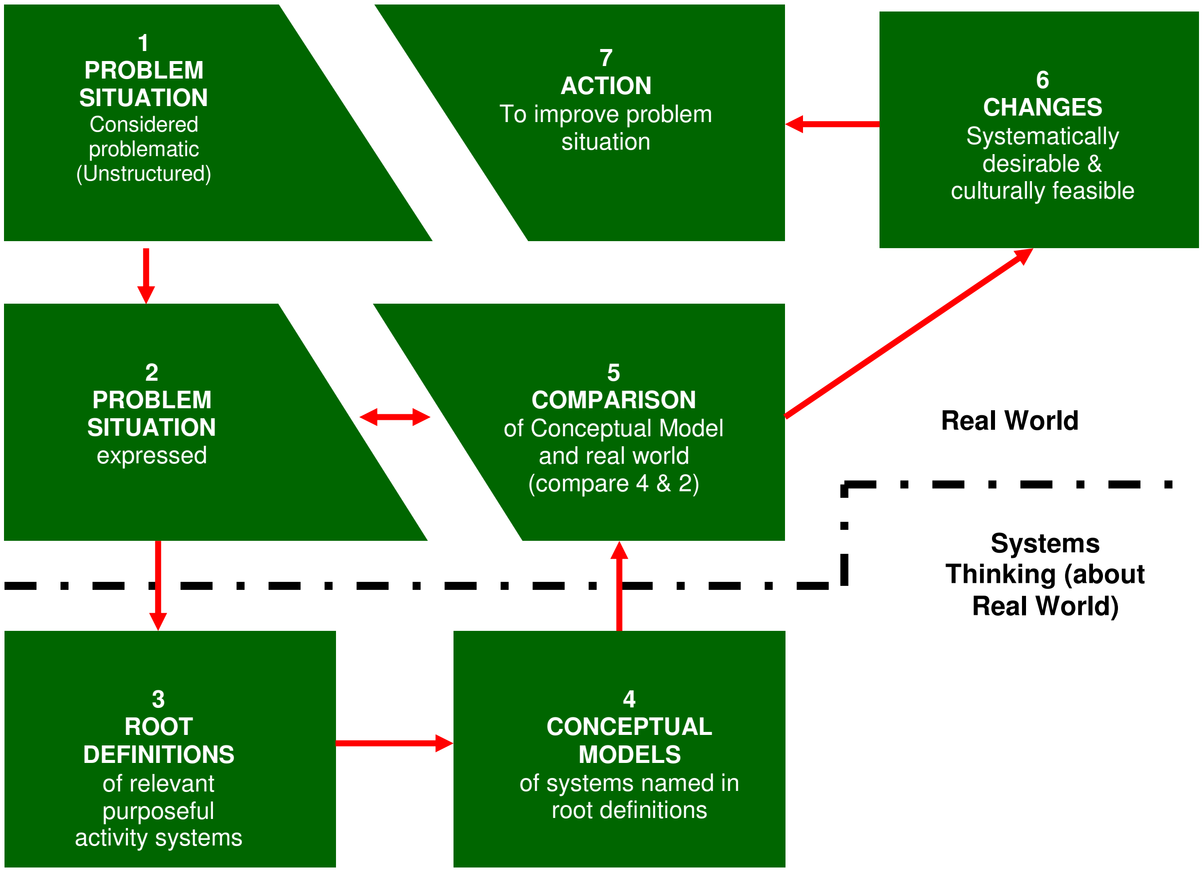

Figure 6.1: The seven stages of SSM enquiry (Checkland & Scholes, 1999)

Stage 3 involves the development of root definitions. This is the setting out of definitions of primary tasks and issues leading to a formal definition of relevant systems that are to be focused on and refined as Root Definitions (RD). The RD is a definition of the purpose of the model. It describes a transformation process, T, whose purpose will have been achieved when the input is transformed into an output. It is the process rather than the input and output that are being described. It requires rules to formulate a precise RD. For a transformation process to be properly formulated, its output and input must be of the same kind i.e. abstract to abstract or physical to physical.

The basic ‘building block’ of the intellectual constructs used in SSM analysis is the root definition/conceptual model assembly (Wilson, 2001). The RD captures the purpose, taken to be relevant, and the Conceptual Model (CM) represents those activities that must take place to achieve the purpose. This is encapsulated in Stage 4 of the process in the construction of the CM from the RD.

The next stage, Stage 5, is the comparison of the conceptual model with formal systems, other systems thinking perspectives and with the real world from which suggestions for change can be established. Once the model has been modified in accordance with the desirable changes in Stage 6, it is then put into action in the final stage (Stage 7) to improve the problem situation. This process lends itself well to the participatory approach of the inclusion of local stakeholders in land use decision-making for sustainable environmental management.

After reviewing the use of soft systems in several sectors, Checkland & Scholes (1999) emphasised that SSM is system thinking based, and that the process of enquiry is the system itself. SSM has not been widely used in spatial decision participatory applications. However, the application of SSM in environmental management is illustrated in a study to combine soft systems and spatial decision support system concepts in the participatory development of an environmental management plan for the highly polluted Cooum River in India (Bunch & Dudycha, 2004).

6.4 The background to the situation in the encroached forest areas of the Copperbelt province

This section provides a brief background of the process that was carried out in the study area to apply the SSM concept. It describes the procedures that were adopted and a summary of the views and perceptions of the various stakeholders involved in the approach to land use decision-making. The stakeholders were divided into 2 main categories: institutional stakeholders and local stakeholders.

Table 6.1: The seven stages of SSM and their description

Stage	Name	Description
1	**Problem Situation**	Reviewing the unstructured problem
2	**Rich Picture**	Clarifying and expressing the problem situation
3	**Root Definition**	Defining the relevant systems and sub-systems, whether these are formal or informal
4	**Conceptual Model**	Building conceptual models, scenarios and analogies
5	**Comparison**	Comparison of conceptual model and real world models with the expressed situation
6	**Changes**	Identifying such changes as are currently both feasible and desirable
7	**Action**	Suggestions of action to take to improve the problem situation

Group meetings open to all stakeholders were arranged in conjunction with the village leaders for facilitated discussions in the villages in the forests. Government officials and NGOs working in the encroached forest areas were invited to participate. For the pilot study area of Chamwanza village in the Chibuluma National Forest in Kalulushi only the village committee attended. There were no NGOs working in the area and the interview with the Kalulushi District Council Planning Officer was the only one conducted with an institutional stakeholder in Kalulushi District.

This process was replicated for the Maposa forest area but the institutional stakeholders did not attend the meetings held at Natwange and Kabulanda villages in the Maposa Local Forest. This presented a problem for the participatory application of SSM techniques. A modified approach was to combine the outcomes of the local stakeholder meetings with views of government officials and NGOs collected using personal interviews.

The views of all the institutional stakeholders interviewed in the Province were summarised and tabulated. Similarly, the facilitated discussions at the group meetings with local stakeholders in both the Maposa and Chibuluma Forests to draw out important themes were also summarised and tabulated.

6.4.1 Institutional stakeholder interview summaries

The general approach used to conduct the interviews was to follow a structured interview with preset questions. Three institutional stakeholders were interviewed in the province. The interviews were conducted at each stakeholder's respective office. The summarised interviews are in Appendix B. The views of all the institutional stakeholders interviewed in the Province are summarised in Table 6.2.

6.4.2 Local stakeholder summaries

Three local stakeholder meetings were held during the research. The first meeting was in the Chamwanza branch of the Chibuluma National Forest in Kalulushi District in November 2004. The second and third meetings were held in the Twashuka and Kabulanda branches of the Maposa Local Forest in October 2005. These meetings were all follow ups to the questionnaire survey carried out earlier in the local branch within the respective forest reserves. The general procedure adopted for the local stakeholder meetings in the villages was to arrange for a meeting through a local branch Chairman who would inform the local villagers in his constituency of the time and place of the meeting.

At each meeting, the researcher was introduced by the local branch Chairman, and invited to explain the purpose of the meeting to the villagers. The purpose was generally explained as being the identification of problems the local community was facing, if any, in using the land and for the meeting to discuss and arrive at possible solutions. The researcher presented two satellite images of the forest reserve and adjoining areas dated 1989 and 2000 respectively, showing the change in land cover that had occurred during the period for the meeting to consider.

Table 6.2: Summary of institutional stakeholder views

Institution	Type	Comments
1. Copperbelt Province Provincial Forestry Office	Central Government	i. Mandate to protect and manage forests, rehabilitate degenerated areas and achieve at least 15% of total forest cover ii. Illegal settlement in forests biggest threat to management. Attributed encroachment to job losses in mines in the province. iii. Unable to engage in JFM for sustainable management of resources due to non-implementation of new Forestry Act. iv. Lack of accurate information about forest resources within Ministry of Environment. v. Need strong political will from Executive and cooperation of other stakeholders to achieve sustainable management of forests. This requires resettlement of local stakeholders encroaching in forests.
2. Kalulushi District Council	Local Government	i. Concerned about general environmental degradation of protected areas in the province due to encroachment. ii. Exercise to demarcate and allocate degraded forest land being carried out in two pilot areas. iii. Criteria for re-distribution of land not yet established. iv. Intends to use JFM for sustainable production of charcoal. v. Of the view that environmental problem has now become a social problem because of demands for amenities and services by settlers.
3. Bridge International	NGO	i. Engaged in advocacy role about land rights with local communities. ii. Observed that local communities mainly from charcoal producing background now engaged in subsistence agriculture. iii. Noted that local communities do not relate their actions to effects on the environment. iv. Concerned about land distribution process by Government not being transparent. v. Had no input in the development of government policy or legislation. Only involved with the implementation of existing policies. vi. All stakeholders need to work together to help local communities be empowered with land and help them to adopt sustainable agricultural practices.

To start the discussion, the researcher asked the meeting to imagine what the area would look like in 10 years time if the current use of land continued. A discussion on the various land use issues would follow and the meeting would then split into two groups for group deliberations. After discussion both groups presented a summary of their discussions and these would then be merged later by further discussion before the close of the meeting.

The summary of all the facilitated discussions at the group meetings with the local stakeholders in both the Maposa and Chibuluma Forests drew out important themes and led to the resolutions summarised in Table 6.3.

The resolutions of the local stakeholders point to the fact that local stakeholders are concerned with the current usage of the land and that they would like to change that by employing various methods to improve their agricultural output. They are also eager to minimise the degradation of the forest by stopping the indiscriminate cutting of trees on their landholdings. A key concern of the local stakeholders is the issue of land ownership. Tenure security kept cropping up throughout the discussions. It appears in the resolutions as a resolution to improve the state of the environment should the land be given to them. This confirms their anxieties about the threat of being evicted from the land.

The divergent views expressed by the various stakeholders make the situation an ideal candidate for analysis using SSM. The next section will investigate the application of SSM to address the situation in the encroached protected forests in the Copperbelt Province.

Table 6.3: Summary of local stakeholder views

Name	Location	Comments
1. Chamwanza branch	Chibuluma National Forest, Kalulushi District	i. Concerned at lack of secure tenure to land. Want government recognition of settlement and title to land. ii. Access to water is a problem. Need communal wells or boreholes with taps provided by government. iii. Access to firewood is a problem. Members proposed to plant trees, uproot tree stumps in fields, and also want electrification of the area. iv. Village committee unable to advise local members on how to use land. v. Want provision of social amenities and agricultural extension services. vi. Members were able to draw map of area and showed areas affected by problems cited.
2. Natwange / Twashuka branches	Maposa Local Forest, Luanshya District.	i. Members anxious about tenure security. Need title to land. Members unable to draw map of area. ii. Felt that charcoal production should only be allowed when clearing land for agriculture and not for commercial use. iii. Members proposed land-use strategies to improve their use of forest resources.
3. Kabulanda / Kosapo / Zambezi branches	Maposa Local Forest, Luanshya District.	i. Members were suspicious of aims of the meeting and were worried about being evicted from land. They were anxious about tenure security and insisted that they had been given the land by the local MP. Just needed title to land. (Demarcation surveys taking place at the time had unsettled them). ii. Members disagreed over cultivation along banks of streams and the practice of diverting parts of streams by some villagers. iii. Members unable to draw map of area to show extent of problems cited. iv. Members also proposed land-use strategies to improve their use of forest resources

6.5 The application stages of SSM in the Copperbelt Province protected forests

The following sections demonstrate the application of all seven stages of SSM to the Maposa Forest and Chibuluma Forest encroachment and land use situation. Each section describes the activities that characterise the relevant SSM step together with results from the analysis. The use of SSM to define a problem situation is akin to the third step identified by Marakas (2003) in the five step decision-making process. The participatory application of SSM will be used in the research project to define the problem situation necessary for the development of a conceptual model required in the modelling of the land-use decision-making processes.

6.5.1 Stage 1: Identification of the problem situation

The aim of this initial section is to review the existing situation for the system under consideration to help recognise and explore the problem situation. Relevant literature discussing land-use management and issues related to the encroachment of protected forest areas is reviewed to gain insight into the system. There is a need to understand the difficulties and challenges involved in land-use decision making

The situation in the protected forest areas in the Copperbelt Province of Zambia has been described in detail in Section 4.4 of this thesis. The forest areas have suffered severe encroachment and this has been attributed to a poor economic environment and the shortage of urban land (Palmer, 2001). These areas are not in the control of local chiefs, they are in the charge of the Minister of Natural Resources and are governed by the Forest Act of 1973 based on the Forest Policy of 1965. The new Forest Policy and Act of 1998 though ratified by parliament are yet to be implemented.

Initial settlement into the forest areas was by invitation from the Forestry Department who licensed them for specific periods of time to thin the forests and prevent them from catching fire in the hot dry seasons. Licence holders were allowed to produce charcoal for sale from the thinning of the forests. However, many of them resorted to small scale agriculture and settled permanently after expiry of their licences. This set them on a collision course with the government as it was against existing policy and regulations. The settlers instead sought political help to ensure their continued occupancy of the forest reserve areas by forming local branches of the ruling party thus guaranteeing election votes to the ruling party.

This gave rise to a situation where the illegal settlers have increased in number thus accelerating the degradation of the forest reserve areas. They have also demanded for the provision of social amenities such as schools and hospitals in return for their votes from the local councils but this has not been forthcoming.

The resulting situation is a complex stand-off between the government on one hand who are unable to remove them from the forests and are also unable to provide amenities in the forest reserves, and local stakeholders encroached in the forest areas considered illegal by the state and the government departments entrusted with protecting the same areas. An appropriate land-use decision making process has to be developed and in so doing, the government has to weigh the demands of managing the protected areas sustainably with the costs of allowing settlers who have encroached to continue occupying and using the land in an uncontrolled manner.

6.5.2 Stage 2: The problem situation expressed

This stage will express the problem situation identified in the preceding section in the form of a rich picture. The main function of the rich picture is to capture and organise all the main components of the system and their relationships in a graphical representation similar to a cartoon (Monk & Howard, 1998). A rich picture identifies all stakeholders, their concerns and some of the structure underlying their relationships. There are three main components of a rich picture: structure, process and concerns (Monk & Howard, 1998).

Structure refers to aspects that do not change or change slowly such as organisational hierarchy, geographic localities and most importantly all the people who will use or could be affected by the system. Process refers to the transformations that might occur in the activities outlined. These might be the flow of goods, data or services. Concerns capture more clearly the motivations of individuals for using the system. These give rise to the different perspectives each individual has in the rich picture and are represented in the form of thought bubbles. Concerns are also known as 'issues' (Checkland & Scholes, 1999). To add to the visual understanding of the rich picture, tensions between stakeholders are shown as crossed swords (Monk & Howard, 1998).

Using the information in Tables 6.1 and 6.2 and the discussions in Appendix B, a rich picture of the problem situation was developed and is depicted in Figure 6.2. A RD of the system under consideration was later extracted from the rich picture.

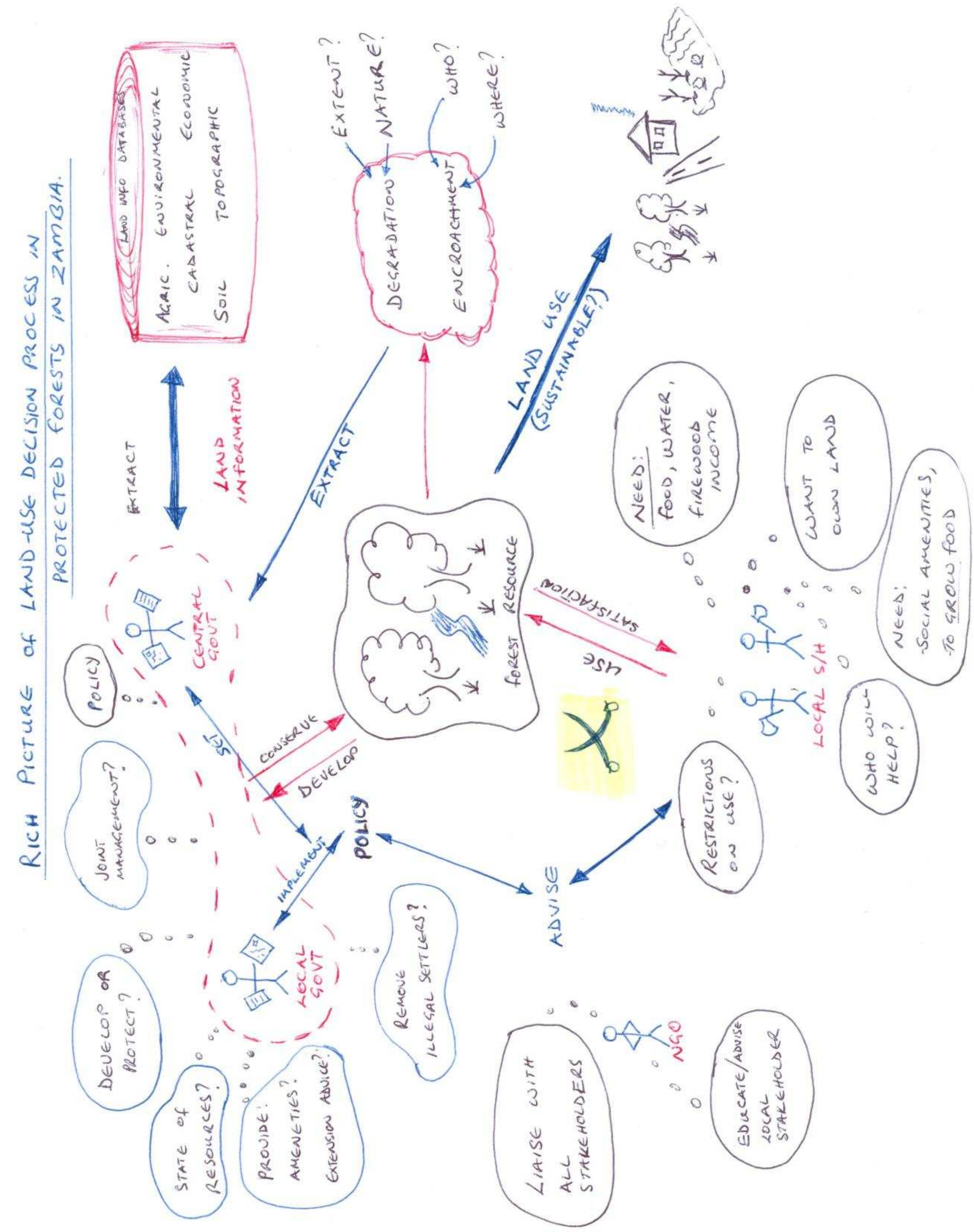

Figure 6.2: Rich picture of land-use decision-making process

The rich picture depicted in Figure 6.2 shows the main aspects that affect the exploitation of resources. These are broadly characterised by the main issues raised by local stakeholders such as title to land, access to water and firewood and the concerns of institutional stakeholders which are also represented largely as interventions in the exploitation of the resources.

6.5.3 Stage 3: The root definition

The main aspect of a RD is the transformation process that takes some function as input and changes that function to produce a different entity or modified form of the function as an output. The RD essentially consists of a short paragraph in which the stakeholders express the 'world view' and emergent properties of the system. Contrasting the stated purpose against a checklist of problem or goal definitions, the mnemonic CATWOE, facilitates the construction of the RD (Checkland & Scholes, 1999). It is argued by Clayton & Radcliffe (1996) that most human system structures are ultimately embodiments of beliefs and perceptions. It is the need to define human systems in human terms that the six elements of CATWOE were designed to support (Checkland & Scholes, 1999).

CATWOE was developed to test the RD and is a test of the structure and words chosen in the RD. If used properly, CATWOE provides a mechanism for testing the RD and ensures that the words chosen are as precise as possible and that they represent the best choice for the meaning captured by them (Wilson, 2001). They should be explicitly described as part of the root definition. The elements of CATWOE are therefore described as follows:

C – Customer (Recipient of output of transformation process victim/beneficiary)

A – Actors (Individuals who would DO the activities in the resultant conceptual model if they were to map onto reality – who would do T.)

T – Transformation process (either input or output conversion or process itself)

W - Weltanschauung (worldview: statement of belief of system within RD – statement of WHAT the belief is and not WHOSE belief it is)

O – Owner (a wider-system decision taker with authority over the system defined, with a concern for the performance of the system)

E – Environmental constraints (those features external to the system defined, which are taken to be significant)

The rich picture in Figure 6.2 represents several contested views from the different groups of stakeholders. There are several potential interpretations that could result in different RDs. SSM does not attempt to define a single right method or course of action but through an iterative process defines an acceptable improved path or action (Wanyama & Zheng, 2010). It can be inferred from Figure 6.2 that the human activity of small scale agriculture was a problem relevant to the management of the Maposa Local Forest and Chibuluma National Forest areas.

The main input for transformation selected in this research as observed from Figure 6.2, is the *'requirement for sustainable land use'*. This can be linked to the views expressed by the institutional stakeholders in Table 6.2, specifically the comments in sections 1(i), 1(v), 2(i) and 3(vi). These are in line with the local stakeholder views expressed in Table 6.3 in sections 2(iii) and 3(iv).

The RD in this context for the observed problem situation is, therefore, defined as:

A system owned by the government and operated by the local authorities to ensure the sustainable exploitation of resources in protected areas which have been encroached upon while considering the views and needs of local stakeholders in consultation with N*GO's and relevant policy and legislation.*

With the help of the CATWOE mnemonic in Table 6.4, the RD is then tested and clarified. It describes the purpose as the management of the exploitation of forest resources in protected areas in a sustainable manner to control the progressive loss of forest resources within these areas while taking into account the views and needs of the inhabitants who have encroached on the forests. The expected transformation that the RD will achieve is outlined as the adoption of sustainable land use practices to achieve sustainable land use in the protected areas. The constraints governing the conditions under which the system is operating have been identified as the state of the natural resources, and the existing legislation and policies relating to forestry, ownership and use of land.

Table 6.4: CATWOE analysis of root definition

Element	Description
C	Government, local authorities, local stakeholders and general public
A	Central government, local authorities, local *stakeholders, NGO's*
T	Sustainable land use required => sustainable land use practices employed
W	Managing access to, and use of natural resources in protected areas, considering views and needs of local stakeholders
O	Central government and local authorities
E	State of protected areas (Physical conditions), existing policy and legislation

The RD identifies the government, local authorities, local stakeholders and NGO's as the actors who will perform the activities necessary to achieve the transformation in the resulting conceptual model. Finally, the beneficiaries (C) and owners (O) of the system are also identified. The next section will address the development of the conceptual model from the RD and the rich picture.

6.5.4 Stage 4: The conceptual model

The Conceptual Model (CM) is developed for the purpose of identifying the activities that must take place in order to achieve the purpose of the model taken to be relevant by the RD (Wilson, 2001). The CM developed from the RD will contain only the activities expressed through verbs in the imperative and the logical dependencies between the activities. They have the characteristics of systems and are termed Human Activity Systems (HAS) or Holons (Checkland & Scholes, 1999; Wilson, 2001). The RD and the resultant model together represent the concept (or intellectual construct).

The CM does not provide a description of a system to be engineered, instead the model puts together the minimum set of activities that would be necessary to carry out the transformation process, T, identified in the RD. The model configuration is based on the logical dependencies and these are depicted with directed arrows.

The development of a CM is based on 3 key questions related to the transformation process:

1. What needs to be done to commence the transformation process?
2. What actions are involved in the transformation process?

3. What action is required to implement the output of the transformation process?

This allows for the development of a general model with several sub-models. Each activity is represented as a specific sub-model. Each sub-model should be relevant to the system and none of them is a single representation of it. This ensures that we do not have to validate any model against the real world but have to ensure that it is structured well enough to be a model of a HAS (Wilson, 2001).

A conceptual model of the situation in the Copperbelt Province was developed from the themes outlined in the rich picture depicted in Figure 6.2 and the purpose identified in the RD. The CM is shown in Figure 6.3 and consists of 7 sub-models. The key questions for the development of the CM related to the transformation process have been addressed.

Firstly, to commence the transformation process, three activities address this issue and these are the sub-systems Gather Knowledge, Collate Land Information and Obtain Resources. The output from these activities feeds into the second tier of sub-systems. This second tier is the core decision-making process and addresses the second question of what actions are involved in the actual transformation. The activities that define this stage are Liaison with Stakeholders and the sub-system Decide. The sub-system Land Use is the final activity which answers the final key question of what must be done to implement the output of the transformation process. The output of this sub-system is also the general output of the entire model and to emphasise this it is shown in a different colour.

Additionally, to ensure overall consistency of the model, there is a need to monitor each of the activities of the model to determine the performance of the system. This is achieved by the sub-system Monitor and Evaluate which fulfils the requirement for additional control actions to guarantee the achievement of the goals defined in the root definition (Wilson, 2001). For completeness of the analysis, each of the system sub-models is further analysed in Appendix B.7 and Appendix B.8.

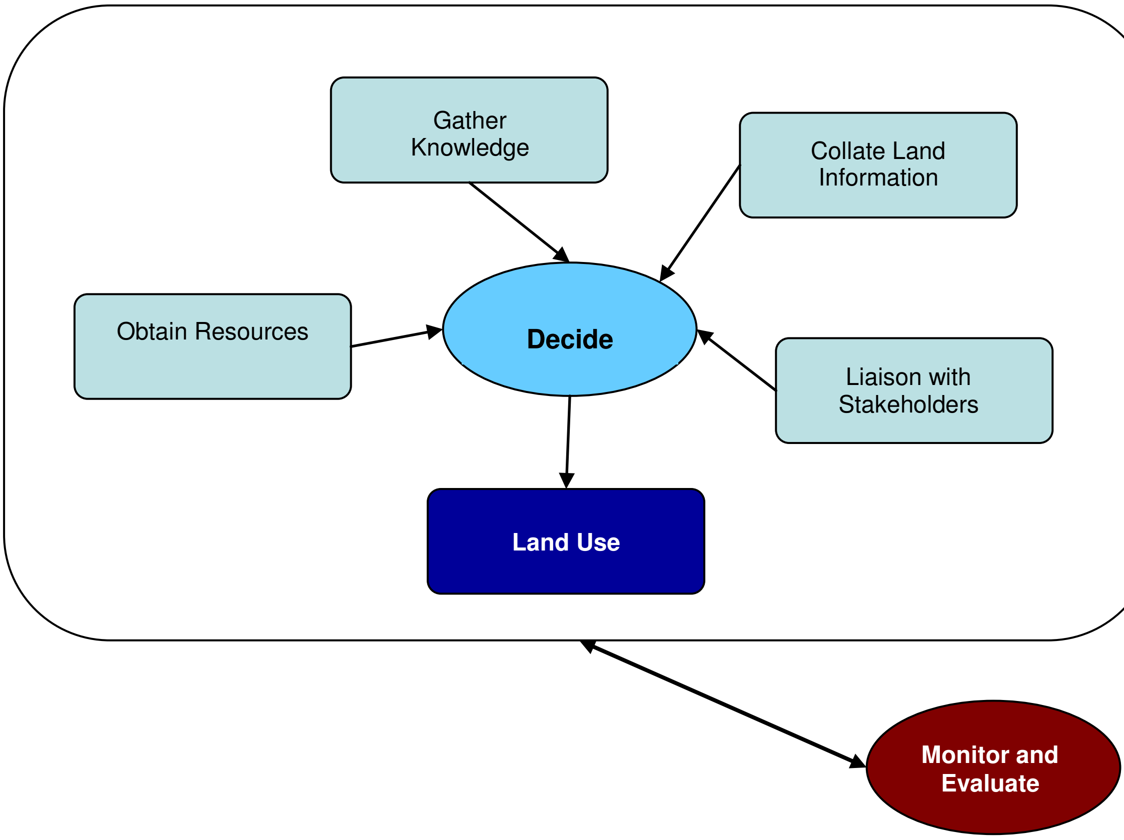

Figure 6.3: Conceptual model for implementing transformation of land use decision-making in the Copperbelt Province.

6.5.5 Stage 5: Comparison of the conceptual model and the real world

This section addresses the comparison of the conceptual model developed from the themes from the rich picture and the RD in the preceding sections. Checkland and

Scholes (1999) suggest four approaches of carrying out the comparison between the CM and the real world.

The first approach uses the CM as basis for ordered questioning of the existing problem situation. The answers to the questions are intended to provide clarity of the problems to the stakeholders. The second approach involves the reconstruction of a sequence of historical events and comparing the existing situation with what would have happened if relevant CM had been applied. This approach allows the meaning of the CM to be examined and to some extent inadequacies of the procedures. It, however, requires delicate application as it may be misinterpreted to be a judgement of participants' past and hence could be offensive to some.

The third approach makes the comparison by asking what features of the CM are especially different from the present reality and why. This arises from the fact that the development of the CM raises strategic questions about present activities rather than detailed queries about procedures.

The fourth approach of comparison is based on the development of a second model of 'what exists' and then overlaying it over the CM based on the RD. The resulting mismatch between the models provides the basis of discussion of change. Another possible outcome suggested by Checkland and Scholes (1999), is to ask of the model what RD is implied by the current system. All four methods of comparison help ensure that this stage is conscious, coherent and defensible.

The method of comparison adopted in this study is the third approach. This allowed the comparison of the CM and the reality at the time of the study. Firstly, the components of the CM were outlined followed by a check on the existence of the activity in the real world. This was then followed by an examination of how the activity was conducted and who was responsible for carrying it out. Finally, an assessment of the activity was done and an alternative suggestion of how to conduct the activity concluded the process of comparison. Table 6.5 summarises the process of comparison carried out in this study.

6.5.6 Stage 6: Changes systematically desirable and culturally feasible

This stage focuses on the identification of changes to the existing system which would lead to its improvement. The following changes to the existing land-use decision-making system in the encroached forest areas of the Copperbelt Province were identified by the analyst as possible improvements:

- The establishment of better resource assessment, requisitioning and access procedures. This could improve access to necessary resources in good time when needed. [Table 6.2: section 1(iv)]

- The establishment of a standardised form of information interchange between institutional stakeholders. This could support data and information exchange between institutional stakeholders. [Table 6.2: sections 1(iv), 1(v) and 3(vi)]

Activity	Activity exists?	How is Activity Conducted?	Who Conducts Activity?	Assessment	Alternatives
Obtain Resources	Yes	*Discussion with relevant departments, requesting and accessing financial and other resources*	*Central government and Local authority planning and technical officers*	*Not effective, requires improvement*	*Improve resource assessment; requisitioning procedures; technology for up-to-date and accessible resources*
Gather Knowledge	Yes	*Discussions, seminars,*	*Central government and Local authority planning and technical officers*	*Not effective, requires improvement*	*Improve discussion and seminar effectiveness, improve recording of and access to information and knowledge, consult experts*
Collate Land Information	Yes	*Access to land information databases in various ministries, Access to remote sensing information of study area*	*Local authority planning and technical officers*	*Not effective, requires improvement*	*Use of up-to-date databases, technology; training of technical staff; regular information updates*
Liaison with Stakeholders	Yes	*Discussion forums, seminars, workshops and regular meetings*	*Local authority planning officers*	*No formal system exists*	*Improve discussion and seminar effectiveness, improve communication with other stakeholders;*
Decide	Yes	*Information analysis, discussion meetings, satisfaction of use by stakeholders*	*Local authority planning and technical officers*	*Not effective, requires improvement*	*Use of computerised systems for decision support; training of staff; improve discussion and seminar effectiveness*
Land Use	Yes	*Implementation of advice on Land use to use land for desired purpose e.g. residential, forestry, agricultural (choice of crop)*	*Local authority planning and technical officer*	*Not in line with user requirement, needs improvement*	*Improve communication between stakeholders; to adopt best practice techniques in line with land use advice*
Monitor and Evaluate	Yes	*Monitor and evaluate extent of use, encroachment*	*Central government and Local authority planning and technical officer*	*Not effective, requires improvement*	*Identify what needs to be monitored and evaluated and how to evaluate; use computerised tools for simulation of land use; technical staff training*

Table 6.5: Comparison of land-use conceptual model with real world

- The establishment of a standard procedure of communication between all stakeholders. This could lead to improved liaison between the various stakeholders. [Table 6.2: sections 1(iv), 1(v) and 3(vi)]

- The establishment of a knowledge base of information related to previous decisions concerning land-use. This could facilitate training of officers and also help in the identification of similar problems much faster. [Table 6.2: sections 1(iv), 1(v), 2(i), 2(ii), 2(iii), 3(ii), 3(iii) and 3(iv)]

- Investment in state-of-the-art tools for simulation to be used for training of staff and for the evaluation of different scenarios. This could help stakeholders prepare for different situations through simulation exercises and extension services based on the outcomes. [Appendix B.1, Table 6.2: section 1(iv),]

- The application of state-of-the-art technology for the collection, storage and analysis of locally and remotely stored information. This could lead to better decision support for stakeholders. [Table 6.2: sections 1(iv), 1(v), 2(ii), 2(iii), and 3(iv)]

- Development of locally accepted monitoring and evaluation procedures. This could be helpful for effective monitoring [Table 6.2: sections 1(i), 1(v), 2(i), and 3(vi)]

6.5.7 Stage 7: Action to improve problem situation

The final stage of SSM aims to identify actions that need to be taken by assessing the feasibility and desirability of the suggested changes. Before any of the changes proposed in Stage 6 can be implemented to the existing system, they need to be carefully evaluated by the stakeholders of the system. This requires discussion with all stakeholders. This is an important final stage of the SSM process. However, given that a modified approach was used to apply SSM, an evaluation was not conducted with the stakeholders in order to determine the actions to implement to improve the problem situation.

For completeness of the SSM analysis, some of the considerations against which the proposed changes could be evaluated against for implementation to improve the land-use decision-making system operating in the Copperbelt Province are listed below:

- the benefits that the expected changes bring to the existing system;
- the quality of and accuracy of results related to the use of suggested tools and procedures;
- the cost and extent of training for technical and planning staff in the local and central government and other stakeholders;
- the cost of state-of-the-art technology (hardware and associated software)

The outlined list is not exhaustive but covers some of the vital elements that need to be included in a final assessment for implementation. It is limited to knowledge gained during the analysis of the land-use decision-making system operating in the Copperbelt Province. Clearly more research needs to be done in order to achieve a model with wider application resulting from a deeper understanding of the system.

6.6 Limitations of SSM

Despite its numerous applications, some critics of SSM have argued that it is not robust enough and that it requires to be improved. They have specifically focussed on the CATWOE which is quite central to SSM. Mingers (1992) argues that a theoretical framework, which both relates the different elements of CATWOE to each other and explains their role and importance would be beneficial to the user. This view is supported by Bergvall-Kareborn et al (2004). They, however, caution that CATWOE helps modellers relate the elements to a context thus making modelling consistent and useful. It is, however, generally agreed that definitions of the elements needs to be broadened in order to reduce ambiguities that may arise due to confusion in their meaning in everyday language and improve their application in modelling (Bergvall-Kareborn et al, 2004; Jayaratna, 1994; Mingers, 1992; Mirijamdotter, 1998; Wilson, 2001).

6.7 Discussion

The SSM analysis conducted in this chapter has revealed the complex nature of the issues and problems embedded in the land-use decision-making system under investigation. The resulting CM obtained for the system was a generalised one that incorporated all the elements from the various stakeholders. The CM developed is an ideal model that addresses the problem situation mainly from an institutional perspective. It does not give particular emphasis to any stakeholder grouping. The model assumes uniform actions from the local stakeholders who are the people who have a direct impact on the resources in the protected areas. It is not a straightforward procedure to model the individual perspectives of local stakeholders using SSM especially given the limitations of the SSM exercise conducted in the study area.

It can be seen from the rich picture in Figure 6.2, that local stakeholders derive satisfaction from the exploitation of resources in the protected areas. Using the same transformation process, T, as that used in the CM in section 6.5.4, the CM for the individual perspective might be as shown in Figure 6.4.

This CM in Figure 6.4 is a simplification of how local stakeholders can affect the management of the environment. The sub-systems of the model are 'current land use', *'current production'*, *'interventions'*, *'satisfaction'* and *'future use'*. The model addresses concerns with the current land use, the current crop production, and takes into account any interventions that might impact on the land use leading to what the future use might be as the resulting land use sub-system. These are linked by the level of satisfaction with current usage represented by the sub-system 'satisfaction.' This could represent a determinant for the rate at which local stakeholders use forest resources. The CM is drawn to reflect this.

The subjective nature of the elements of the CM based on individual local stakeholder perspectives makes it very difficult to effectively analyse the system using SSM alone. This is acknowledged by Kinloch et al. (2009) who stress that the SSM analysis only suggests the *'what'* to change and not the *'how'* to change it. Kinloch et al. (2009) propose using other systems within the wider process of SSM to help analyse problem situations. This is implied in Stage 5 of the SSM process where comparison of the CM and other systems takes place.

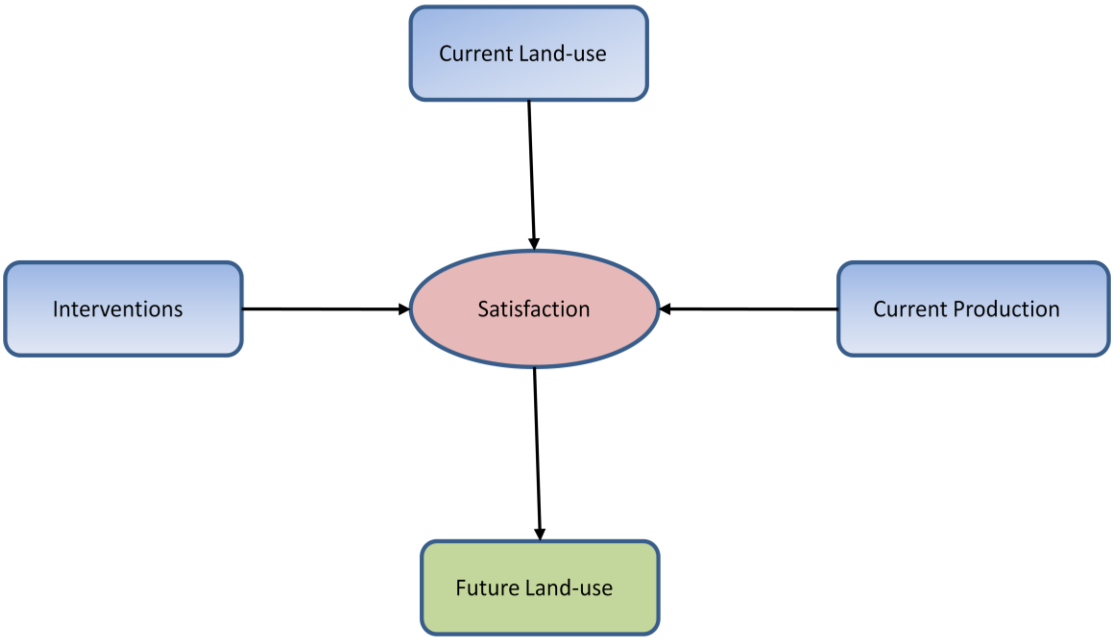

Figure 6.4: Conceptual model based on individual perspectives.

The preceding analysis has looked at what possible changes need to be made and not how to change it. This study intends to explore land-use decision-making outcomes further using Belief Networks and Decision Trees. The system model shown in Figure 6.4 will form the framework on which further analysis of land-use decision-making in the Copperbelt Province will be done and be later compared to the model based on the institutional perspective. It is hoped that these will use the outcomes from SSM to develop a better understanding of the land use decision-making process in the Copperbelt Province.

The application of SSM to the situation in encroached forest areas has managed to show a representation of divergent views about the problem situation and the steps necessary to encapsulate poorly defined situations that could lead to the resolution of complex problems as suggested by Checkland & Scholes (1999) and Wilson (2001).

6.8 Summary

The chapter has addressed the theory and application of the SSM process in the development of the CM of land-use decision-making in the encroached forest areas of the Copperbelt Province of Zambia. The preceding sections have outlined the theory of SSM. The various stages that make up the SSM methodology are described. Its applications and limitations are discussed. Also presented in this chapter are the summaries from the various stakeholder interviews and meetings in the Copperbelt Province. These are then used to develop a RD of the system under consideration and a conceptual model was finally developed.

Firstly, the chapter has addressed what SSM is and then outlined the basic principles of SSM. The seven stages in the SSM process have been briefly described in this section. This is in essence a theoretical description of the methodology.

The theoretical description is then followed by a review of the application domain. This is a description of the situation in the study area formed by the encroached forest areas in the Copperbelt Province. The data collection process in the study area is also addressed in this section. The constraints encountered in the process are outlined and the modified procedure which was applied is described in this section.

The application of the SSM process to the data collected is addressed in the next section, Section 6.5. It addresses the identification of the problem situation in the study area, the expression of the problem situation using a ‘rich picture’ and the subsequent development of a RD from it. The RD is then used to develop a CM that addresses the problem situation. The resulting CM is then compared to the real world and the outcomes tabulated in table 6.5. It is from this comparison that possible changes aimed at improving the overall land-use decision-making process are identified. An identification of what actions must be implemented to improve the problem situation is then suggested. This last stage only suggested the possible factors against which the proposed changes can be evaluated against as it requires thorough discussion with all stakeholders and was not done during the field study exercise due to the limitations described in the data collection process related to SSM.

The limitations of SSM are described in section 6.6. These mainly focus on the perceived shortcomings of the framework of the CATWOE mnemonic. It is suggested that the definitions of the elements of CATWOE be broadened to reduce ambiguities that may arise due to confusion in their meaning. This is envisaged to improve their application in modelling.

Finally an alternative model based on the individual local stakeholder perceptions applying the same transformation process, T, used in the development of the other CM was developed. Due to the difficulty in effectively analysing this alternative model using SSM, it will be analysed using other analytical methods namely the

Bayesian Belief Network (BN) and Decision Tree (DT) approaches. The final conceptual model developed will form the basis of further analysis using the BN approach to be developed and tested in the next chapter.

Chapter 7: Construction of a Belief Network Model for the Copperbelt Province

7.1 Introduction

This chapter looks at the construction of a BN model. The chapter first describes Bayesian theory and then addresses the stages involved in the development of the BN model before dealing with the issue of filling the Conditional Probability Tables (CPTs) for the nodes in the model. Data collected from the Maposa Local Forest were used to develop and test the BN model.

7.1.1 Bayes' Rule

The basic concept governing the treatment of probabilities in causal networks is Conditional probability. That is, whenever a statement of the probability of an event A, p(A), is given, it is conditioned by other known factors. It can be said to be the probability of an event occurring given that another, prior, event occurred. This is illustrated by Jensen (1996: 15) and Pearl (1998: 32) as follows:

Given two events A and B, whose probability values range between 0 and 1, the conditional probability of event A occurring given the prior occurrence of B will be denoted as follows:

$$P(A|B) \qquad 7.1$$

Now, the joint probability of the two events A and B is given by:

$$p(A|B)\ p(B) = p(A,B) \qquad 7.2$$

where **p(A,B)** is the joint event. This represents all combinations of values of a set of random variables called the Joint Probability Distribution (JPD) (Pearl, 1988).

It follows from Equation 7.2 that:

$$p(A|B)\ p(B) = p(B|A)\ p(A) \qquad 7.3$$

yielding

$$p(B|A) = p(A|B)\ p(B)\ /\ p(A) \qquad 7.4$$

which is known as Bayes' Rule. Since probabilities should be conditioned by a context, **C**. Bayes' Rule conditioned on **C** yields:

$$p(B|A,\mathbf{C}) = p(A|B,\mathbf{C})\ p(B|\mathbf{C})\ /\ p(A|\mathbf{C}) \qquad 7.5$$

It is worth noting the following from equation (7.4): that the prior probability of event B, **p(B),** is the initial probability of B before knowing any information of event A and the posterior probability of event B, **p(B|A),** is the probability of B knowing the prior probability of event A. The prior probability can be successively updated with the addition of new evidence. This means that the posterior probability, by adding one piece of evidence can be treated as the new prior for a new posterior probability (Bonham-Carter, 1994).

7.1.2 Graph theory

The JPD of an event **p(A,B)** represents all possible probability combinations of the set of variables and their states and to manipulate these values becomes very complicated as the number of variables to be considered increases exponentially (D'Ambrosio, 1999). This makes it impractical to handle as the number of variables increases. However, D'Ambrosio (1999) notes that the inherent structure of a model can be used to model the JPD as a graph. A graph is described as a finite set of nodes that are joined to one another with a set of relationships and if all the relationships in the graph are directed and there are no feedback cycles, the graph is said to be a Directed Acyclic Graph (DAG) (D'Ambrosio, 1999; Jensen, 1996; Pearl, 1988).

Each DAG simplifies the representation of a JPD by capturing the dependences and independences between variables. This is best illustrated by way of a concept called the direction-dependent criterion of connectivity also known as **d-separation** (Jensen, 1996; Pearl, 1988; Russell & Norvig, 1995). It is used to determine if two nodes are conditionally independent given evidence of another node. Jensen (1996) defines d-separation as follows: *"…Two variables* **A** and **B** in a causal network are d-separated if for all paths between **A** and **B** there is an intermediate variable **V** such that either

- the connection is serial or diverging and the state of **V** is known

or

- the connection is converging and neither **V** *nor any of V's descendants have* received any *evidence."*

Using d-separation will now help us to understand the dependence relationships from the topology of the graph as described by Russell & Norvig (1995):

- The relationship between nodes **A** and **B** is said to be dependent if nodes **A** and **B** have a path directly connecting them in the graph.
- The relationship between nodes **A** and **B** is said to be independent if nodes **A** and **B** are not connected by any path in the graph.
- The relationship between nodes **A** and **B** is said to be conditionally independent if nodes **A** and **B** are connected via a third node, **V**. Nodes **A** and **B** will have an influence on each other if nothing is known about the state of node **V**. They will, however, be d-separated from each other if the state of node **V** is known.

7.1.3 Definition of a belief network

Taking into account the concepts described in the preceding sections, it is now possible to revisit the definition of a BN. A BN is a directed acyclic graph that represents a joint probability distribution with the nodes representing random variables and the arcs representing the probabilistic relationships between the variables. The dependence/independence relationships are represented in the qualitative information in the paths between variables. The quantitative probability information in the conditional probability table for each node specifies the probability of each possible state given the possible states of it parents (Heckerman, 1995; Jensen, 1996; Pearl, 1988).

The development of a BN model can be broadly split into three phases: qualitative modelling, graphical structure identification and quantitative modelling (Cain, 2001; Cowell et al., 1999; Drudzel & van der Gaag, 2000). The model recommended development process is as follows:

Qualitative modelling: This involves the identifiying a set of relevant variables to represent the process that is being modelled. This step allows the participatory incorporation of different points of view about a specific problem. It is intended to encode the natural judgements of relevance and irrelevance. This can be considered to be the definition of the ontological component of the system.

Identification of graphical structure: This involves the identification of the states or classes of each variable and their relationships expressed in a graphical structure. This is a critical step in the process as the graphical structure represents the qualitative structural assumptions of the process being modelled. This is the process of defining the qualitative component of the system

Quantitative modelling: This phase involves the estimation of probabilities assigned to each state from statistical data, literature or human expertise. It is the specification of the CPT of each variable. This is the quantitative component of the system.

Three types of nodes can be developed in a BN : query nodes, evidence nodes and intermediate nodes (Russell & Norvig, 1995). Query nodes are the nodes which we wish to gain knowledge for. Evidence nodes are the nodes which we already have evidence and the intermediate nodes the ones between the query and evidence nodes.

There are four types of inference that can be used with BNs and these are the Diagnostic, Causal, Intercausal and Mixed inference (Russell & Norvig, 1995; Woodberry, 2003). Diagnostic inference involves the updating of beliefs from effects to causes sometimes known as the bottom-up approach. Casual inference involves updating beliefs from causes to effects. It is also known as prediction and is sometimes referred to as the top-down approach. Intercausal inference also known as 'explaining away' involves the updating of beliefs between causes of a common effect. Mixed inference involves the updating of beliefs from a mixture of the other three inference methods described.

7.2 Belief network design

The development of BN models for ecological and conservation applications to help quantify relationships between ecological variables and sample measurements is a fundamental problem (Marcot, 2006). Unlike medical applications where the application of BNs for decision-making is advanced, in ecology and natural resource management, very often the problem of scant data arises. This section looks at the stages involved in the development of a BN from conceptual model to final BN with fully specified CPTs.

The process of designing and building a BN can be divided into 3 stages; identifying the set of variables and their states, identifying the graphical structure of the BN and finally identifying the CPTs for each variable. The third stage is usually considered to be the most difficult and therefore the first two stages aim to define the problem domain in its simplest yet sufficient form (Woodberry, 2003). The aim of constructing a BN model should be to ensure that most of the factors relevant to the solution of the problem situation are clearly captured by the network. The logic underlying these ideas will be represented by the network structure, the names of the nodes and the names of the node states. It is necessary, therefore, to understand the general structure of a BN. The general structure of a BN is composed of six main elements as illustrated in Figure 7.1; the objectives, interventions, intermediate factors, controlling factors, implementation factors and additional impacts (Cain, 2001; Woodberry, 2003). The six elements are:

i) **Objectives** also known as query or target variables, form the output of the network, that is the things the end user would like to know about. They define the criteria on which management choices are made.

ii) **Controlling factors** also known as observation or evidence variables, form the input of the network. These can potentially help infer the states of the query variables.

iii) **Intermediate factors** also known as context variables. They form the link between the query and evidence variables.

iv) **Intervention variables** are potential interventions to the system. They may be considered as management options.

v) **Implementation factors** directly affect the successful implementation of an intervention. Examples of implementation factors are land availability for increased forest cover or funding for construction of a dam.

vi) **Additional impacts** are secondary factors which are changed as a result of interventions, but do not affect anything else in the environmental system. An example is an increase in bird population due to increasing forest which has resulted from a decreasing river flow (Cain, 2001). A change in bird population is unlikely to affect the water flow and so may be classed as an additional impact.

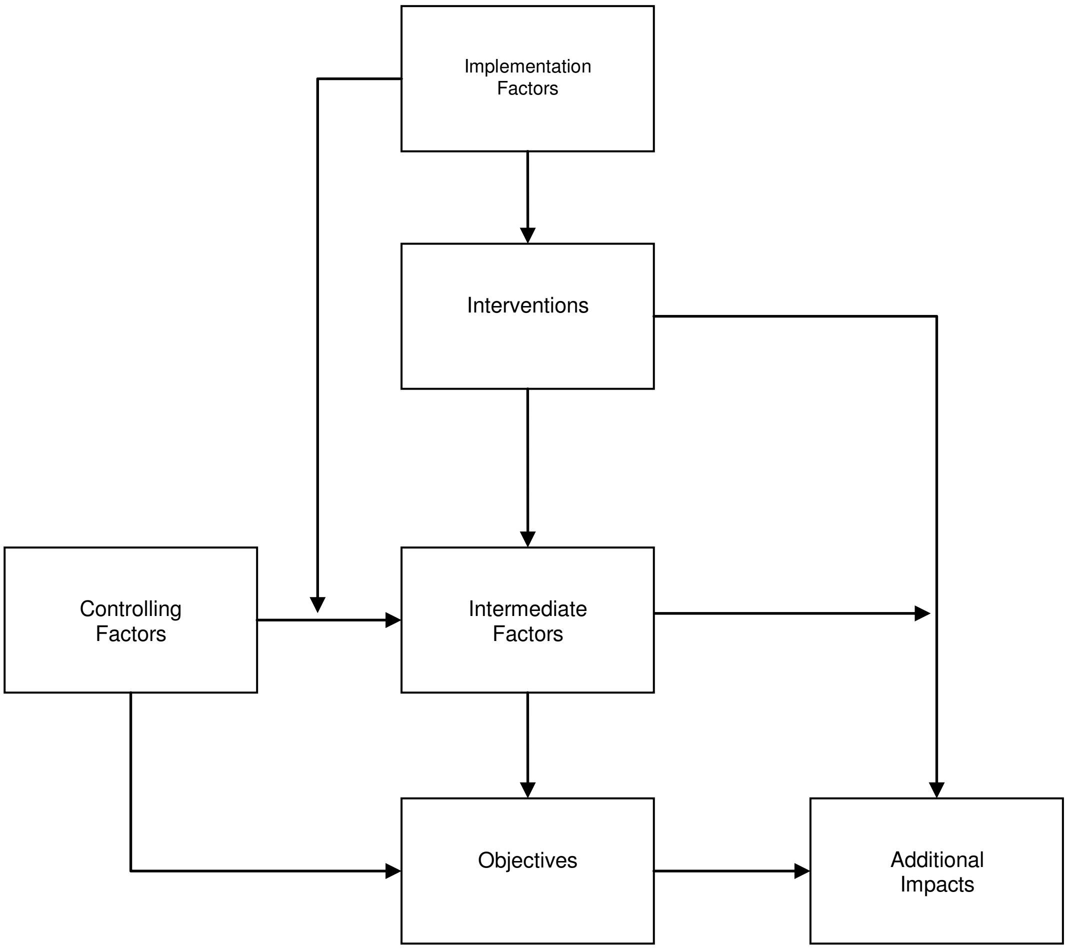

Figure 7.1: The general structure of a BN model (Cain, 2001)

7.2.1 Identifying the set of variables

Variables in BNs in the context of environmental management can represent tangible and intangible concepts ranging to include any physical, social or institutional factor (Cain, 2001). This flexibility in representation is important in capturing ideas effectively. Each variable can be represented as a separate node in the network. The choice of what variables to use in a BN is usually a result of discussion with stakeholders, subject-matter specialists and a review of existing literature (Bashari et al., 2009; Cain, 2001; Renken & Mumby, 2009; Uusitalo, 2007). It is suggested by Cain (2001) that it is important to consider the spatial area and temporal period that the BN being constructed will cover as this helps in the choice of variables to be included in the BN. Depending on the number of variables, the network may quickly become very complicated. In such a case, it may be necessary to combine some factors in order to reduce the size of the BN. It is useful to minimize the number of variables to use in a network to a minimum but sufficient size. Exceptions may occur where the objective of the network is to represent the complexity of the process being modelled rather than predictive accuracy or model parsimony (Castelletti & Sessa, 2007; Marcot et al., 2006).

After identifying the variables, the next step is to choose the states that the variables can take to effectively represent the ideas. As with selecting variables, it is useful to limit the number of states a variable can take. A general guide to choosing variable states needs consideration of what state it is currently in, what state it is likely to move towards under the proposed management plan and finally any intermediate states it may take (Cain, 2001). Only the states a variable is likely to take should be included and these should be exhaustive and exclusive. This means that a state variable can only have one value at a given point in time. It has also been recommended (Cain, 2001; Marcot et al., 2006; Uusitalo, 2007), that continuous variables be represented as discrete variables by converting them to a set of sub-ranges using the fewest states possible in order to maintain a balance between network precision and parsimony.

7.2.2 Identifying the graphical structure of the BN

The outcome of identifying variables and their states is to illustrate the key influences that relate to the outcome of interest in the manner of a graphical structure usually expressed in the form of figures consisting of boxes and arrows arranged in a way that depicts expected causal influences on the outcome of interest being investigated (Reckhow, 1999; Marcot et al., 2006). When determining the structure of a network it is important to focus on the relationships between key variables in the network. The graphical structure can then be developed into a BN where each box represents a node with discrete states. Parent nodes connect to child nodes and a child node may become a parent to other nodes. The process of determining the structure of the BN can sometimes be automated using complex learning algorithms (Zhang & Poole, 1996). All the nodes of a BN should be observable, quantifiable or testable quantities. If that is not possible, they should be carefully documented and explained (Marcot et al., 2006).

Sometimes, the structure of the BN can be determined by using model induction approaches. These induce the model structure using case data by calculating specific relationships among variables from the data tables. This approach has been criticised by Clark (2003) and Marcot et al. (2006) among others for the tendency to over-fit data. This is a problem for situations where the data are scant (Marcot et al., 2006). Since BNs can become very complex, it is often helpful to simplify the network to make it easily understandable and also make it easier for the next step of estimating the CPTs of each of the nodes of the BN.

7.2.3 Creating the CPTs for the variable nodes

Having constructed the BN, the next step is to estimate the CPTs for each node in the network in order to turn it into a fully functioning BN that can be used to help make decisions. The best and most appropriate data is used for this purpose. Every functioning BN consists of a set of conditional probability tables underlying each node. The data in the CPT describes how a node changes in response to changes in the states of it parents. Parentless nodes have unconditional probability tables that represent prior knowledge on frequencies of each state or alternatively, they will have uniform probabilities if there is complete uncertainty about prior conditions, that is no information. Child nodes have CPTs that represent combinations of all states of their parent nodes. Each row represents the sum of probabilities of all possible outcome states for a given set of prior conditions and the sum for each row is 100% (Cain, 2001; Marcot et al., 2006). Column totals do not sum up to 100, and Marcot et al. (2006) suggest that values in a column can be interpreted as likelihoods of prior states given an outcome state.

Each row in a CPT represents a question and each of the questions suggests the data that must be collected to fill in the CPT. There are different approaches that can be used to populate the CPTs of a BN and these depend on the type of information that will be used. They can be calculated explicitly if the child node has an equation or they can be initially specified by experts. Cain (2001) identifies four types of data that can be used to populate a CPT:

i) Information Type 1: Raw data collected by direct measurement such as groundwater depth recorded in the field, population by census and income derived from accounting.

ii) Information Type 2: Raw data collected through stakeholder elicitation such as stakeholder perceptions of groundwater depth, population and income.

iii) Information Type 3: Output from process-based models calibrated using raw data collected by direct measurement

iv) Information Type 4: 'Expert' opinion based on theoretical calculation or best judgement.

Type 1 information is the best data type to use but unfortunately is the most time consuming to obtain and least likely to be available easily. Type 4 information should be used when no other information is available. These approaches require some basic mathematical manipulation.

7.2.4 Using Type 1 and Type 3 information to calculate CPT values

When using type 1 information, CPT values are calculated by comparing the total number of cases that report a particular state for a child node and comparing it to the total number of cases that refer to a particular parent state combination. Cain (2001) suggests that at least 20 cases for each possible combination of parent states should be used and if that is not possible then Type 3 information should be considered.

For example, given that the prior probability for the parent state combination 1 is denoted as p^0 then the updated prior probability for each child state is calculated using

$$P^1(i) = [N(1) + (p^0(i)N^0)] / N^1 \tag{7.6}$$

Where:

$p^1(i)$ is the updated probability estimate for a child state and

N(1) is the number of cases in the child node in state 1 for the particular parent state combination

N^0 is the prior estimate of number of cases in the child state node before updating.

N^1 is the updated number of cases given by $N^1 = N^0 + N$

This process can be automated using the learning algorithms in the appropriate modelling shell and the resulting probabilities are automatically filled into the CPTs.

7.2.5 Using Type 2 and Type 4 information to calculate CPT values

Type2 and Type 4 information is considered subjective and the data are obtained in consultation with experts or stakeholders who make initial estimates of the probabilities of child node states given a particular parent state combination. The probability tables arising from such a process are sometimes referred to as Elicited Probability Tables (EPTs). These do not contain all the probabilities required by the CPT. The EPTs help to complete filling in of the table thus resulting in a CPT eventually when it has been fully specified.

The general approach for filling an EPT and thus converting it to a CPT is illustrated using Table 7.1 from Cain (2001). The table represents probabilities at a child node with 2 states, X and Y having three parents (1, 2 & 3) each with two states; a positive and negative state. Interpolation factors are used to calculate the remaining probability values in an EPT.

Table 7.1: Sample CPT table (Cain, 2001)

Parent state combination number	State of non-modifying parent			Probability that child is in state	
	1	**2**	**3**	**X**	**Y**
1	Positive	Positive	Positive	P_{1X}	P_{1Y}
2	Positive	Positive	Negative	P_{2X}	P_{2Y}
3	Positive	Negative	Positive	P_{3X}	P_{3Y}
4	Positive	Negative	Negative	P_{4X}	P_{4Y}
5	Negative	Positive	Positive	P_{5X}	P_{5Y}
6	Negative	Positive	Negative	P_{6X}	P_{6Y}
7	Negative	Negative	Positive	P_{7X}	P_{7Y}
8	Negative	Negative	Negative	P_{8X}	P_{8Y}

The first line of the EPT represents all the parents in their positive states. The second line shows the state of parent 3 switched to a negative state. The switching is done line by line until all parent state combinations for the node are listed. The probabilities for the child state are X for success (or positive state) and Y for failure (or negative state).

At every switch in state from positive to negative state for a parent, interpolation factors are calculated in relation to the difference between the highest probability for the success state, when all parents are positive, and the lowest one when all parents are negative:

$$(P_{1X} - P_{8X}) \tag{7.7}$$

The interpolation factor quantifies this difference for each parent as a proportion of the total difference. Mathematically this can be expressed as:
Interpolation factors for non-modifying parents 2 and 3:

$$IF_3 = (P_{2X} - P_{8X}) / (P_{1X} - P_{8X}) \tag{7.8}$$

$$IF_2 = (P_{3X} - P_{8X}) / (P_{1X} - P_{8X}) \tag{7.9}$$

Using the interpolation factors, IF_2 and IF_3, the unknown probabilities P_{4X} to P_{7X} can be calculated as follows:

$$P_{4X} = [(P_{3X} - P_{8X}) \times IF_3] + P_{8X} \tag{7.10}$$

$$P_{7X} = [(P_{5X} - P_{8X}) \times IF_2] + P_{8X} \tag{7.11}$$

The corresponding probabilities for state Y are

$$P_{4Y} = 100 - P_{4X} \quad (7.12)$$

$$P_{7Y} = 100 - P_{7X} \quad (7.13)$$

It must be noted that probabilities must be elicited for parent-state combinations rows 1, 2, 3, 5 and 8 before the other probabilities can be calculated. The EPT in Table 7.1 can be adjusted to represent child nodes that have more than two states with more than two parents each having more than 2 states (Cain, 2001). The procedure described above was used to fill the CPTs for the Maposa BN model.

7.3 Building the Maposa BN model

The preceding sections have covered the methods used in the construction of BNs. The next sections will cover the design process employed for the Maposa BN up to the stage of filling in of the CPT. The first step was to identify the set of variables to be used. The process of identifying the variables to be used for the development of the BN involved the use of data collected from the group meetings using SSM, data collected from the questionnaire survey and data collected from measurements in a GIS model of the Maposa site. Some data from national reports were also used to supplement the BN development process.

7.3.1 Development of the conceptual model using SSM

The process to develop a conceptual model using SSM was covered in the previous chapter. This used information from the local stakeholder meetings and interviews of the institutional stakeholders. A modified approach was used to combine the outcomes of the local stakeholder meetings with views of government officials and NGOs collected using personal interviews. The resulting model is shown in Figure 7.2.

7.3.2 Developing the BN from the conceptual model

The output from the questionnaire was used as the main input for developing the BN from the conceptual model. The outputs were grouped according to their relation to the main themes outlined. These are shown in Table 7.2 which reflects the relationships between the data collected and the variables to be used in the land use BN model. The basic model to be developed further is the on developed using SSM in Chapter 6 and is depicted in Figure 6.4. The process to develop the model further is based on the relationships outlined in Table 7.2. The following sections will now address the development of each sub-model using questionnaire data as basis for preparation of the model for subsequent analysis.

7.3.2.1 Sub-model for current land use

Using Table 7.2, relationships based on activities that would affect land use within the context of the root definition were developed for the sub-model Current Land Use. Access to resources stands out as an important aspect in shaping the land use for local stakeholders. This is divided into several categories: access to water, access to forest food resources, access to firewood for energy, and access to markets in order to sell any surplus produce. Underlying this is the stakeholders' degree of security of tenure reflected by the ownership and status in the village.

Table 7.2: Data table for BN model

	Theme in questionnaire	What it Captures	Variable it Maps To in Belief Network
1.	Status	Social status of decision maker in village	Status in Village
2.	Village	Location of decision maker	Location of Field
3.	Tribe	Ethnic origin	Ownership (Tenure)
4.	Rainfall	Access to water (perception of DM)	Rainfall
5.	Acquisition of fields	Ethnic origin and status of DM	Ownership (Tenure)
6.	When were fields acquired	Tenure security	Ownership (Tenure)
7.	Reason for not acquiring extra land	Ownership restrictions	Ownership / Land use restrictions
8.	Restricting authority for land acquisition	Existence of limitations on the acquisition of land	Land Use restrictions
9.	Type of land use restrictions	Scope of land use restrictions	Land use restriction
10.	Restricting Authority	Who sets out land use restrictions	Local Community / local authority interaction / policy awareness
11.	Land Policy awareness / consultation / implementation	Awareness of existence and (possibly) details of policy / involvement in formulation and implementation by DM	Land policy
12.	Forest Policy awareness / consultation / implementation	Awareness of existence and (possibly) details of policy / involvement in formulation and implementation by DM	Forestry policy
13.	Crops grown	Crops grown and current land use	Current land use
14.	Sale of harvest	Possibility of income generation	Income
15.	Distance to firewood	Accessibility of firewood to DM	Access to firewood
16.	Forest resource access in DM's field by other villagers / forest product harvest	Forest resource access by DM	Forest food resources
17.	Disposal of land	Security of tenure	Ownership (Tenure)
18.	Environmental problem in area	Awareness of DM to any local environmental problems and their remedy	Location characteristics of field
19.	Resolution of environmental problem	Ability and willingness of DM to remedy perceived environmental problem	Local action
20.	Community awareness / resolution of environmental problem	Ability and willingness of community to remedy perceived environmental problem	Community action
21.	Institutional awareness / resolution of local council	Ability and willingness of local council to remedy perceived environmental problem	Extension services

Table 7.2 (cont): Data table for BN model

	Theme in questionnaire	What it Captures	Variable it Maps To in Belief Network
22.	Proximity of land holding to nearest market	Distance measured on map from field to nearest market	Distance to market
23.	Proximity of landholding to nearest main road	Distance measured on map to main road	Distance from road
24.	Crops grown / land use	Measure of current proportional use of field	Current land use
25.	Land use / types of land use restrictions	Measure of satisfaction of DM on land use upon which decision of future land use will be based	Satisfaction

The access to water is based on perceptions of change in rainfall and how far the landholding is from a stream. To avoid too many parent variables for the Current Land Use node, a new variable, Field Properties has been defined to represent the physical properties of access to water, roads and the market. A factor which is relevant to Field Properties is that of security of tenure which is influenced by the status of the owner in the village. The sub-model is shown in Figure 7.2.

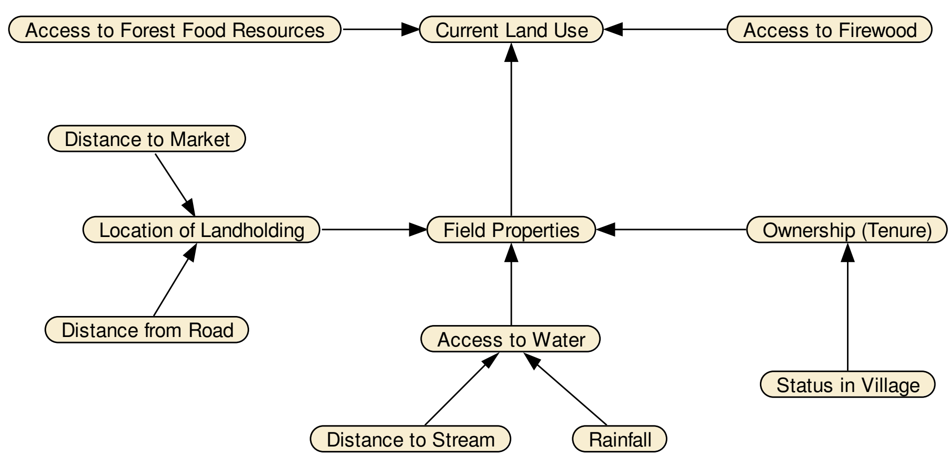

Figure 7.2: Land use sub-model

7.3.2.2 Sub-model for current crop production

Current crop production is influenced by the availability of forest food resources and the location of the landholding with regard to distance from a road and the distance to market. This is illustrated in Figure 7.3.

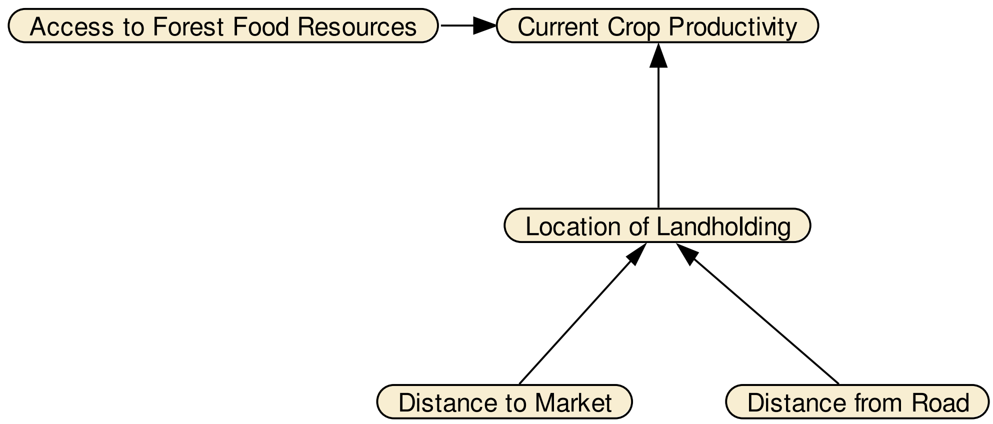

Fig. 7.3: Current crop productivity sub-model

7.3.2.3 Sub-model for interventions

The interventions sub-model consists of two inputs; the Land Use Restrictions node and the Extension Services node. The Land Use Restrictions node deals with restrictions arising from statutory regulations and these are embodied in the Policy Awareness node which comprises Land Policy and Forestry Policy awareness. Other factors are the influences of Local Community Action and Local Authority Action.

Extension services depend on the actions of local stakeholders, local communities and local authorities as shown in Figure 7.4. It is perceived by the local stakeholders that actions by any of these may affect the implementation of interventions to the BN.

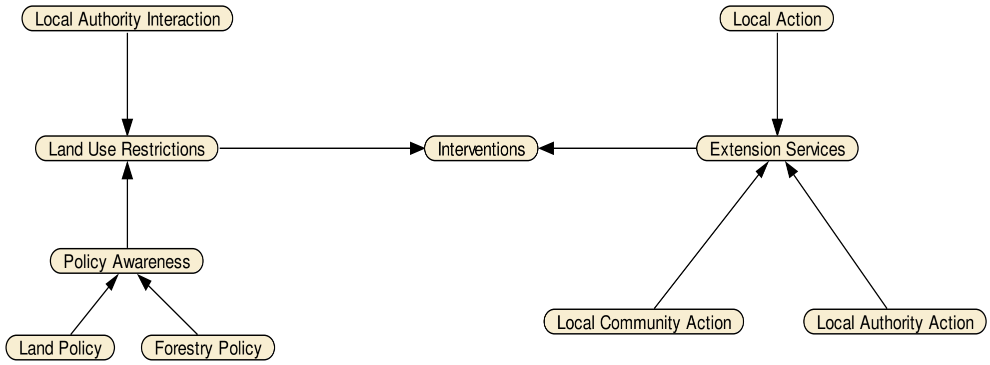

Figure 7.4: The Interventions sub-model

7.3.3 Preliminary version of BN model

The preliminary version of the model shows the sub-models connected to form the BN model as shown in Figure 7.5. This shows clearly the fact that location of the landholding has an influence on both the current crop production and on the field properties of the landholding. Access to forest food resources influences both the current crop production and current land use.

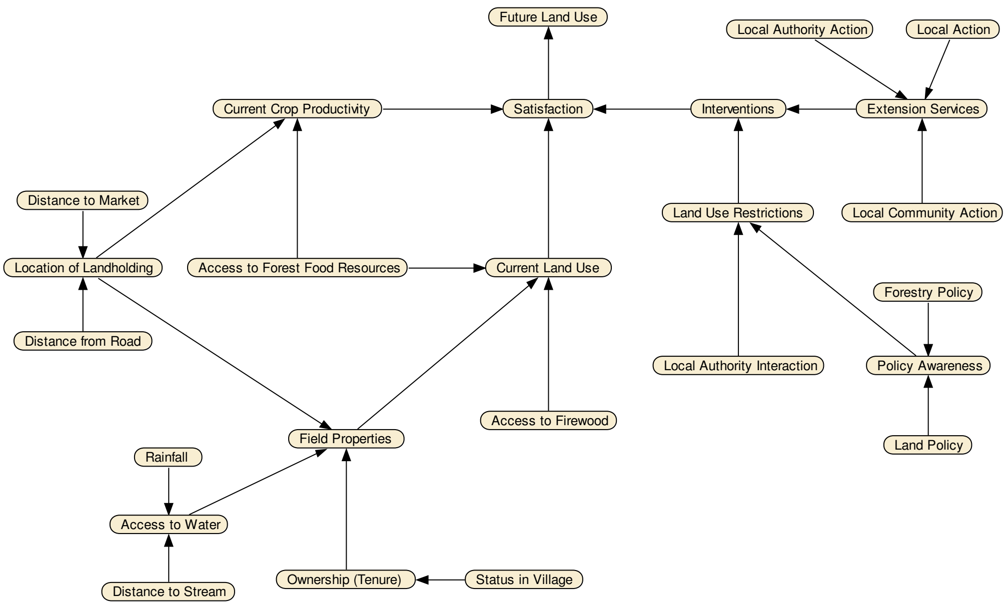

Figure 7.5: Preliminary version of model

7.3.4 Revision of the preliminary BN model

An inspection of the network reveals some relationships that were not initially apparent. The first is the fact that restrictions on the use of land are sometimes imposed by the community in order to protect community interests. This implies linking the Local Community Action node to the Land Use Restrictions node in the Interventions sub-model. Secondly, the local stakeholders felt an increased level of security of tenure if they had an interaction with the Local Authority through their local Councillor. There is therefore a link between the node Ownership in the Field properties sub-model and the Local Authority Interaction node in the Interventions sub-model.

A factor important to the satisfaction of the decision-maker that needs inclusion is that of income. It was probably omitted due to the fact it did not fit well into any of the nodes of the main themes of the conceptual model. It however has an influence on the satisfaction of the local stakeholder making a decision on land use. This was included in the model.

Another factor that requires to be addressed is that of output from the satisfaction node. The output is limited in terms of the fact that only one measure is being projected. Further inspection of the network shows that there are two main inputs concerning land use, and these are the Current Crop Production and the Current Land Use, however only one output, Future Land Use reflects the inputs. A node representing Future Crop Production was also included. Figure 7.6 reflects the final model incorporating the changes.

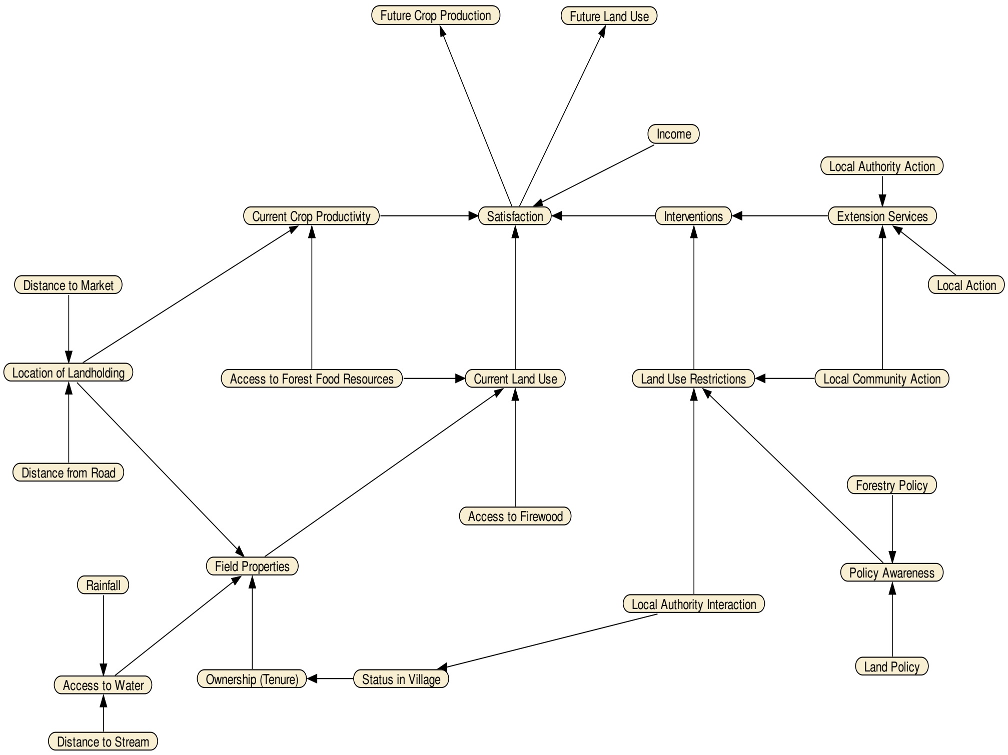

Figure 7.6: Final version of BN model

The BN model is now ready to have the variable states and the CPTs fully specified in order to have a fully functioning BN model. The specification of variable states was done largely by using the responses from the questionnaire for those variables which mapped directly onto the BN model while the state variables which did not have corresponding variables in the data collection phase had to be estimated as suggested by Marcot et.al. (2006) and Cain (2001). The following is a summary of variables for which the states had to be estimated and their rationale.

Table 7.3: Summary of variable states

Variable name	Variable states chosen	Reason for choice
Satisfaction	High, Medium, Low	Three basic steps to reflect levels of satisfaction
Current Crop Productivity	High, Medium, Low	Three basic steps to reflect levels of current production
Current Land Use	Crop, Forest, Dambo	Three main types of land use in the Maposa area
Location of Landholding	Good, Fair, Poor	Three levels to reflect the grading of a location
Field Properties	Good, Fair, Poor	Three levels to reflect the grading of field properties
Future Land Use	Improve Productivity, Continue Previous Use, Alternate Use	Three levels to reflect the direction of change as opposed to actual future use.
Future Crop Productivity	High, Medium, Low	Three basic steps to reflect levels of future production

The final land use BN model is shown in Figure 7.7 with all network variables showing equal states for the options at each node prior to specification of the CPTs.

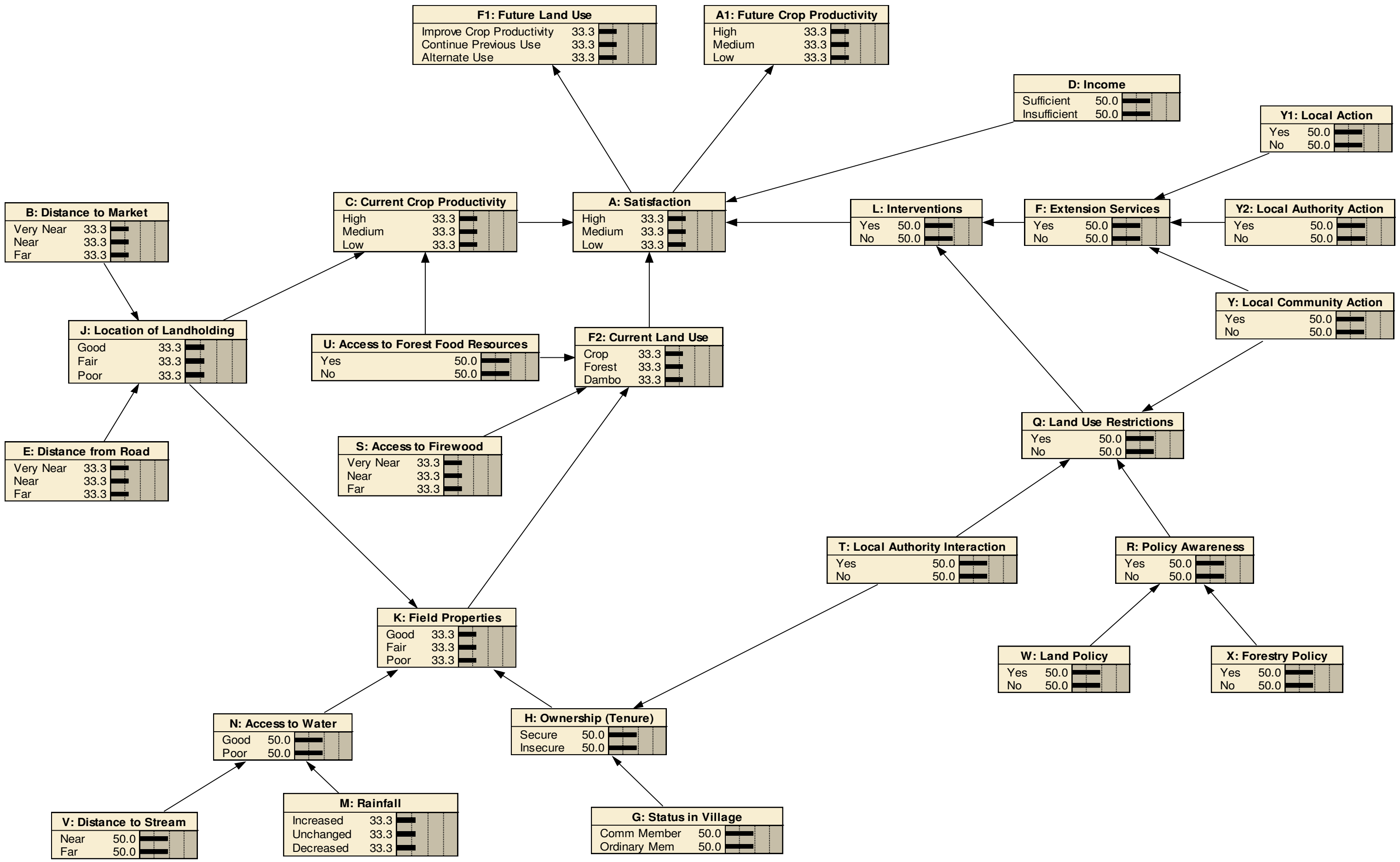

Figure 7.7: BN network model prior to specification of CPTs. All node states in the BN model have equal probability.

7.4 Calculation of CPTs for BN model

Firstly, EPT values were estimated by using cross-validation of data variables from a frequency analysis of the categorised values in the questionnaire and the rest of the probabilities were then calculated using Equation 6.2 to Equation 6.8. For nodes which do not have observations, their values were estimated from the literature as illustrated by an example of the node for Current Land Use.

It is estimated that maize production per household for small scale farmers in Zambia in 1999 was 85% of farm area and that crop production can sometimes be as low as 20% of farm area (ECZ, 2000). The highest estimate of crop was used by adding the projected increase in area under cultivation for all crops of 11% to give a value of 96% for maximum crop cultivation. Similarly for forest and dambo the values were estimated from national estimates given in ECZ (2000). The maximum and minimum values for crop cultivation area are used in Table 7.4 showing the EPTs for the node Current Land Use.

The rest of the probabilities are then calculated using the interpolation factors described by Cain (2001). These are:

For IF_3:

$IF_{3,Chx} = (P_{2X} - P_{18X}) / (P_{1X} - P_{18X}) = 35/18$

$IF_{3,Chz} = (P_{2z} - P_{18z}) / (P_{1z} - P_{18z}) = 13/14$

And for IF_2:

$IF_{2,Chx} = (P_{3X} - P_{18X}) / (P_{1X} - P_{18X}) = 15/19$

$IF_{2,Chz} = (P_{3z} - P_{18z}) / (P_{1z} - P_{18z}) = 4/7$

Table 7.4: EPT for the node Current Land Use. The table shows values elicited and calculated from public data sources. The blank spaces indicate probabilities to be calculated to completely fill the EPT table and become CPTs for the node.

Access to Forest Resources	Field Properties	Access to Firewood	Crop (X)	Forest (Y)	Dambo (Z)
Yes	Good	Very Near	0.96	0.03	0.01
Yes	Good	Near	0.9	0.08	0.02
Yes	Good	Far	0.8	0.13	0.07
Yes	Fair	Very Near			
Yes	Fair	Near			
Yes	Fair	Far			
Yes	Poor	Very Near			
Yes	Poor	Near			
Yes	Poor	Far			
No	Good	Very Near	0.4	0.465	0.135
No	Good	Near			
No	Good	Far			
No	Fair	Very Near			
No	Fair	Near			
No	Fair	Far			
No	Poor	Very Near			
No	Poor	Near			
No	Poor	Far	0.2	0.65	0.15

The complete CPT for the node Current Land Use node is now calculated and tabulated in Table 7.5.

Table 7.5: Completely specified CPT for node Current Land Use

Access to Forest Resources U	Field Properties K	Access to Firewood S	Crop (X)	Forest (Y)	Dambo (Z)
Yes	Good	Very Near	0.96	0.03	0.01
Yes	Good	Near	0.9	0.08	0.02
Yes	Good	Far	0.8	0.13	0.07
Yes	Fair	Very Near	0.67368	0.22204	0.10428
Yes	Fair	Near	0.63628	0.25618	0.10754
Yes	Fair	Far	0.60184	0.28759	0.11057
Yes	Poor	Very Near	0.51724	0.35529	0.12747
Yes	Poor	Near	0.49219	0.37873	0.12908
Yes	Poor	Far	0.46912	0.40031	0.13057
No	Good	Very Near	0.4	0.465	0.135
No	Good	Near	0.38421	0.47972	0.13607
No	Good	Far	0.36967	0.49327	0.13706
No	Fair	Very Near	0.33395	0.52344	0.14261
No	Fair	Near	0.32338	0.53348	0.14314
No	Fair	Far	0.31364	0.54273	0.14363
No	Poor	Very Near	0.28972	0.56392	0.14636
No	Poor	Near	0.28264	0.57074	0.14662
No	Poor	Far	0.2	0.65	0.15

The rest of the CPTs for the BN model have been calculated similarly and are tabulated in Appendix C. The BN model specified in Figure 7.8 was calculated by using a sample of the data. The data were collected at the group meetings and only reflected the general location of the respondent through the village name and thus could not be used to plot the respondent's homestead in a GIS. The rest of the data collected from the door to door sampling were used to test the model. An effect of using data from the meetings is that the distance nodes had no information prior to testing of the network.

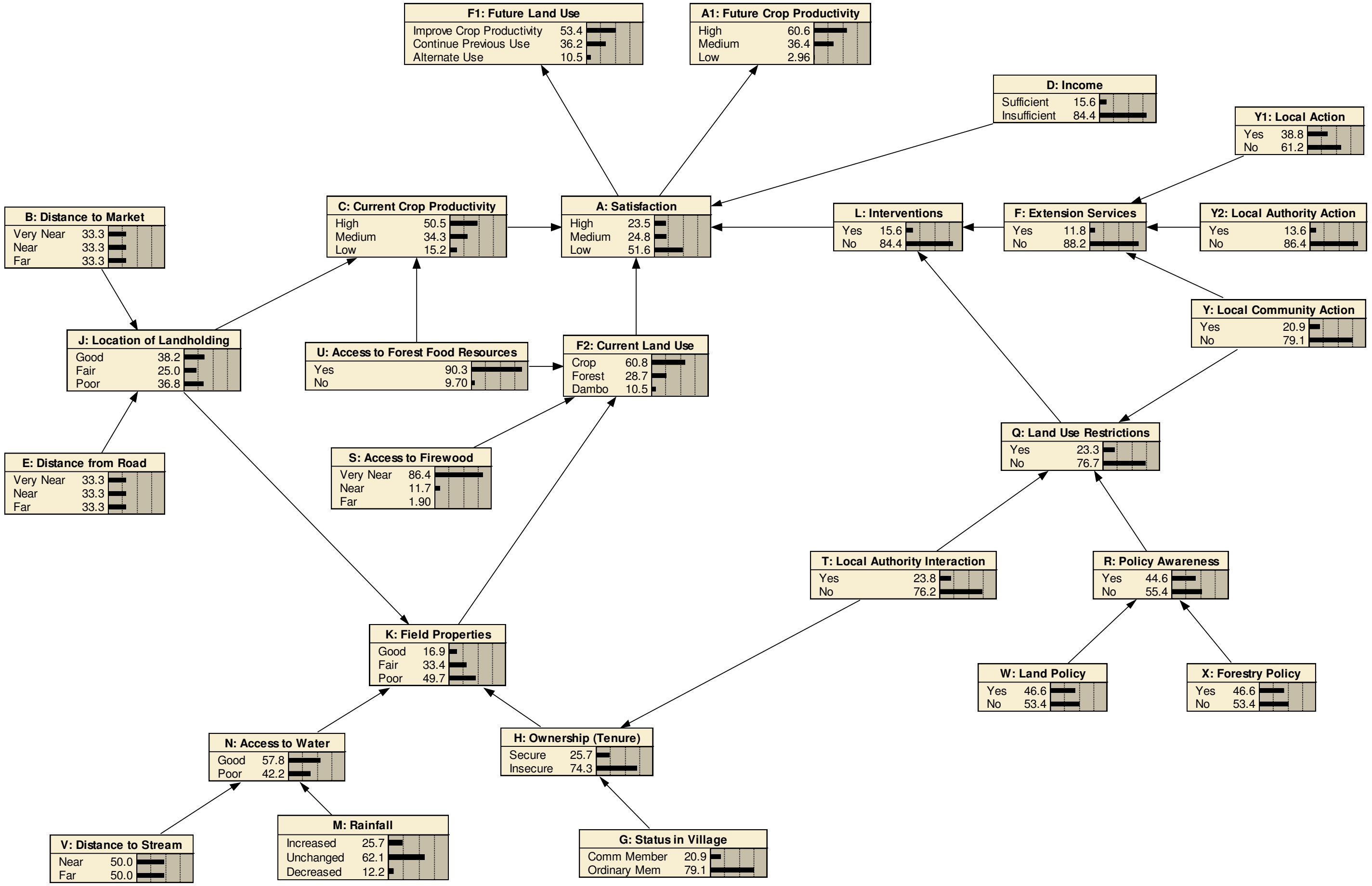

Figure 7.8: Final BN model after specification of CPTs.

7.5 Summary

The chapter has dealt with the construction of a BN model using the framework of the conceptual model developed from using SSM. The BN model was developed by identifying key influences on the nodes of the conceptual model. The various themes identified from the data were tabulated showing the possible nodes that could be used in the BN.

Sub-models were developed and these were then linked together on the conceptual model to form the preliminary BN model. This model was then revised to include relationships that were not initially apparent during the development.

The next stage was to fill in the CPTs for each node in the network in order to have a fully functioning BN. The CPTs were estimated using the interpolation approach applied by Cain (2001) to populate the BN. Two BN models were developed from using this method. The BN model shown in Figure 7.8 was conditioned using information which did not have any coordinate information from the questionnaire survey.

Chapter 8: Testing the Maposa BN model

8.1 Introduction

This chapter focuses on the testing and validation of the BN model developed in Chapter 7. It addresses the testing of the model with case data in order to assess its performance. The model was tested using sensitivity tests and other tests for reliability and robustness with data collected from the Maposa Local Forest. The resulting BN was then validated by using data collected during the reconnaissance survey in the Chibuluma National Forest No.4 in Kalulushi District. This was followed by an interpretation of what the BN could be used to infer using the Maposa data.

8.2 Modelling software

The modelling shell chosen for this research is NETICA Bayesian Belief Modelling Software, developed by Norsys Software Corporation (Norsys, 2003). It provides standard parameter learning and inference algorithms and allows the user great control over a BNs output. It has a downloadable reduced version available free of charge but this limits the size of the network that can be used.

8.3 Model testing

The testing, calibrating and validation of BN models is an essential step in the model building process to ensure that they do not represent unconfirmed belief structures whose reliability and accuracy cannot be verified. Case data can be used to test the accuracy of the models.

Evaluation procedures of model testing include error measures to establish the model's accuracy in estimating the satisfaction of a local stakeholder through the management objective variable, satisfaction, in the BN model. A sensitivity analysis is also used in the evaluation to understand better how the variables in the model affect the management objective satisfaction.

8.4 Error Measures

8.4.1 Introduction to error measures

The BN model was tested with real case data and then scored based on how well the model predictions matched the case data. Four error measures were used to score the BN model. The error measures employed to test the BN model are Error Rate, Logarithmic loss, Quadratic Loss and Spherical Payoff.

The error rate is the percentage of cases in the case data set that the model has predicted incorrectly. The case data value at a node is compared to the state with the highest probability at the node. When the model value did not concur with the case data value, an error was recorded. Consequently, a lower error rate is indicative of a more accurate model prediction (Norsys, 2003).

The logarithmic loss, quadratic loss and spherical payoff do not just take the most likely state as a prediction, but rather consider the actual belief levels of the states in determining how well they agree with the value in the case data (Norsys, 2003), that is to say they include the entire probability distribution in their calculations (Pearl, 1978; Morgan & Henrion, 1990). They are given as follows:

$$\text{Logarithmic Loss} = \text{MOAC}\left[-\ln(P_c)\right] \qquad 8.1$$

$$\text{Quadratic Loss} = \text{MOAC}\left[1 - 2P_c + \sum_{j=1}^{n} P_j^2\right] \qquad 8.2$$

and

$$\text{Spherical Payoff} = \text{MOAC}\left[\frac{P_c}{\sqrt{\sum_{j=1}^{n} P_j^2}}\right] \qquad 8.3$$

where, MOAC is the mean probability value of a given state averaged over all cases, P_c is the probability predicted for the correct state, P_j is the probability predicted for state j and n is the number of states at the node (Pearl, 1978; Morgan & Henrion, 1990; Norsys, 2003).

The ranges for the logarithmic loss are from **0** to ∞ inclusive with 0 as the best score, quadratic loss (also known as Brier score) ranges from **0 to 2** with 0 as the best score, and the spherical payoff ranges from **0 to 1** with 1 as the best score (Norsys, 2003). The choice of scoring rule depends on the decision problem for which the probability assessment is required (Pearl, 1978). It is, however, suggested by Marcot et al. (2001), that spherical payoff is perhaps the most useful index for measuring model performance and suggests a score of 0.8 as being acceptable.

8.4.2 Results of error measure tests

For the Maposa BN model, NETICA was used to calculate the error measures. This was done on the two models; Maposa model, the BN model for Maposa Local Forest and Kalulushi model, the BN model for the pilot study area in Chibuluma National forest. The Maposa model is depicted in Figure 7.8 conditioned with data from Transect 2, a partition from the data set. This model was tested with 364 data cases. The results are tabulated in Table C.1, Appendix C.

Data collected from Kalulushi District during the pilot study a year earlier, was also used as evidence to test the model for the model Kalulushi conditioned using random data from the pilot study area. The case data for Kalulushi did not have any information collected for 3 nodes: Local Action, Local Authority Action and Local Community Action because the data collection for Kalulushi District was during the preliminary data collection phase. The output is tabulated in Table C.1, Appendix C alongside that of the Maposa data.

The output from Table C.1 is summarised in graphs from Figure 8.1 to Figure 8.3 showing how the scores vary at each of the nodes for each of the error measures. On the graph, Maposa represents the Maposa BN model, and Kalulushi represents the Kalulushi BN model for Kalulushi.

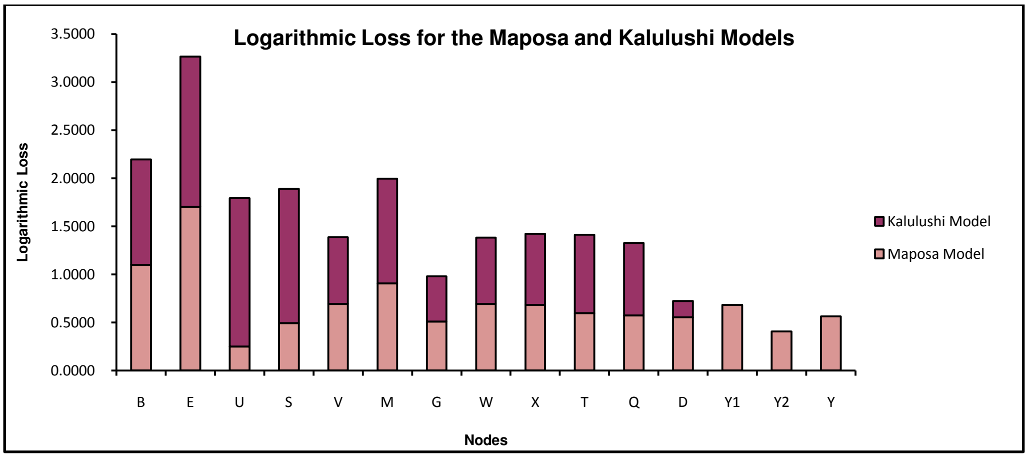

Figure 8.1: Logarithmic loss for the Maposa and Kalulushi BN Models. The logarithmic loss for the two BN models at the nodes depicted in the BN model structure in Figure 7.8 was performed only at the nodes for which data was collected in the field. The logarithmic loss ranges from 0 to ∞ with a best score of 0. There is no corresponding information for nodes Y, Y1 and Y2 in the Kalulushi BN model. The nodes outlined are: B = Distance to market, D = Income, E = Distance from road, G = Status in village, M = Rainfall, Q = Land use restrictions, S= Access to firewood, T = Local authority interaction, U = Access to forest food resources, V = Distance to stream, W = Land policy, X = Forest policy, Y = Local community action, Y1 = Local (individual) action, Y2 = Local authority action.

From Figure 8.1, the model Maposa, consistently scores better than the model Kalulushi, at 6 of the nodes with lower logarithmic loss values. However at 3 of the nodes, B, V and W representing distance to market, distance to stream and land policy awareness, the two models score equal values. The model Kalulushi, however, scores better at 3 nodes namely the nodes G, D and E representing status in village, income and distance to road. The better scoring could be attributed to the larger sample size for the Maposa model compared to the Kalulushi model. Therefore for 50% of the nodes with common data, the Maposa model has a better score for logarithmic loss.

The scores for quadratic loss for the Maposa model are still consistently better than those for the Kalulushi model. The exception is at nodes D and E representing ‘distance to road’ and ‘income’ where the Kalulushi model performs better as depicted in Figure 8.2. Similar trends are observed in Figure 8.3 which represents the spherical payoff scores for the models.

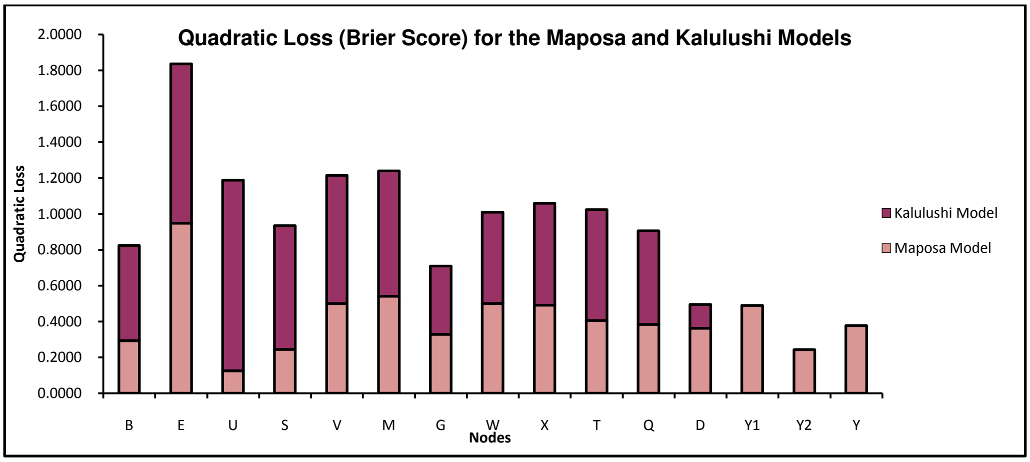

Figure 8.2: Quadratic loss (Brier score) for the Maposa and Kalulushi BN models. The quadratic loss for the two BN models at the nodes depicted in the BN model structure in Figure 7.8 was performed only at the nodes for which data was collected in the field. The quadratic loss ranges from 0 to 2 with a best score of 0. There is no corresponding information for nodes Y, Y1 and Y2 in the Kalulushi BN model. The nodes outlined are: B = Distance to market, D = Income, E = Distance from road, G = Status in village, M = Rainfall, Q = Land use restrictions, S= Access to firewood, T = Local authority interaction, U = Access to forest food resources, V = Distance to stream, W = Land policy, X = Forest policy, Y = Local community action, Y1 = Local (individual) action, Y2 = Local authority action.

The scores for spherical payoff for the Maposa model are generally between 0.6 and 1.0 except node E which scored below 0.4 for the model. This is indicative of a good accuracy assessment for the nodes in the model (Norsys, 2003; Marcot et al., 2006). The model Kalulushi scores slightly lower, between 0.5 and 0.8 and represent a similarly good assessment for the nodes in the model.

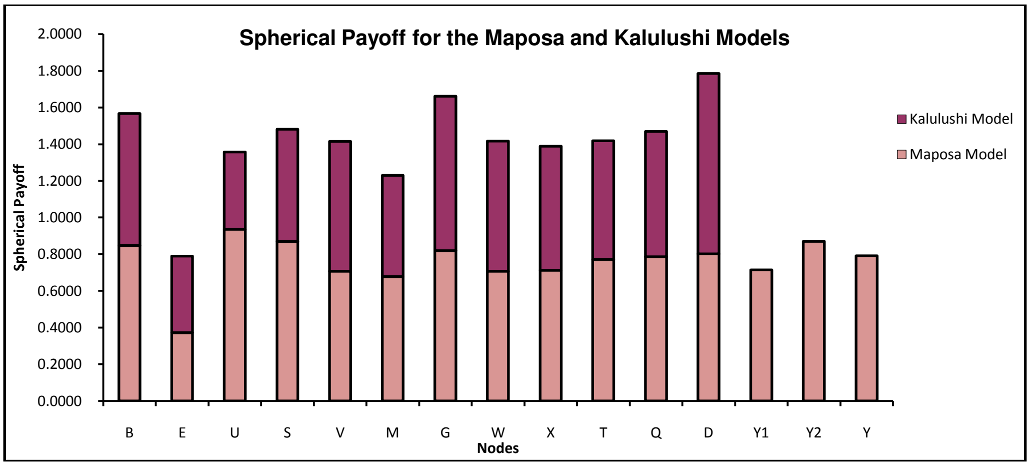

Figure 8.3: Spherical payoff for the Maposa and Kalulushi BN models. The spherical payoff for the two BN models at the nodes depicted in the BN model structure in Figure 7.8 was performed only at the nodes for which data was collected in the field. The spherical payoff ranges from 0 to a best score of 1. There is no corresponding information for nodes Y, Y1 and Y2 in the Kalulushi BN model. The nodes outlined are: B = Distance to market, D = Income, E = Distance from road, G = Status in village, M = Rainfall, Q = Land use restrictions, S= Access to firewood, T = Local authority interaction, U = Access to forest food resources, V = Distance to stream, W = Land policy, X = Forest policy, Y = Local community action, Y1 = Local (individual) action, Y2 = Local authority action.

The error rates are shown in Figure 8.4 and they show that the models had poor estimates for distance since almost half the cases sampled did not have any distance information. This is manifested at nodes B and E which represent the distances to the market and from a road respectively of a sampled point. The best error rate obtained is that of node D representing 'Income' for the Kalulushi model which had an error rate of zero. Both models have poor scores at nodes B and E. The model Kalulushi performs better at nodes representing distance to stream and status in village i.e. nodes V and G respectively.

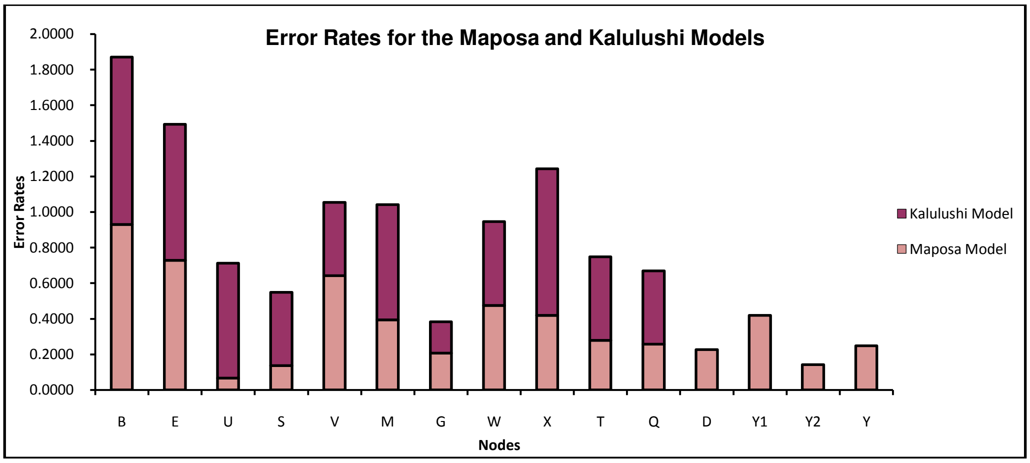

Figure 8.4: Error rates for the Maposa and Kalulushi BN models. The error rates for the two BN models at the nodes depicted in the BN model structure in Figure 7.8 was performed only at the nodes for which data was collected in the field. The error rate is a percentage of cases in the case data predicted incorrectly by the model. A lower score represents a more accurate model prediction. There is no corresponding information for nodes Y, Y1 and Y2 in the Kalulushi BN model. The nodes outlined are: B = Distance to market, D = Income, E = Distance from road, G = Status in village, M = Rainfall, Q = Land use restrictions, S= Access to firewood, T = Local authority interaction, U = Access to forest food resources, V = Distance to stream, W = Land policy, X = Forest policy, Y = Local community action, Y1 = Local (individual) action, Y2 = Local authority action.

8.4.3 Summary of analysis of error measures

Having analysed the error measures of the two models, it can be seen that the Maposa model tends to score better than the Kalulushi model in all four tests. The most useful of the tests, the spherical payoff, according to Marcot et al. (2001), shows a good model performance according to Figure 8.3. Similar trends can be observed for the other tests for both models. However, two nodes, U (access to forest food resources) and S (access to firewood), consistently show marked differences between the scores for both models in all tests with the Kalulushi model scoring poorly in all tests. It is not clear why this is the case, but further analysis of the model behaviour will now be done and it is hoped that it may shed some light on these findings. The next section will look at the influence of the model variables on land-use decision-making. This will be done by looking at the influence of model variables on the variable 'Satisfaction'.

8.5 Sensitivity analysis

8.5.1 Introduction to sensitivity analysis

The variables in the BN model, Maposa, all have an effect on the variable 'Satisfaction' in varying degrees and to measure the influence that each of the variables has on the beliefs in 'Satisfaction', two methods were used for this: the variance and the entropy reduction, I.

The variance is calculated for each node as follows according to Spiegelhelter (1989) cited by Norsys (2003):

$$\text{Variance} = \sum_{f}\sum_{q} P(q, f)\left[P(q \mid f) - P(q)\right]^2 \qquad 8.4$$

where, q is a state of the query variable, Q which in this case is 'Satisfaction' while f, is a state of the findings variable, F, which in this case represents all the other variables in the BN model. The findings represent the knowledge or evidence of the states of one or more nodes in the BN model.

The second measure of sensitivity of a BN model is the entropy reduction, I. It is used for non-numeric variables (Pearl, 1988) in place of variance reduction. The measure entropy, given by H(Q) is commonly used to evaluate the uncertainty or randomness of a probability distribution. Measuring the effect of one variable on another, is also referred to as the Mutual Information or entropy reduction, I. It is the expected reduction in mutual information of a variable Q (measured in information bits) due to a finding, F, and is outlined in Equation 8.5.

$$I = H(Q) - H(Q \mid F) = \sum_{q}\sum_{f} \frac{P(q, f)\log_2\left[P(q, f)\right]}{P(q)P(f)} \qquad 8.5$$

The log is base 2 thus giving the units of the results in bits. Entropy reduction can take on values from 0 to the entropy of Q, with 0 indicating no influence between the query variable, Q and F, the finding.

8.5.2 Results of sensitivity analysis for Maposa BN model

The option 'Sensitivity to findings' in NETICA was run for the 'Satisfaction' node for the case data available. The data were partitioned into segments to reflect transects that were used to collect the data, T1 to T7. The basis used for creating the base BN model was Transect 2, upon which each of the remaining transect data sets was used separately to generate models representing the beliefs in each transect surveyed. Transects T1 to T7 are shown in Figure 8.5. The sensitivity for the Maposa BN model using the combined data from the transects T1, T3, T4, T5, T6 and T7 as evidence for the Maposa BN model is shown in Table 8.1.

The variables in Table 8.1 are ranked in order of decreasing influence on the satisfaction of the local stakeholder as represented by the variable 'satisfaction' at node A. In the table, node **A** would have maximum influence and node **X** the least influence. The entropy reduction of node A is interpreted as the influence that a variable 'satisfaction' would have on itself.

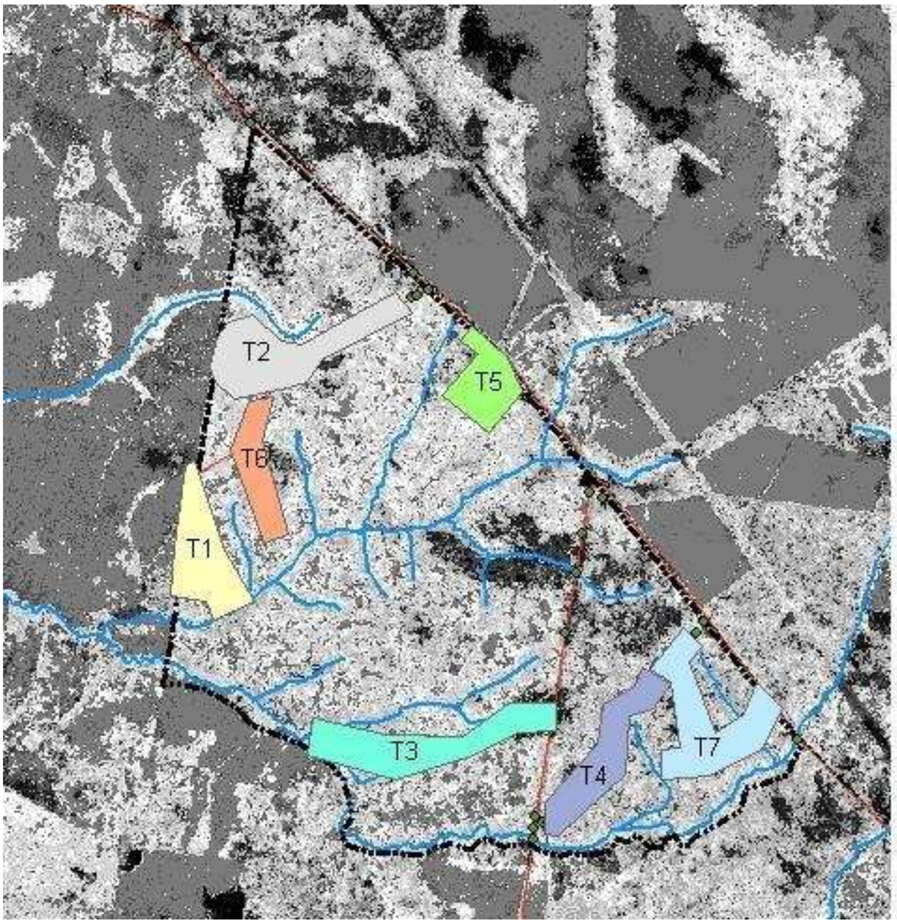

Figure 8.5: Transects of the study area. The shapes labelled T1 to T7 show the areas where questionnaires were administered in the Maposa Local Forest.

After the node A, the variables having the most influence on A are the 'Future land use' and 'Future crop productivity', represented by F1 and A1 respectively.

This can be attributed to a back propagation of the probabilities from F1 and A1. The ranking of the nodes after a sensitivity analysis of the BN model using transect data is shown in Table 8.2. This has been compiled from the individual sensitivity analysis tables for each transect and these are tabulated in Appendix C.2.

Table 8.1: Sensitivity analysis for Maposa BN model M2 combining all transects.

Node	Name of Node	Mutual Info	Variance of Beliefs
A	Satisfaction	1.44354	0.3819910
F1	Future Land Use	0.42736	0.0618486
A1	Future Crop Productivity	0.33999	0.0614306
C	Current Crop Production	0.20876	0.0344508
J	Location of Landholding	0.05101	0.0087115
D	Income	0.03798	0.0061052
E	Distance from Road	0.02017	0.0034692
B	Distance to Market	0.00669	0.0011803
F2	Current Land Use	0.00658	0.0010694
K	Field Properties	0.00339	0.0005709
U	Access to Forest Food Resources	0.00113	0.0001861
L	Interventions	0.00067	0.0001053
F	Extension Services	0.00025	0.0000391
H	Ownership (Tenure)	0.00011	0.0000176
Q	Land Use Restrictions	0.00009	0.0000136
Y	Local Community Actions	0.00005	0.0000074
N	Access to Water	0.00003	0.0000047
T	Local Authority Interaction	0.00002	0.0000025
Y1	Local (Individual) Action	0.00001	0.0000022
G	Status in Village	0.00001	0.0000022
Y2	Local Authority Action	0.00001	0.0000017
M	Rainfall	0	0.0000007
S	Access to Firewood	0	0.0000006
R	Policy Awareness	0	0.0000002
W	Land Policy	0	0.0000001
V	Distance to Stream	0	0.0000001
X	Forestry Policy	0	0

The table shows at a glance which nodes have greater influences on the satisfaction variable for each transect used in the study area and which nodes have the least influence. This can help with the prioritisation of which data to collect for different areas of the study site in the event that not enough information is available.

In Table 8.2, the columns represent the rankings of the variables for the sensitivity analysis of each. Column Mp represents the sensitivity analysis ranking of variables for the entire study site, while T1 to T7 represent the rankings for the sensitivity analyses for each transect, T1 to T7. It can be seen from Table 8.2, for example, that the trends for ranking are similar for all columns up to rank number 5 where differences in the influences begin to appear. In rank 5, the influence of variable J, 'Location of landholding' is more important for all areas except for transects T2 and T5 which show that the influence of variable D, 'Income', is more important. From rank 6 onwards, the differences in the influences of the variables become more pronounced.

Table 8.2: Sensitivity analysis ranking of node influences on the variable 'satisfaction' for all transects

Rank	Mp	T1	T2	T3	T4	T5	T6	T7
1	A	A	A	A	A	A	A	A
2	F1	F1	F1	F1	F1	F1	F1	F1
3	A1	A1	A1	A1	A1	A1	A1	A1
4	C	C	C	C	C	C	C	C
5	J	J	D	J	J	D	J	J
6	D	D	J	D	D	J	D	D
7	E	E	E	E	E	F2	E	E
8	B	F2	F2	F2	F2	E	F2	B
9	F2	K	K	K	U	B	K	F2
10	K	U	U	U	K	K	L	K
11	U	L	L	L	L	U	U	L
12	L	F	F	F	F	L	F	H
13	F	H	B	H	Q	F	H	U
14	H	Q	H	Q	H	H	Q	F
15	Q	B	Q	B	Y	Q	Y	Q
16	Y	Y	Y	Y	B	Y	Y1	N
17	N	N	N	N	N	N	N	T
18	T	G	G	T	T	Y2	Y2	G
19	Y1	T	Y1	Y1	Y2	Y1	T	Y
20	G	Y1	Y2	G	Y1	G	G	Y1
21	Y2	M	T	Y2	G	S	B	S
22	M	Y2	M	M	S	T	M	M
23	S	R	S	S	M	M	S	R
24	R	S	R	R	R	R	R	Y2
25	W	W	W	W	V	W	W	V
26	V	X	V	X	X	X	X	W
27	X	V	X	V	W	V	V	X

8.5.3 Sensitivity analysis by transect

Although the ranking by variable for the sensitivity analysis provides a rapid way to interpret which variables have great influence on the variables of interest, it is also helpful to look at how these changes affect the belief states by transect.

The belief states for each node were tabulated for transects T1 to T7 except T2 and the variance in the belief state at each node across the transects, T1 to T7 calculated to help choose the state with the most variance across the transects. This then allowed a ranking of the transects in order of increasing values in the belief for the variable 'Satisfaction'. It was then possible to compare the changes in given variable states from transect to transect. This is illustrated in Table C.11 in Appendix C.

Using increasing 'Satisfaction' to rank the transects, groupings of variables were plotted to show the changes in their most likely belief states. The following broad themes were used to group the variables: Income and future use, Location, Local authority interaction and ownership, and Water access and land use restrictions. The variables chosen for each theme and their states are indicated in Tables 8.3 to 8.6 with corresponding graphs showing the changes in state.

i) Income and future use theme

Table 8.3: Income and future use theme

Node	State	% Change in Belief State
Satisfaction	High	27.62
FCP	High	-18.57
CCP	High	34.75
FLU	Continue Previous Use	22.29
CLU	Crop	-1.89
Income	Insufficient	-46.85

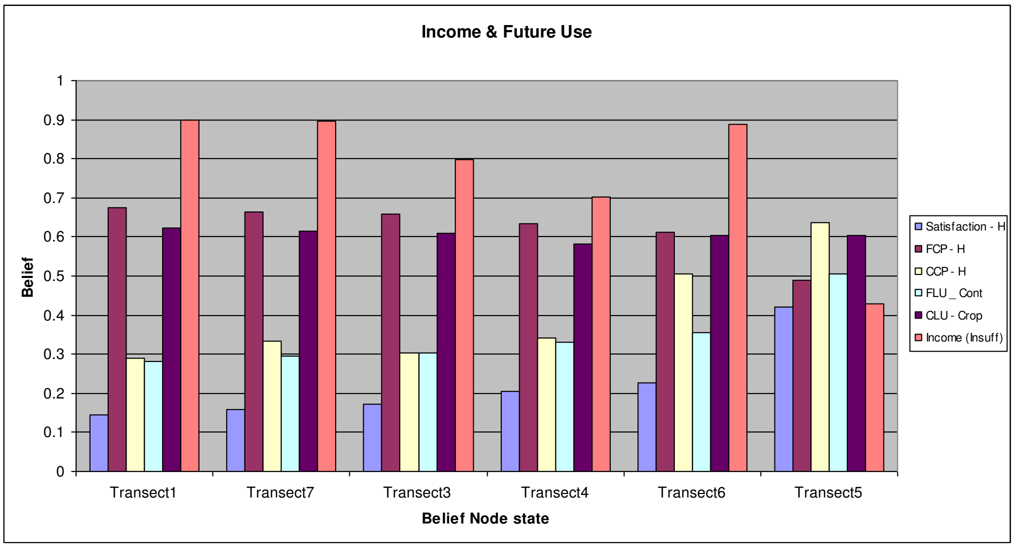

Figure 8.6: Variation of satisfaction in the 'income and future use' theme. The variation of satisfaction at all the transects in the theme 'income and future use' showing the states of the nodes tested in this theme. The nodes tested at each transect are outlined: Satisfaction – H = state 'High' at the node *Satisfaction*, FCP – H = state 'High' at node *Current Crop Production*, FLU_Cont = state 'Continue' at node *Future Land Use*, CLU – Crop = state 'Crop' at node *Current Land Use*, Income (Insuff) = state 'Insufficient' at node *Income*.

The results in Figure 8.6 suggest that for the transects there is a 28% increase in satisfaction, there is a 35% increase in the belief that current crop productivity increases. This is reflected by a 47% fall in the belief that income is insufficient. There is a 22% increase in the belief that future land use will continue with current use of cropping which has largely remained unchanged with a 1.9% change. In other words, for the 'Income and future use' theme, an increase in satisfaction is supported by a belief that crop productivity increases.

This is matched by a corresponding belief that income is sufficient and a likely decision to continue with the current land use.

ii) Location theme

Table 8.4: Location theme

Node	State	% Change in Belief State
Satisfaction	High	27.617
D_Road	Far	-58.918
D_Market	Far	-80.055
D_Stream	Far	27.906
Location	Poor	-62.544

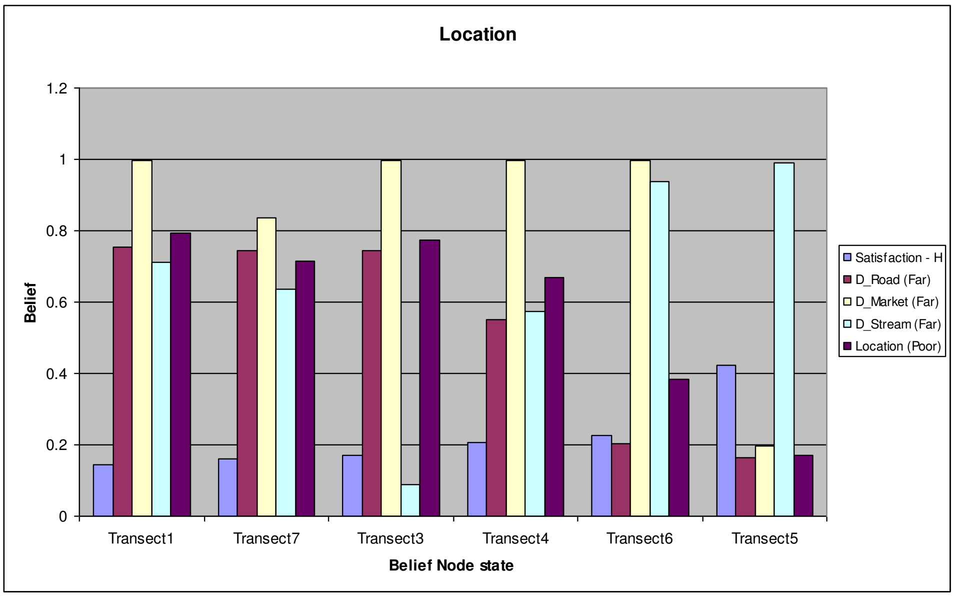

Figure 8.7: Variation of satisfaction in the 'location' theme. The variation of satisfaction at all the transects in the theme 'location' showing the states of the nodes tested in this theme. The nodes tested at each transect are outlined: Satisfaction – H = state 'High' at the node *Satisfaction*, D_Road (Far) = state 'Far' at node *Distance to Road*, D_Market (Far) = state 'Far' at node *Distance to Market*, D_Stream (Far) = state 'Far' at node *Distance to Stream*, Location (Poor) = state 'Poor' at node *Location of Landholding*.

Figure 8.7 shows that across the transects, satisfaction increases with the decrease in distance to market and to a road. The variable with the highest change appears to be distance to market which shows an 80% drop in the belief that distance to a market is far. Proximity to a stream does not seem to have as much an effect on the satisfaction. This is illustrated by T5 which exhibits the highest satisfaction but with poorest belief of proximity to a stream.

So, for the Location theme, the closer a land-holding is to a road, the higher the satisfaction. Proximity to a stream does not seem to affect the likely land-use decision as it appears not to have an effect in all the transects, T1 to T7.

iii) Local authority interaction and ownership theme

Table 8.5: Local authority interaction and ownership theme

Node	State	% Change in Belief State
Satisfaction	High	27.62
Extn. Services	No	-9.79
Ownership	Insecure	7.99
Field Props	Poor	-5.48
LUR	No	-2.05
Local Auth. Int.	No	6.55

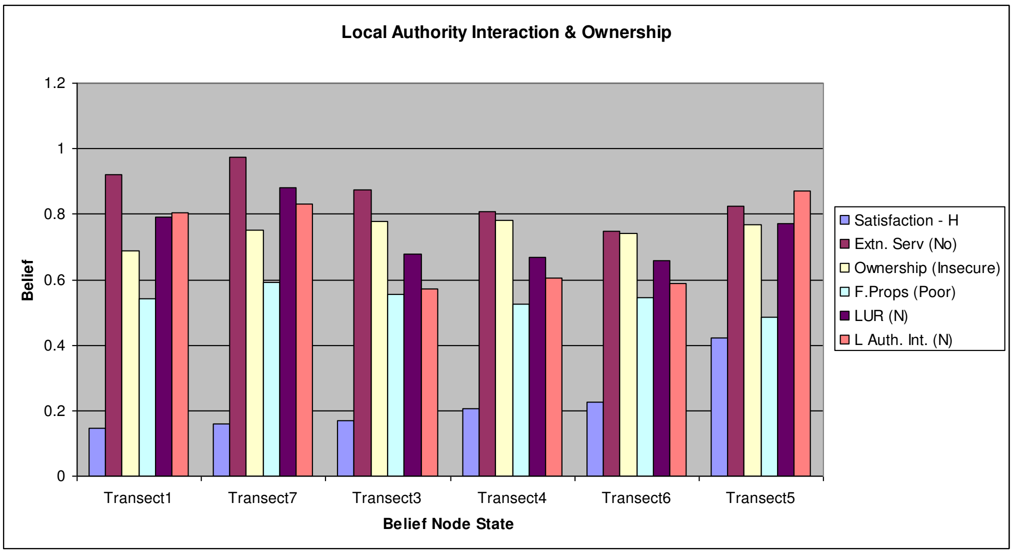

Figure 8.8: Variation of satisfaction in the 'local authority interaction and ownership' theme. The variation of satisfaction at all the transects in the theme 'local authority interaction' showing the states of the nodes tested in this theme. The nodes tested at each transect are outlined: Satisfaction – H = state 'High' at the node *Satisfaction*, Extn. Serv (No) = state 'No' at node *Extension Services*, Ownership (Insecure) = state 'Insecure' at node *Ownership (Tenure)*, F.Props (Poor) = state 'Poor' at node *Field Properties*, LUR (N) = state 'No' at node *Land Use Restrictions,* L Auth. Int. (N) = state 'No' at node *Local Authority Interaction*.

The chart in Figure 8.8 shows that the beliefs for all properties exhibit similar trends across the transects. The properties do not seem to have an effect on the satisfaction. The overall changes across the transects are not as high as exhibited for the previous themes, the highest being about 10% for the belief that extension services will be provided.

iv) Water access and LUR theme

Table 8.6: Water access and LUR theme

Node	State	% Change in Belief State
Satisfaction	High	27.617
Field Props	Poor	-5.481
Rainfall	Increased	-14.149
Water Access	Good	-12.245
LUR	No	-2.053
Local Auth. Int.	No	6.552

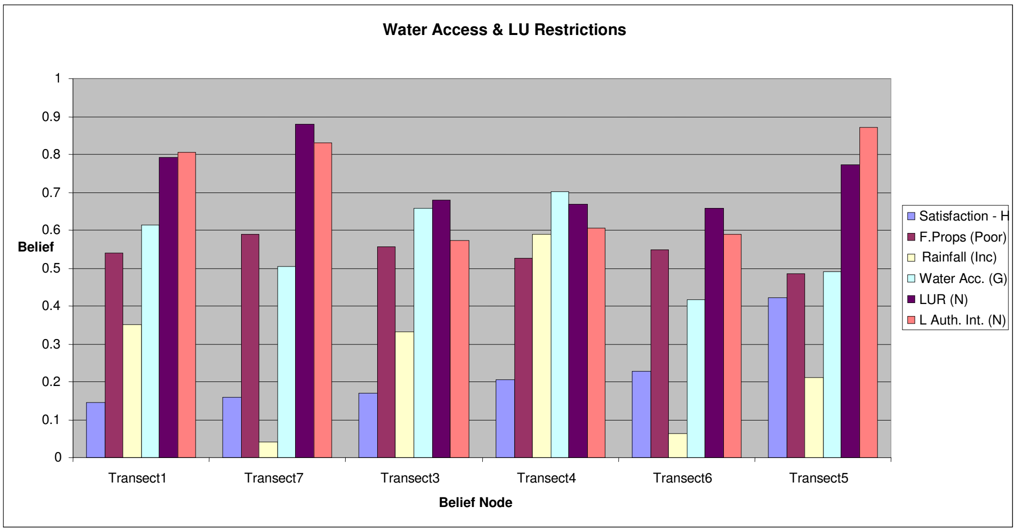

Figure 8.9: Variation of satisfaction in the 'water access and LUR' theme. The variation of satisfaction at all the transects in the theme 'water access and LUR' showing the states of the nodes tested in this theme. The nodes tested at each transect are outlined: Satisfaction – H = state 'High' at the node *Satisfaction*, F.Props (Poor) = state 'Poor' at node *Field Properties*, Rainfall (Inc) = state 'Increased' at node *Rainfall*, Water Acc. (G) = state 'Good' at node *Access to Water*, LUR (N) = state 'No' at node *Land Use Restrictions,* L Auth. Int. (N) = state 'No' at node *Local Authority Interaction*.

The trends exhibited for this theme do not show dramatic changes in the belief states with the increase in satisfaction. The belief that rainfall is high decreases by about 14%, this is matched by a corresponding decrease of about 12% in the belief that water access is good. It is curious to note that for T7, the belief that rainfall is high is less than 10% while the belief that access to water is good, is about 50%.

8.5.4 Summary of sensitivity analysis by transect

The investigation into the sensitivity of the BN model by transect has shown that the theme 'Location' had the highest variance in belief states. It showed a variance of about 80% in the belief that Distance to Market was Far. This was followed by theme 'Income and Futre Use' which had a variance of 47% in the perception that income was insufficient. The theme for 'Water Access and Land Use Restrictions' ranked 3rd and was followed lastly by the theme 'Local Authority Interaction'.

It is interesting to note how a BN model can be used to highlight trends and features of variables in relation to each other and to the management objective by looking at the changes in node states with the highest variance across the transects T1 to T7. This feature can help a land manager to target appropriate resources to the required areas in order to achieve the desired management objectives.

The high variance in the theme 'Location' could be attributed to the spatial distribution of transects as shown in Figure 8.5. However, the theme 'Income and Future Use' seems to address the concerns of the local stakeholders with respect to income and what they can grow to generate an income in the future as well as whether they will still have access to land

8.5.5 Sensitivity analysis by sub-models

Another way of looking at the effect of variables on the management objective, is by looking at the impact of sub-models (Marcot, 2006). This involves sub-dividing the BN model into sub-models to be used to analyse the impact of groups of variables on the management objectives. This may involve the core sub-models identified in the conceptual stage of the model building process.

For the Maposa model case, the BN model was divided into five sub-models and then for each sub-model, the states of a chosen variable in a sub-model were varied from the highest state to the lowest state and the corresponding changes in the belief states of the management objective, 'satisfaction' noted. The changes in the states of the other variables in the sub-model are noted and plotted together with those of the satisfaction variable. The states with the highest variance were chosen for this. The five sub-models in Figure 8.10 are:

i) Location of landholding
ii) Access and productivity
iii) Properties of landholding
iv) Local interventions
v) Land use restrictions

The output nodes for future land-use could be considered as the sixth sub-model which is only used to observe the outcomes with varying node states in the other sub-modules.

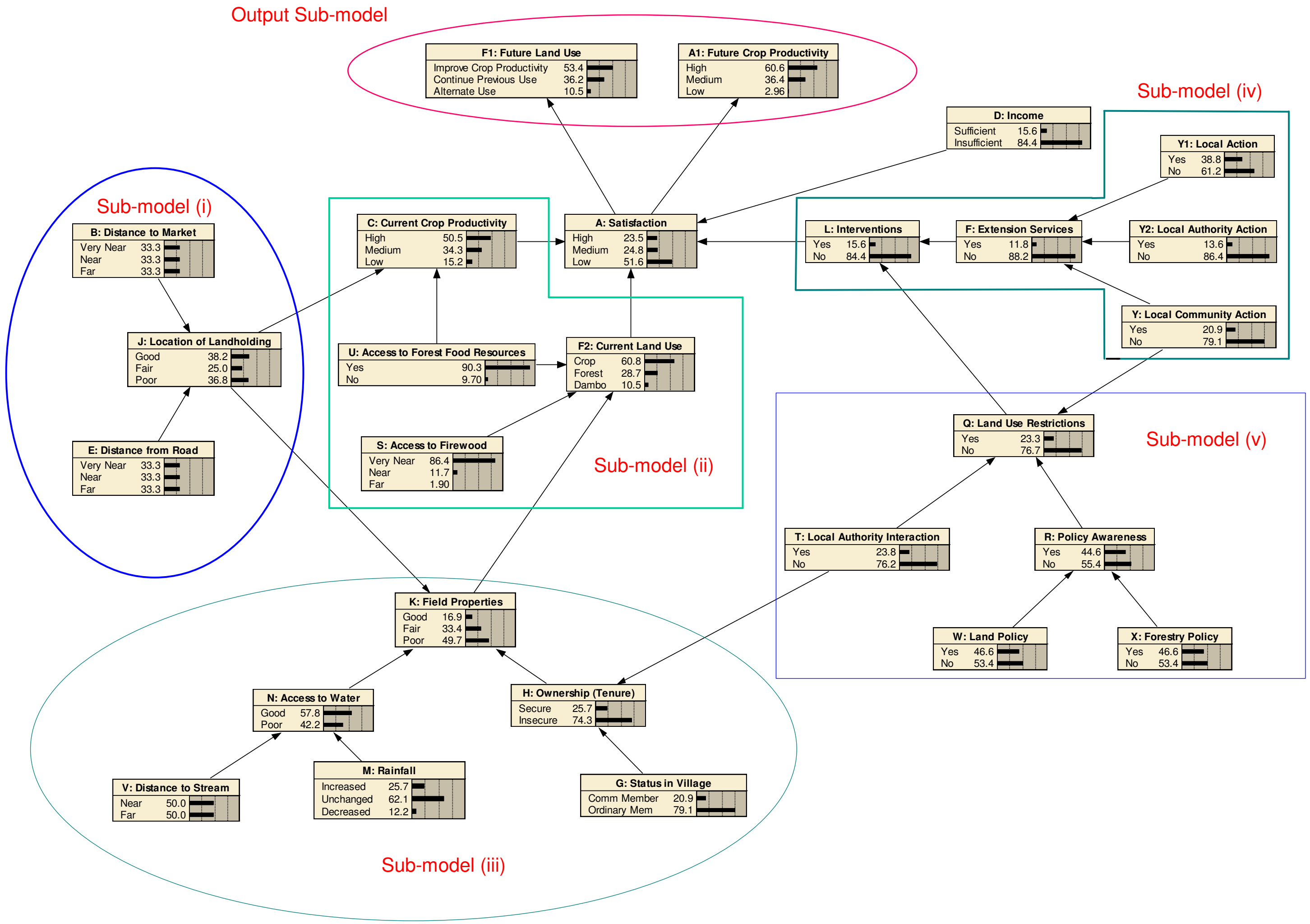

Figure 8.10: BN model showing sub-model divisions

8.5.5.1 Sub-model (i): Location of landholding

The location sub-model represents the grouping of variables to represent the impact of the location of the local stakeholder from the market and from roads where they generally they conduct their business. For the location of landholding sub-model, the variables that were chosen in order to vary their states are nodes B and E and their states were varied from Very Near (VN) to Far (F). These are shown on the category axis of Figure 8.11. The overall changes in belief states have been summarised in Table 8.7.

Table 8.7: Location sub-model outputs

Node	State	% Change in Belief State
Satisfaction	Low	23.85
FCP	High	16.8
FLU	Continue previous use	-19.60
CCP	High	-55.5
CLU	Crop	-5.16
Location	Good	-90

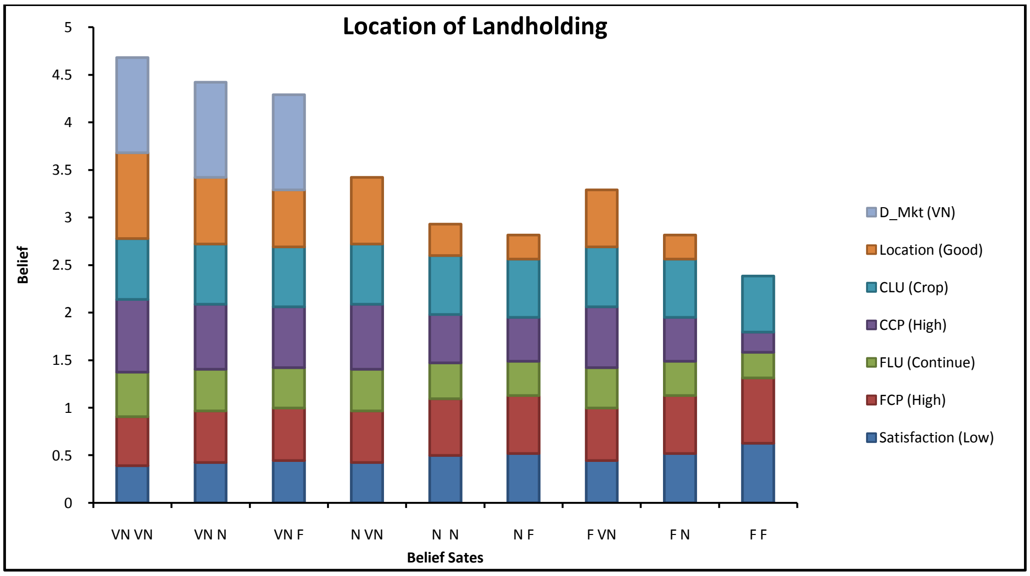

Figure 8.11: Location of landholding sub-model. The chart shows various belief states and their corresponding belief levels for the *Location of Landholding* sub-model. The belief states are: D_Mkt (VN) = state 'Very Near' at node *Distance to Market*, Location (Good) = state 'Good' at node *Location*, CLU (Crop) = state 'Crop' at node *Current Land Use*, CCP (High) = state 'High' at node *Current Crop Productivity*, FLU (Continue) = state 'Continue' at node *Future Land Use*, FCP (High) = state 'High' at node *Future Crop Productivity*, Satisfaction (Low) = state 'Low' at node *Satisfaction*.

The results show that with increasing distance to the market, there is a decrease in satisfaction of about 24%. This is marked by a 56% drop in belief that the current crop production would be high. The future land use variable indicates that the belief that the previous land use would continue has decreased by 20%.

8.5.5.2 Sub-model (ii): Access and productivity

This sub-model constitutes the grouping of variables that represent access to forest resources and it used nodes U and S to simulate the decrease in access to forest resources. The surprising output from this tabulated in Table 8.8 and Figure 8.12 is that with the decrease in access to forest resources, there is a drop in belief of 37.1% for the state that the current land use will be crop. The belief that current crop productivity will be high, decreased by 12%. The belief that Satisfaction would be in a low state decreased by about 7%.

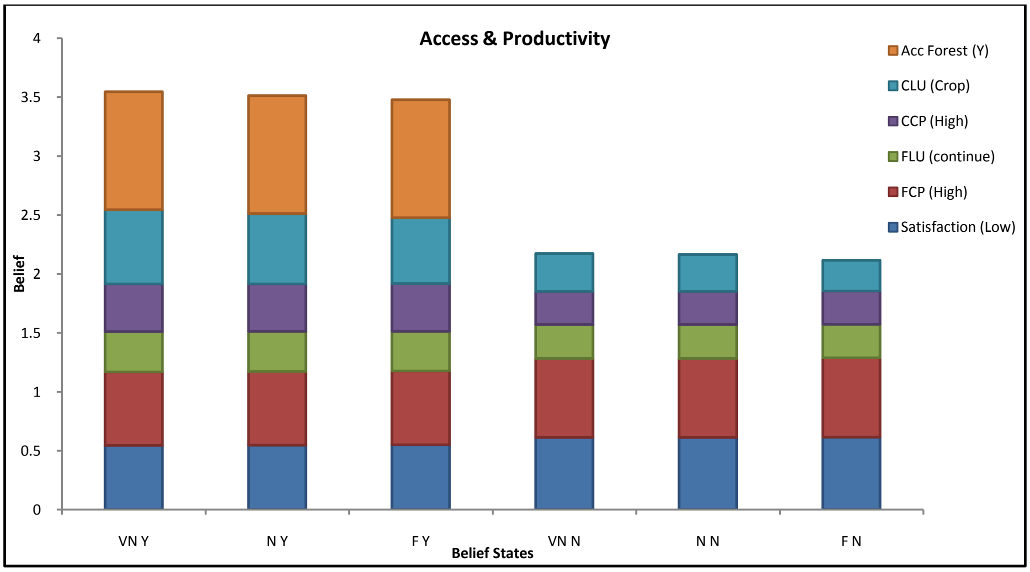

Figure 8.12: Access and productivity sub-model. The chart shows various belief states and their corresponding belief levels for the *Access and Productivity* sub-model. The belief states are: Satisfaction (Low) = state 'Low' at node *Satisfaction*, Acc Forest (Y) = state 'Yes' at node *Access to Forest food Resources*, CLU (Crop) = state 'Crop' at node *Current Land Use*, CCP (High) = state 'High' at node *Current Crop Productivity*, FLU (Continue) = state 'Continue' at node *Future Land Use*, FCP (High) = state 'High' at node *Future Crop Productivity*.

Table 8.8: Access and productivity sub-model outputs

Node	State	% Change in Belief State
Satisfaction	Low	6.91
FCP	High	4.86
FLU	Continue previous use	-5.665
CCP	High	-12.03
CLU	Crop	-37.08
Access Forest Resources	Yes	

8.5.5.3 Sub-model (iii): Properties of landholding

This sub-model is made up of a grouping of variables that represent the physical properties of a landholding. The change in belief states was simulated by varying the node states for the nodes M (Rainfall), V (distance to stream) and G (status in village). The results shown in Table 8.10, indicate minor changes in the belief states for all the nodes except Field properties which shows an increase of 43% in the belief that field properties will be poor with a decreasing rainfall. This is matched by a drop in belief of 15% in the state of current land use being used for crops. Figure 8.13 illustrates the changes in belief state at the nodes of the landholding sub-model.

Table 8.9: Properties of landholding sub-model outputs

Node	State	% Change in Belief State
Satisfaction	High	-0.95
FCP	High	0.60
FLU	Continue previous use	-0.80
CCP	Medium	0
CLU	Crop	-15.74
Field Properties	Poor	43.13

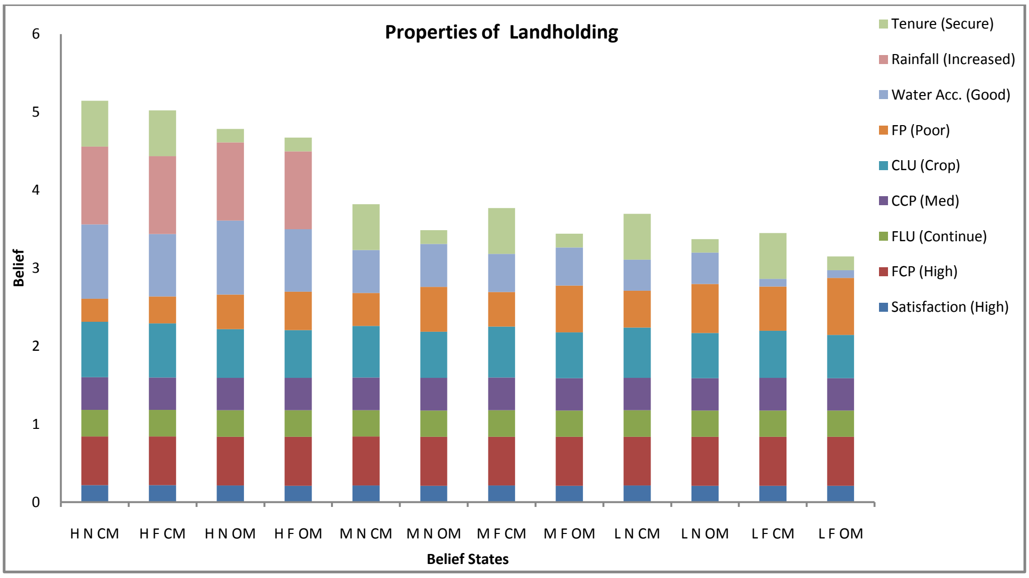

Figure 8.13: Properties of landholding sub-model. The chart shows various belief states and their corresponding belief levels for the *Properties of Landholding* sub-model. The belief states are: Satisfaction (High) = state 'High' at node *Satisfaction*, Tenure (Secure) = state 'Secure' at the node *Ownership (Tenure)*, Rainfall (Increased) = state 'Increased' at the node *Rainfall*, Water Acc. (Good) = state ' Good' at node *Access to Water*, FP (Poor) = state 'Poor' at node *Field properties*, CLU (Crop) = state 'Crop' at node *Current Land Use,* CCP (Med) = state 'Medium' at node *Current Crop Productivity*, FLU (Continue) = state 'Continue' at node *Future Land Use*, FCP (High) = state 'High' at node *Future Crop Productivity.*

8.5.5.4 Sub-model (iv): Local interventions

The sub-model represents the local interventions on land use and are simulated with a decrease in the belief state of node Y (Local action). The results show very little change in the belief states of satisfaction and the other variables except for a decrease of 98% in the belief that extension services will be provided. This is supported by an increase in belief of 69% that no interventions will occur to assist the local stakeholder as shown in Table 8.10 and Figure 8.14.

Table 8.10: Local interventions sub-model outputs

Node	State	% Change in Belief State
Satisfaction	High	-2.30
FCP	High	1.58
FLU	Continue previous use	-1.87
CCP	Medium	0
CLU	Crop	0
Interventions	No	69.45
Extension Serv.	Yes	-98

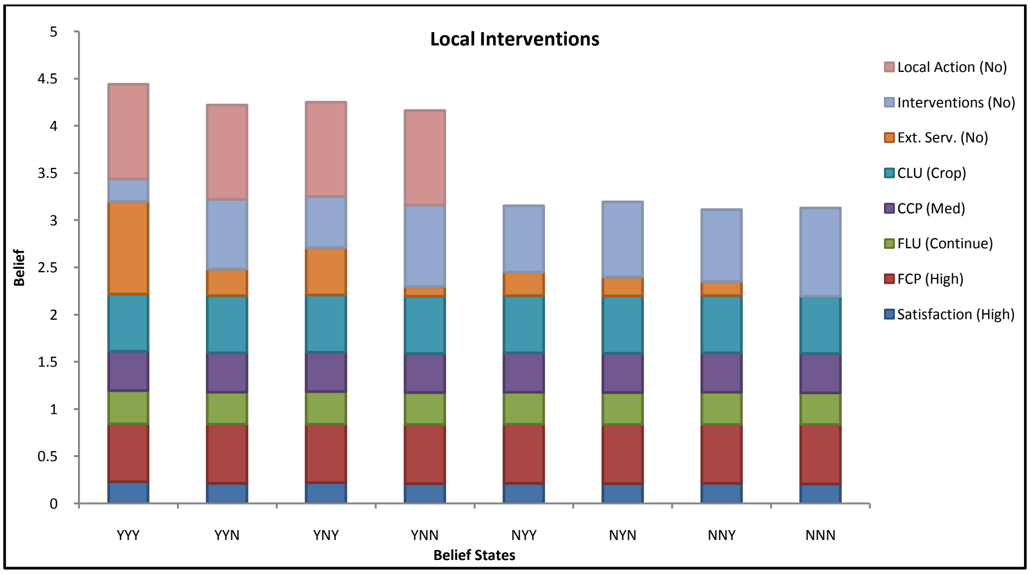

Figure 8.14: Local interventions sub-model. The chart shows various belief states and their corresponding belief levels for the *Local Interventions* sub-model. The belief states are: Satisfaction (High) = state 'High' at node *Satisfaction*, Local Action (No) = state 'No' at the node *Local Action*, Interventions (No) = state 'No' at the node *Interventions*, Ext. Serv. (No) = state 'No' at node *Extension services*, CLU (Crop) = state 'Crop' at node *Current Land Use,* CCP (Med) = state 'Medium' at node *Current Crop Productivity*, FLU (Continue) = state 'Continue' at node *Future Land Use*, FCP (High) = state 'High' at node *Future Crop Productivity.*

8.5.5.5 Sub-model (v): Land use restrictions

The sub-model simulates the change in belief states arising from land use restrictions. It uses a decrease in the state of the belief for land policy awareness to induce change in the other states. The results in Table 8.11 and Figure 8.15 show that belief states for the management variables hardly change. This sub-model does not seem to have an impact on the management objectives.

Table 8.11: Land use restrictions sub-model outputs

Node	State	% Change in Belief State
Satisfaction	High	-0.48
FCP	High	0.33
FLU	Continue previous use	-0.40
CCP	Med	0
CLU	Crop	-1.70
Policy Awareness	Yes	0

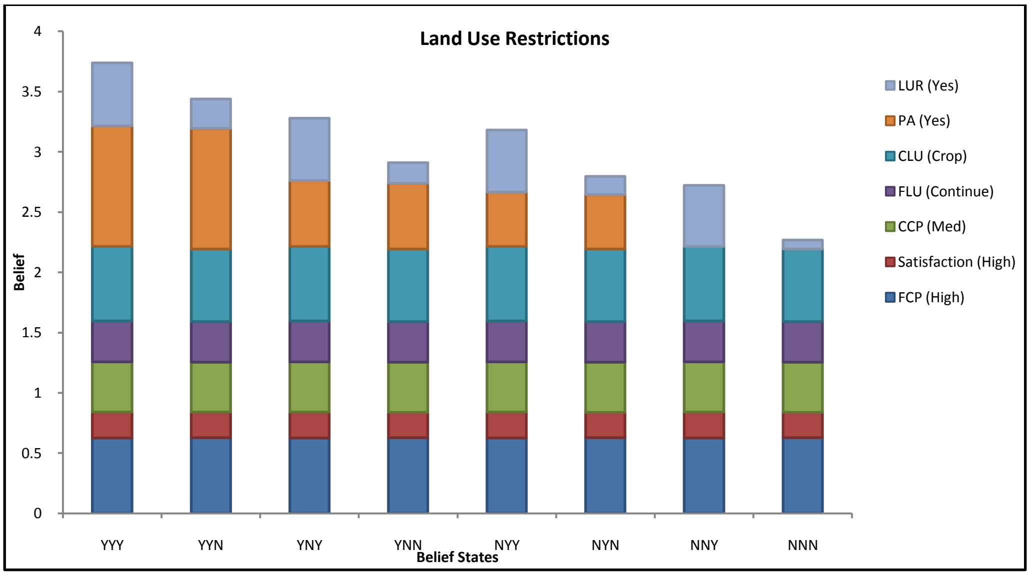

Figure 8.15: Land use restrictions sub-model. The chart shows various belief states and their corresponding belief levels for the *Land Use Restrictions* sub-model. The belief states are: Satisfaction (High) = state 'High' at node *Satisfaction*, LUR (Yes) = state 'Yes' at the node *Land Use Restrictions*, PA (Yes) = state 'Yes' at the node *Policy Awareness*, CLU (Crop) = state 'Crop' at node *Current Land Use,* FLU (Continue) = state 'Continue' at node *Future Land Use*, CCP (Med) = state 'Medium' at node *Current Crop Productivity*, FCP (High) = state 'High' at node *Future Crop Productivity.*

8.5.6 Summary of sub-model impacts

The investigation of the impacts of the five sub-models has shown that the sub-model for location of landholding has the highest effect on the management objective, satisfaction. The access and productivity sub-model ranks second in impact on satisfaction followed by the properties of landholding sub-model. The sub-models local interventions and land use restrictions barely have any impact at all on the satisfaction variable.

Table 8.12: Summary of change in belief state for satisfaction

Sub-model	% Change in Belief State
Location of landholding	23.85
Access & productivity	6.90
Properties of landholding	-2.30
Local interventions	-0.95
Land use restrictions	-0.48

It is not clear from the results above why the Location of Landholding and the Access & Productivity sub-modules have more influence on the management objective based on change in belief state and why the others do not as shown in Table 8.12. Cain (2001) suggests that increased distance of a node from the management objective may affect how much effect it has. Since the changes in state were obtained by changing the belief state from the maximum value to the minimum value, it can be concluded that the distance of the nodes being varied has caused this for some sub-models. This is illustrated by the Land use restrictions node which showed the least impact in the analysis carried out.

8.6 Summary

This chapter has shown how the potential application of BN models to environmental management can reveal trends not immediately visible. Firstly the testing of the Maposa BN model showed that the model scored well in respect of the three error measures of logarithmic loss, quadratic loss and spherical payoff. The spherical payoff scores for Maposa of between 0.6 and 1.0 are indicative of a good accuracy assessment according to Marcot et al.

(2006). The error rates also indicate that the BN model had a good predictive accuracy for the network. A comparison with the scores obtained using data from Kalulushi District collected a year earlier for the Kalulushi BN model showed that the Kalulushi BN model generally achieved poorer scores compared to the Maposa model. This could be attributed to the low number of cases used for the Kalulushi data. Only 17 cases were used for the pilot study compared to 364 cases used for the Maposa model.

Having achieved good scores for model performance, it was then decided to test how well the Maposa BN model worked by carrying out sensitivity tests on the model. This was done in two ways: Firstly a sensitivity analysis that compared and ranked the influences of the various nodes on the management objective, 'Satisfaction' by transect. Secondly, model performance was tested by investigating the impact of changes in node states of groupings of variables also called sub-models.

The results of the transect analysis showed the potential to use BNs as a tool for targeted and prioritised action by Land Managers within large management areas. The results for the analysis by sub-module provided insight into the effect groupings of variables could have on the management objective. The results of the two approaches are tabulated in Tables 8.13 and 8.14 showing the influence of single variables and groupings of variables on the level of Satisfaction with land use. This has an effect on the land-use decision making.

Table 8.13: Ranking of impact on Satisfaction by sensitivity analysis of nodes

Rank	Node
1	*Future Land Use*
2	*Future Crop Productivity*
3	*Current Crop Productivity*
4	*Location of Landholding*
5	*Income*
6	*Distance from Road*
7	*Current land use / Distance to Market*
8	*Field properties / Current Land Use*
9	*Access to Forest Food Resources / Field Properties*
10	*Interventions / Access to Forest Food Resources*
11	*Extension Services*

Table 8.14: Ranking of impact on Satisfaction by sub-model

Rank	Sub-model
1	*Location of landholding*
2	*Access & productivity*
3	*Properties of landholding*
4	*Local interventions*
5	*Land use restrictions*

It can be seen from Table 8.13 that the first two rankings refer to the back propagation of probabilities in the network. However, starting from rank 3 onwards, the top 5 nodes that have influence on satisfaction are Current Crop Productivity, Location of Landholding, Income, Distance from Road and Current Land Use. These however, do not match exactly with the ranking in Table 8.14. This suggests that there is no direct match of the impacts of the two approaches although in both approaches, location of a land holding and access to land and productivity rank highly. A factor that does not appear in both approaches is that of access to firewood. This factor does not seem to impact satisfaction significantly. From Table 8.2, it ranks a lowly 23. This would seem to suggest that the distance to firewood is not an issue that is taken into account by the local stakeholders.

A key strength of the BN model is the inclusion of a wide variety of variables which encompass the physical, regulatory and social components which affect land use decision making. It is suggested by Pradhan et al. (1996) and Reckhow (1990) that error measures can be improved by using larger data sets. This may not always be possible.

A weakness of the model is that few variables have a direct link to the management objective although they do have indirect influence. It is a reflection of the difficulty of modelling a multidimensional entity like satisfaction.

Chapter 9 Modelling land-use decision-making using decision trees

9.1 Introduction

This chapter introduces decision trees as means of understanding the land-use decisions made by stakeholders. They will be used to model characteristics of local stakeholders' land-use decisions based on their agricultural activities in order to infer their land-use decisions.

The application of how BNs developed from the SSM conceptual model have been used to test and to infer decision-making by local stakeholders has been investigated. A comparative approach is to use data mining approaches and in particular, machine learning for automated learning from the data. This allows for the extraction of hidden patterns from the data and helps interpret their meaning. This approach will utilise Decision Trees as a tool to help identify patterns from which learning may occur to assist in land-use decision-making.

9.2 Machine learning

Machine learning is described by Langley & Simon (1995) as the study of computational methods for improving performance by mechanizing the acquisition of knowledge from experience. They further state that machine learning aims to provide increasing levels of automation in the knowledge engineering process, replacing much time-consuming human activity with automatic techniques that improve accuracy or efficiency by discovering and exploiting regularities in training data. Machine learning techniques generate decision tables, trees, or rules that are easily understood and are most compatible with human reasoning (Provost & Kohavi, 1998; Langley & Simon, 1995; Witten & Frank, 2005). In a review of applications of machine learning, Langley & Simon (1995), outlined the diversity in applications and pointed out the main branches as neural networks, instance-based learning, genetic algorithms, rule induction and analytic learning. They cited numerous examples of the application of the rule induction method ranging from credit decisions, diagnosis of mechanical devices, and astronomy to monitoring of quality in a production process. This research used rule induction methods and in particular, classification trees to investigate land-use decision-making in the Copperbelt Province.

9.3 Decision trees

Classification is an important problem in data mining and has been studied extensively as a possible solution to the knowledge acquisition problem (Garofalakis et al., 2003). The input to a classifier is a training set of records, each with attribute values tagged with a class label. There are two types of attributes: those with discrete domains often referred to as categorical and those with ordered domains often referred to as numeric. The aim of classification is to induce a concise description for each class in terms of the attributes also called a model. This resulting model is then used to classify future records with unknown classes (Garofalakis et al., 2003; Pal, 2006). There are many different techniques for classification including, Bayesian classification, neural networks, genetic algorithms and decision tree classifiers (Garofalakis et al., 2003; Pal, 2006; Witten & Frank, 2005; Quinlan, 1992). Among them, decision tree classifiers have found the widest application range. Garofalakis et al., (2003) cite four main reasons for their widespread usage:

i) Firstly, decision trees offer a very intuitive representation that is easy to assimilate and translate to standard database queries compared to the other classifiers;

ii) Decision tree induction is very efficient and suitable for large data sets compared to training neural networks which can take thousands of iterations and large amounts of time;

iii) Decision trees do not require prior knowledge of statistical distributions of the data;

iv) The accuracy of decision tree classifiers is comparable to that of the other classification techniques

The next sub-section will now address the description of what a decision tree is and how the classifier works.

9.3.1 Description of a decision tree

A decision tree classifier is a non-parametric classifier that does not make any prior statistical assumptions about the distribution of the data. It is a predictive model that uses a tree-like graph to model the outcomes of sequential tests. A review of the construction of decision trees is addressed by Quinlan (1992) and Safavian & Landgrebe (1991). Decision tree techniques follow a top-down induction strategy also called the "divide and conquer" approach to decision tree induction and build tree-like sequential graph models that have branches, nodes and leaves that can be easily translated into a set of mutually exclusive decision rules (Witten & Frank, 2005: 105).

The basic structure of a decision tree consists of a root node, a number of internal nodes and a set of terminal nodes. Each leaf node of the tree corresponds to a rule while a branch represents the conjunctions of the features that led to the classification (Witten & Frank, 2005; Quinlan, 1992). A decision tree can be used to classify a case by starting at the root of the tree and moving through it until a terminal node is encountered. At each non-terminal node, a test is carried out on one or more attributes. Once the outcome of the test for the case is determined, attention is then shifted to the root of the sub-tree corresponding to this outcome. When this process finally leads to a leaf, the class of the case is predicted to be that recorded at the leaf (Quinlan, 1992). In other words, the data are recursively divided down the decision tree according to the defined classification framework and at each node, a decision rule is needed for use as a splitting test (Otukei & Blaschke, 2010).

9.3.2 Building the classification tree

The process involved in the construction of a tree is outlined by Quinlan (1992) by using an example of set training cases, T.

Given a set of training cases, T, denoted $\{C_1, C_2, \ldots, C_k\}$ there are three possibilities to be considered:

i. T contains cases all belonging to a single class, C_j,

   The decision tree for T is a leaf identifying class C_j.

ii. T contains no cases.

   The decision tree is a leaf but the class to be associated with the leaf must come from information other than T.

iii. T contains cases that belong to a mixture of classes.

In this situation, T is refined into subsets of cases that are or seem to be heading towards single class cases. A test is chosen based on a single attribute that has one or more mutually exclusive outcomes $\{O_1, O_2, \ldots, O_n\}$.

T is partitioned into subsets $T_1, T_2, \ldots, T_n$ where T_i contains all cases of T that have outcome O_i of the chosen test. The decision tree for T consists of a decision node identifying the test and one branch for each possible outcome. This is illustrated in Figure 9.1 showing the structure of a tree.

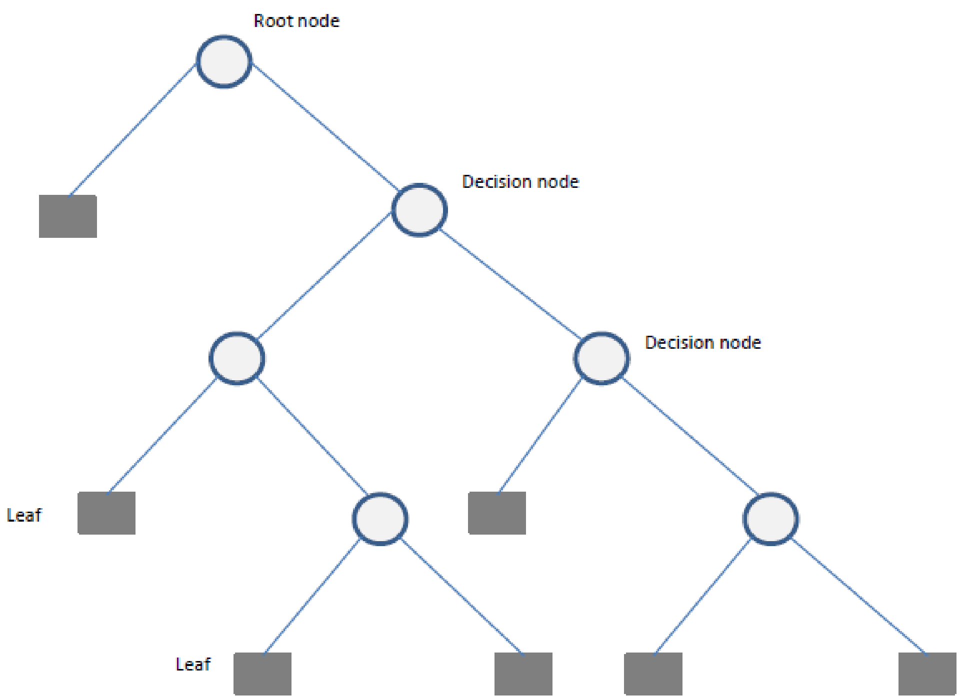

Figure 9.1: Structure of a decision tree.

Most decision tree classification algorithms contain two distinct phases: a building phase followed by a pruning phase. In the building phase, the data set is recursively partitioned until all the records have been partitioned to form a 'perfect' tree. This is then iteratively 'pruned'. The pruning is performed to prevent overfitting the model to the training dataset. It is better to use a smaller imperfect data set for training in order to avoid statistical bias (Garofalakis et al., 2003; Quinlan, 1992).

The resulting decision tree is tested on a test data set provided one is available. If no training data set is available, the classification algorithm performs a cross-validation on the entire data set. The cross-validation is carried out by dividing the data into a fixed number of partitions or folds. If the number of folds for cross-validation is x, then $\left[\frac{x-1}{x}\right]$ of the training data is used to construct the model and $\left[\frac{1}{x}\right]$ of the training data is used to test the model. This process is then repeated x times so that all the training data is used exactly once in the test data. The x different error estimates are then averaged to yield an overall error estimate. While extensive tests on numerous datasets have shown that ten-fold cross-validation is one of the best numbers for getting an accurate error estimate, other values can be used. Varying the number of folds will change the dataset for the training data, and may change the accuracy of the decision tree.

The flexibility of decision trees for handling data in the form of continuous and categorical variables and ancillary or missing data supports their use in environmental management applications and especially for land cover classifications from remotely sensed data (Brown de Colstoun & Walthall, 2006; Garofalakis et al., 2003; Pal, 2006; McCarty et al., 2007; Otukei & Blaschke, 2010; Witten & Frank, 2005). They, however, have not been applied to land-use decision-making analysis and will be tested for their possible application to land-use decision making.

It is important to note that even after pruning, the decision tree structures that are induced can be complex, with hundreds and sometimes thousands of nodes which may make it impossible for human comprehension and interpretation. This has also been made worse by the high data volume multi-dimensional training data sets that are increasingly available especially for decision support applications. It is a serious problem that can affect the understanding and application of the resulting trees. This is part of an active research area into decision tree induction methods (Garofalakis, 2003).

9.4 Choice of software

The platform chosen for use in this research is the WEKA (Waikato Environment for Knowledge Analysis) program, version 3.4 (Witten & Frank, 2005). It provides numerous machine learning algorithms from various learning paradigms. The algorithm that was used in this research is the J4.8 Classifier developed by Witten & Frank (2005) and is based on the C4.5 Classifier originally developed by Quinlan (1992). The WEKA platform was chosen because its J4.8 classifier is able to process continuous and categorical data input simultaneously for classification. This property was found to be most suitable for the data set.

9.5 Application of the J4.8 decision tree classifier to the Maposa data set

In order to model the characteristics of the local stakeholders land use decision characteristics using the decision tree approach, the Maposa data set was used as data input into WEKA software. The program was run with the test mode set for a 10-fold cross-validation on the entire data set. The output was set to show the characteristics within the attributes that would be most prominent for different crop combinations grown by the local stakeholders. The data set that was used contained attributes of individuals whose location was noted using GPS during the questionnaire survey. The rationale of the process was to plot the classification output in a GIS and show the spatial distribution of crop combinations grown in the study area together with other characteristics. This would then allow for the development of a spatial model of the land use decision making process for local stakeholders who have encroached into the protected forests. The flowchart outlining the process is shown in Figure 9.2.

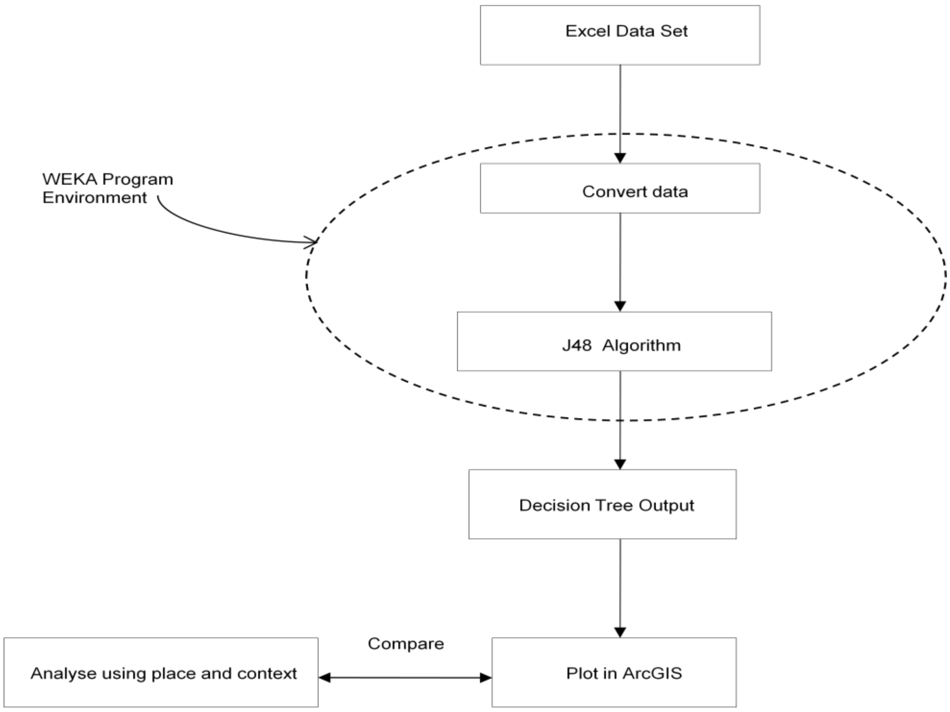

Figure 9.2: Flowchart showing process of using WEKA and GIS to explore land use decisions.

WEKA reads in spreadsheet or database files to use for analysis. A sample of the input file before and after conversion to the arff file format used by WEKA is shown in Figures 9.3a and 9.3b. The sample shown in the figures has 9 attributes to be considered and each instance of the data is listed in separate rows.

Crops_Comb.csv - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J
1	STATUS	RAIN	S_AGE	REP_VH	LU_RST	CROP_SEL	FWOOD_D	EPM_IND	CROPS	
2	CM	INCREASED	5	Y	Y	N	VN	N	CTLF	
3	OM	INCREASED	14	N	N	SOME	VN	Y	CT	
4	CM	DECREASED	5	Y	N	N	VN	N	CTLV	
5	OM	INCREASED	9	Y	N	SOME	F	N	CTL	
6	CM	INCREASED	3	N	N	N	F	N	CFT	
7	CM	DECREASED	15	N	N	N	VN	N	CTLV	
8	CM	INCREASED	16	N	N	SOME	VN	N	CTL	
9	CM	INCREASED	20	N	N	SOME	VN	N	CTLF	
10	CM	INCREASED	10	N	N	N	VN	N	CTLF	
11	CM	INCREASED	7	N	N	N	VN	N	CTL	
12	CM	INCREASED	15	Y	Y	SOME	VN	N	CTL	
13	CM	DECREASED	15	Y	N	N	VN	N	CT	
14	CM	INCREASED	17	Y	Y	N	VN	N	CTLF	
15	CM	INCREASED	23	Y	Y	N	VN	N	CTLF	
16	CM	DECREASED	15	N	N	N	VN	N	CTL	
17	OM	INCREASED	7	N	N	SOME	VN	N	CTL	
18	CM	INCREASED	19	N	N	N	VN	N	CTL	
19	CM	INCREASED	33	N	N	SOME	VN	N	CFTFSH	
20	OM	INCREASED	16	Y	N	N	VN	N	CTL	
21	OM	DECREASED	11	N	N	N	VN	Y	CTL	
22	OM	DECREASED	24	N	N	N	VN	N	CL	
23	OM	DECREASED	14	N	N	N	VN	Y	CTL	
24	CM	DECREASED	21	N	N	ALL	VN	N	CTLV	
25	OM	INCREASED	10	N	N	N	VN	N	CT	
26	OM	INCREASED	5	N	N	N	VN	N	CFT	
27	OM	INCREASED	15	N	N	N	VN	N	CTL	
28	CM	INCREASED	16	N	N	ALL	VN	N	CFT	
29	OM	INCREASED	13	Y	N	ALL	VN	Y	CTLF	
30	CM	DECREASED	5	Y	N	N	VN	Y	CFT	
31	OM	INCREASED	4	Y	Y	N	VN	Y	CTL	

Crops_Comb.csv

Figure 9.3a: Chart showing the input file before conversion to the arff file-format.

```
@relation Crops_Comb.csv

@attribute STATUS {CM,OM,O}
@attribute RAIN {INCREASED,DECREASED}
@attribute S_AGE numeric
@attribute REP_VH {Y,N}
@attribute LU_RST {Y,N}
@attribute CROP_SEL {N,SOME,ALL}
@attribute FWOOD_D {VN,F,N}
@attribute EPM_IND {N,Y}
@attribute CROPS
{CTLF,CT,CTLV,CTL,CFT,CFTFSH,CL,CTLVF,CTV,CLF,CVL,CVFL,CV,CTLVFSH,TF,C,CTVF,TLF}

@data

CM,INCREASED,5,Y,Y,N,VN,N,CTLF
OM,INCREASED,14,N,N,SOME,VN,Y,CT
CM,DECREASED,5,Y,N,N,VN,N,CTLV
OM,INCREASED,9,Y,N,SOME,F,N,CTL
CM,INCREASED,3,N,N,N,F,N,CFT
CM,DECREASED,15,N,N,N,VN,N,CTLV
```

Figure 9.3b: Chart showing the input file after conversion to the arff file-format. The header shows the filename and attributes. The data section shows the instances and their attribute states.

In Figure 9.3a, the attributes are represented by the columns. Each row represents a record or instance of the data. Each instance is shown with various state combinations of the attributes. The attributes shown in Figure 9.3a are described in Table 9.1.

Table 9.1: Meaning of Attribute abbreviations

Attribute	Representation
STATUS	*Status in village hierarchy*
RAIN	*Perception of annual rainfall in area*
S_AGE	*How long local stakeholder has lived in area*
REP_VH	*Fear of repossession of landholding by village head*
LU_RST	*Land use restrictions?*
CROP_SEL	*Are crops grown for sale?*
FWOOD_D	*Distance to firewood*
EPM_IND	*Is individual aware of any environmental degradation in area?*
CROPS	*What are the crop combinations grown?*

The arff file format used by WEKA is illustrated in Figure 9.3b. Firstly, the source file is listed at the top and in this case, it is listed as *@relation Crops_Comb.csv*. This is followed by the list of attributes and their possible states. The attribute STATUS is listed as *@attribute STATUS {CM,OM,O}*. This means that the attribute STATUS can take on any of the 3 possible categorical values, CM, OM and O. If the attribute is ordered, it shall have the suffix *numeric* next to the attribute name in the file. An example is the attribute S_AGE which is numeric. Some attributes may have a lot of possible states, such as the attribute CROPS which has 18 possible states. Finally, each instance is shown on its own line below the heading *@data* with the various attribute states that it has taken on. Table 9.2 shows the attributes, their possible states and their meaning.

Table 9.2: Attribute states and their meaning

Attribute	State	Meaning of Attribute State
STATUS	CM OM O	Village Committee Member Ordinary Member Other
RAIN	INCREASED DECREASED	Perceived High Rainfall Perceived Low Rainfall
S_AGE	Numeric	Length of time Local stakeholder has lived in area
REP_VH	Y N	Yes - Fears repossession of landholding by Chairman of Village Committee No - Does not fear repossession of landholding by Chairman of Village Committee
LU_RST	Y N	Yes - Land Use Restrictions in place No - Land Use Restrictions not in place
CROP_SEL	N SOME ALL	No - Do not sell any crop harvest at all Some - Sell some of the crop harvest All - Sell all the crop harvest
DIST. FIREWOOD	VN N F	Distance to Firewood ≤ 500m Distance to Firewood is between 500m and 1,000m Distance to Firewood ≥ 1,000m
EPM_IND	Y N	Yes - Individual believes that there is environmental degradation in area No - Individual does not believe that there is environmental degradation in area

(Table 9.2 continues overleaf)

Table 9.2 (continued): Attributes states and their meaning

Attribute	State	Meaning of Attribute State
CROPS	CTLF	Cereal, Tuber, Legume, Fruit
	CT	Cereal, Tuber
	CTLV	Cereal, Tuber, Legume, Vegetables
	CTL	Cereal, Tuber, Legume
	CFT	Cereal, Fruit, Tuber
	CFTFSH	Cereal, Fruit, Tuber, Fish-Farming
	CL	Cereal, Legume
	CLTVF	Cereal, Legume, Tuber, Vegetable, Fruit
	CT V	Cereal, Tuber, Vegetables
	CLF	Cereal, Legume, Fruit
	CVL	Cereal, Vegetable
	CVFL	Cereal, Vegetables, Fruit, Legume
	CV	Cereal, Vegetables
	CTLVFSH	Cereal, Tuber, Legume, Vegetables, Fish-farming
	TF	Tuber, Fruit
	C	Cereal Only
	CTVF	Cereal, Tuber, Vegetables, Fruit
	TLF	Tuber, Legume, Fruit

A look at the detailed output in Appendix E.3 from the WEKA classification run for the first approach has two sections: the *'run info'* section and the *'classifier model'* section. The file name and attribute information are shown in the *'run info'* section including the test mode which has been chosen as the 10-fold cross-validation.

The *'classifier model'* section for this case shows that *DIST. FIREWOOD* is at the root of the tree and determines the first decision. The first decision is that for the state *DIST. FIREWOOD=VN* and *Dist. Market=VN*, then when *RAIN=INCREASED*, the crop combination *CTLF* will be grown. For this case, 3 instances were correctly classified. This leaf is pure as there are no instances misclassified by the model. However, when *RAIN=DECREASED* at this node, the tree shows that environmental considerations and the length of stay in the settlement are further determinants in the choice of crop combination to grow. The presentation of the decision tree in the form given in Appendix E.3 can easily become complex to interpret. A graphical structure form which is easy to read is also presented as an option to the output in the WEKA environment. This is depicted as a tree structure with nodes and leaves in Figure 9.4.

The resulting classification tree for the first approach is depicted in Figure 9.4 and the summary of accuracy measures from WEKA is shown in Table 9.3. Similarly, the resulting classification tree for the second approach is shown in Figure 9.5 and the corresponding summary of accuracy measures listed in Table 9.4. The detailed outputs of these two program runs are recorded in Appendix E.3 and Appendix E.4.

The resulting classification tree for the third approach is shown in Appendix E.6 due to its size. The corresponding summary accuracy measures for the third approach from WEKA are shown in Table 9.5 and the detailed run information is shown in Appendix E.5.

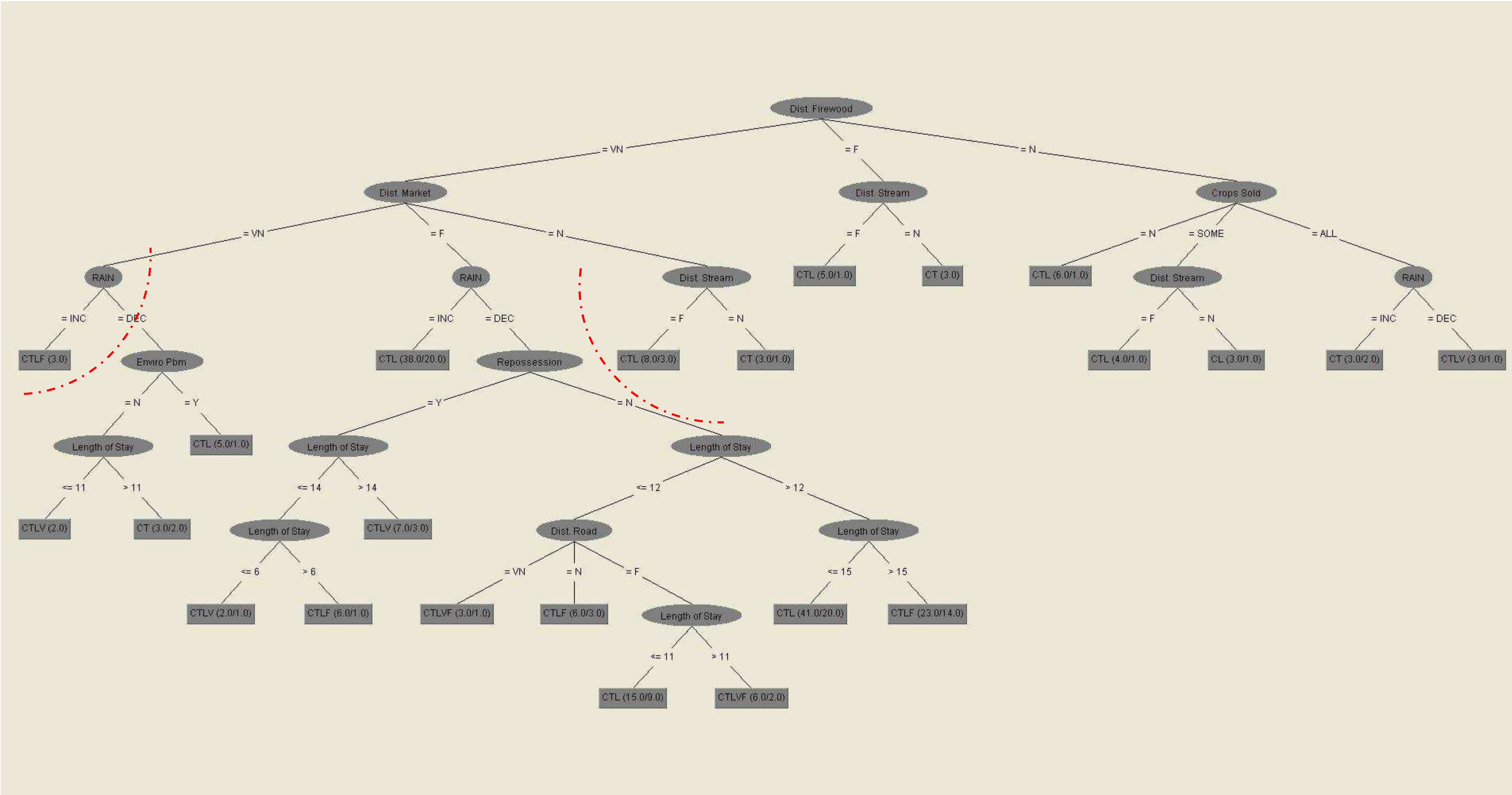

Figure 9.4: Classification tree 1 without policy considerations taken into account. The area between the arcs at node *Dist. Market* is different from that in Figure 9.5 although the rest of the tree is exactly the same. This shows the environmental and social considerations that were taken into account when arriving at decisions at node *Dist. Market* for this tree.

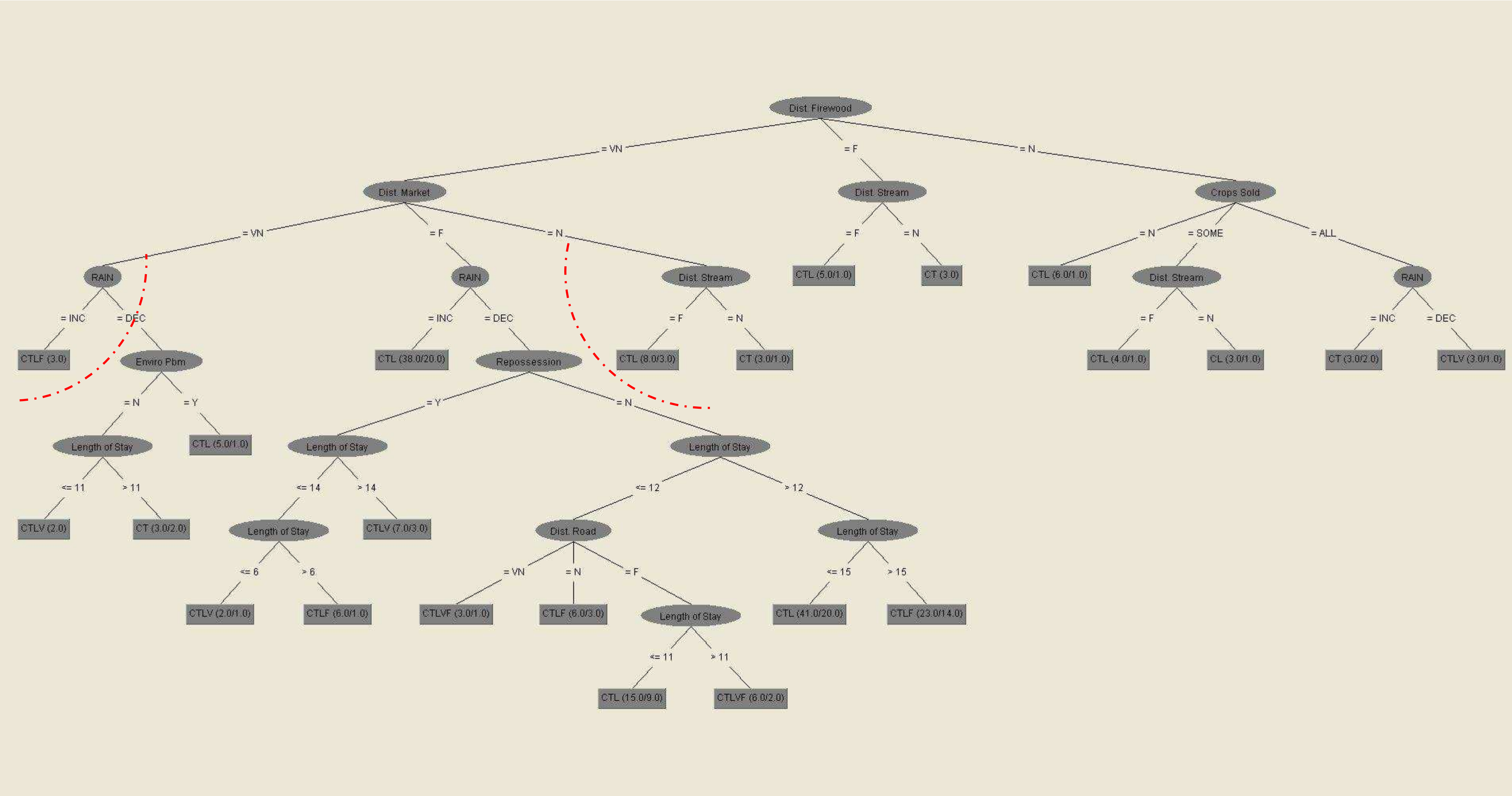

Figure 9.5: Classification tree 2 with policy considerations taken into account. The area between the arcs at node *Dist. Market* is different from that in Figure 9.4 although the rest of the tree is exactly the same. This shows the policy considerations that were taken into account when arriving at decisions at node *Dist. Market* for this tree.

Table 9.3: Accuracy measures for tree 1

TP Rate	FP Rate	Precision	Class
0.727	0.636	0.421	CTL
0.243	0.168	0.25	CTLF
0.231	0.038	0.3	CT
0.048	0.051	0.1	CTLV

Number of leaves:	23	
Size of leaves:	41	
Correctly Classified Instances	69	34.8485 %
Incorrectly Classified Instances	129	65.1515 %
Kappa statistic	0.0607	
Mean absolute error	0.1093	
Root mean squared error	0.2608	
Relative absolute error	95.8587 %	
Root relative squared error	109.8471 %	
Total Number of Instances	198	

The stratified cross-validation gives an indication of the error levels during the 10-fold cross-validation process. The kappa statistic measures the agreement of the prediction with true class. A value of 1 signifies complete agreement. The other error measures are useful for regression tasks (Witten & Frank, 2005).

The True Positive (TP) rate in Table 9.3 is the proportion of instances classified as class x among all instances which truly have class x. It is similar to Recall in the confusion matrix. The False Positive (FP) rate is the proportion of instances which were classified as class x but belong to a different class among all instances which are not of class x. The Precision is the proportion of instances which truly have class x among all those which were classified as class x. The Confusion Matrix, also known as a Contingency Table, shows what classification the instances from each class received when they were used as testing data during the classification.

Table 9.4: Accuracy measures for tree 2

TP Rate	FP Rate	Precision	Class
0.675	0.471	0.477	CTL
0.486	0.224	0.333	CTLF
0.308	0.022	0.5	CT
0.048	0.085	0.063	CTLV

Number of leaves: 26

Size of leaves: 46

Correctly Classified Instances	75	37.8788 %
Incorrectly Classified Instances	123	62.1212 %
Kappa statistic	0.1371	
Mean absolute error	0.1039	
Root mean squared error	0.2569	
Relative absolute error	91.1164 %	
Root relative squared error	108.184 %	
Total Number of Instances	198	

Table 9.5: Accuracy measures for tree 3

TP Rate	FP Rate	Precision	Class
0.784	0.68	0.471	CTL
0.243	0.147	0.258	CTLF
0.047	0.078	0.067	CTLV

Number of leaves: 42

Size of tee: 75

Correctly Classified Instances	157	38.8614 %
Incorrectly Classified Instances	247	61.1386 %
Kappa statistic	0.0538	
Mean absolute error	0.0808	
Root mean squared error	0.2163	
Relative absolute error	94.8137 %	
Root relative squared error	105.3546 %	
Total Number of Instances	404	

9.6 WEKA output for classification tree 1 and classification tree 2

Tables 9.3 and 9.4 show that the trees shown in Figures 9.4 and 9.5 incorrectly classified more than 60% of the instances and the relative and absolute errors were quite poor. However, both trees identified 4 significant crop combinations which presented themselves as classes for the leaves in both trees. The order of significance of the classes is shown in the two tables with the most significant being crop combination class CTL and the least significant CTLV. These were ranked by using the TP rates of the crop combinations in both cases. The 4 main crop combinations in decreasing order are ranked in Table 9.6.

The root factor that characterises the individuals in the area is distance to firewood which is the main node *DIST. FIREWOOD* of the trees. The tree structure is the same for the branches where distance to firewood is far denoted by *F* and near denoted by *N*. Differences between the trees appear from the node *Dist. Market*. The area bounded by the two red arcs drawn onto the figures indicates where differences in the two tree structures lie.

Table 9.6: Ranking of top 4 crop combination types

Rank	Crop Combination	Crop Types
1	**CTL**	*Cereal, Tuber, Legumes*
2	**CTLF**	*Cereal, Tuber, Legumes, Fruit*
3	**CT**	*Cereal, Tuber*
4	**CTLV**	*Cereal, Tuber, Legumes, Vegetables*

Considering classification tree 1, from the node *Dist. Market*, it shows that for individuals who are not aware of policy, when the distance to collect firewood is very near and the distance to the market is far, rain will be the next influential factor. If the rainfall increases, they will tend to grow the most common crop combination, CTL. If however the rainfall decreases then they will tend to take into consideration other factors related to the security of their tenure.

Looking at the same node, *Dist. Market*, for classification tree 2, it shows that for those who are aware of policy, when the distance to the market is far and firewood is very near, awareness of Land Policy, LP, is the most influential and that those not aware of it are instead influenced by the Forest Policy in their considerations leading to the choice of crops to grow.

The branches from the node *DIST. FIREWOOD* were plotted in ArcGIS by creating rules based on the descriptions to show the geographical distribution of where the various crop combinations are grown. Figure 9.6 shows the spatial distribution representing access to firewood for node *DIST. FIREWOOD*.

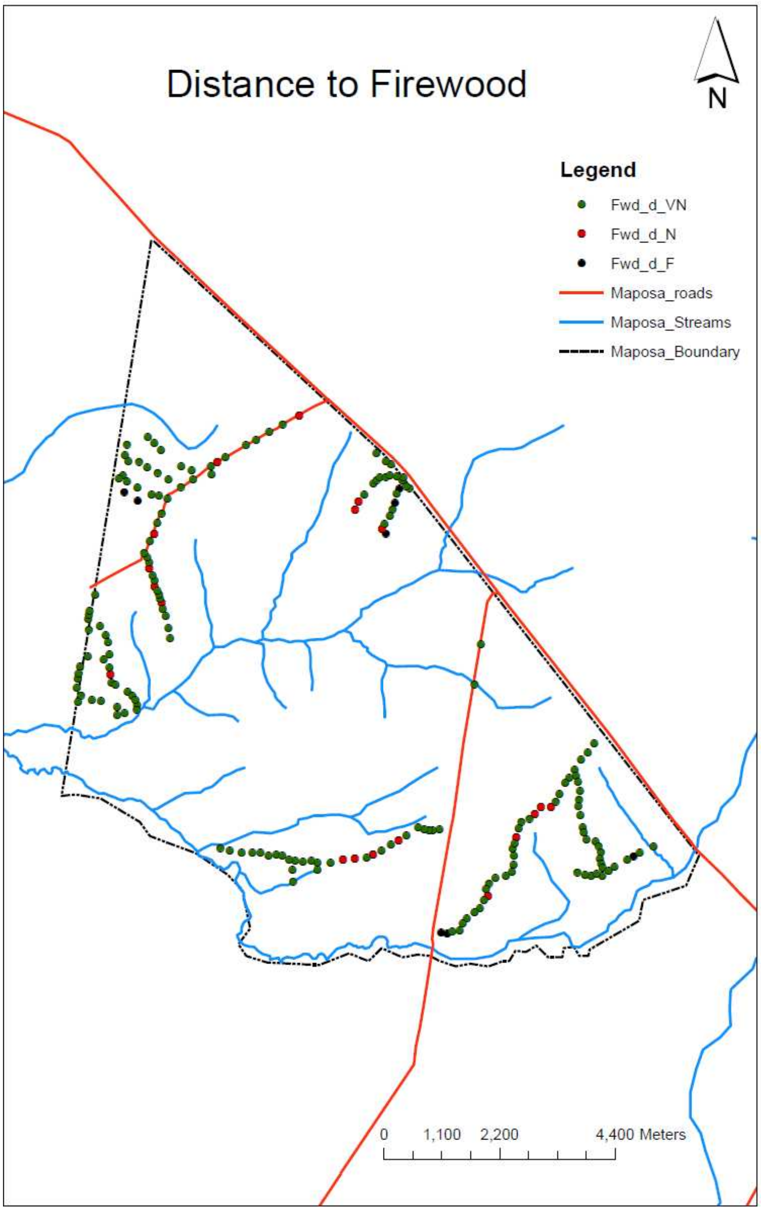

Figure 9.6: Distance to firewood. The green dots show where respondents said distance to firewood, D< 500m; the red dots D is between 500m to 1km and black dots D > 1km.

Figure 9.6 shows that the majority of individuals are able to access firewood within 500m from where they live. The crop distributions are shown in Figure 9.7. The distribution of the crop combinations does not show any discernible pattern although crop combination CTL is quite widespread over the study area. The node *Dist. Market* has 171 instances out of the total 198 instances entered into the analysis. This implies that the other factors at this node do not have much influence. The branch F at node *Dist. Market* has a cumulative 147 instances in both trees.

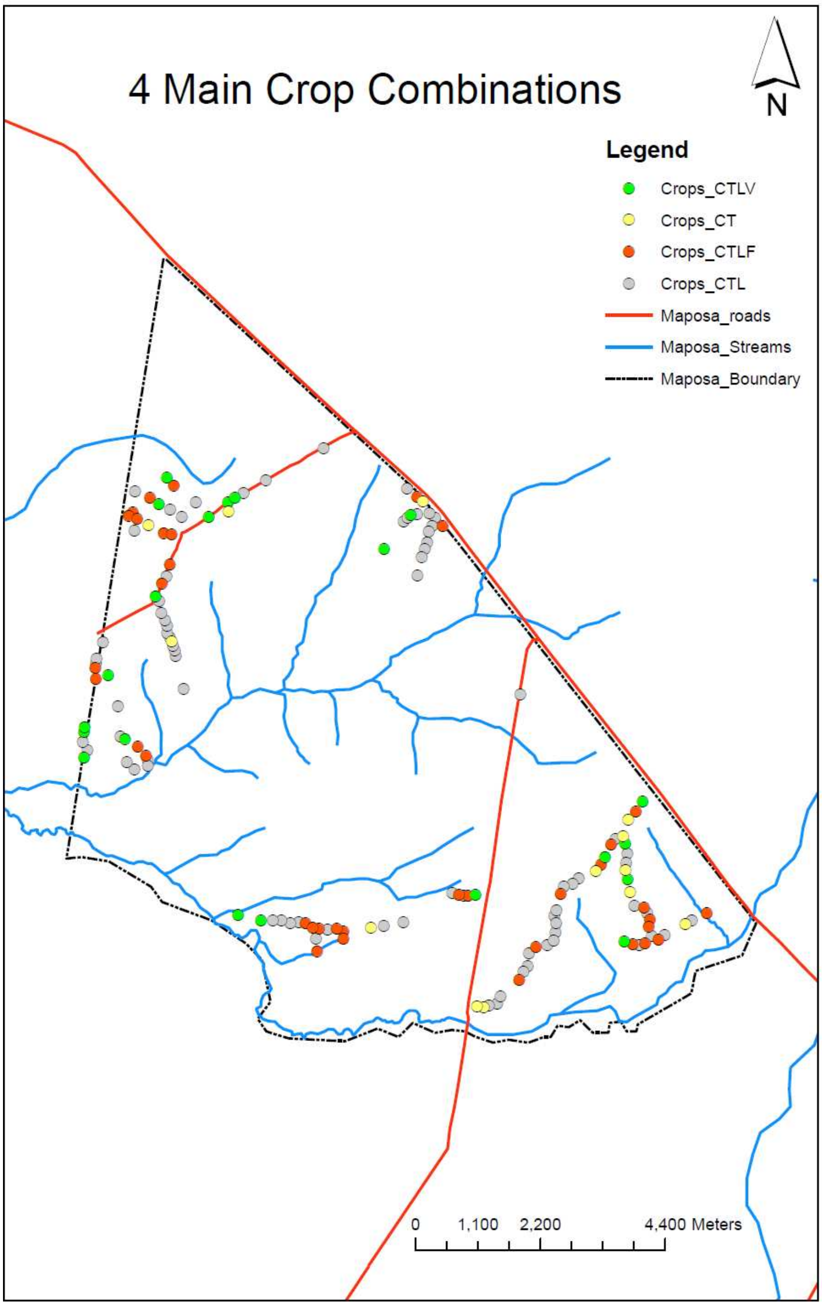

Figure 9.7: Crop distribution for the 4 main crop combinations. The dots show the distribution of the 4 main crop combinations CTLV, CT, CTLF and CTL in the Maposa Local Forest study area.

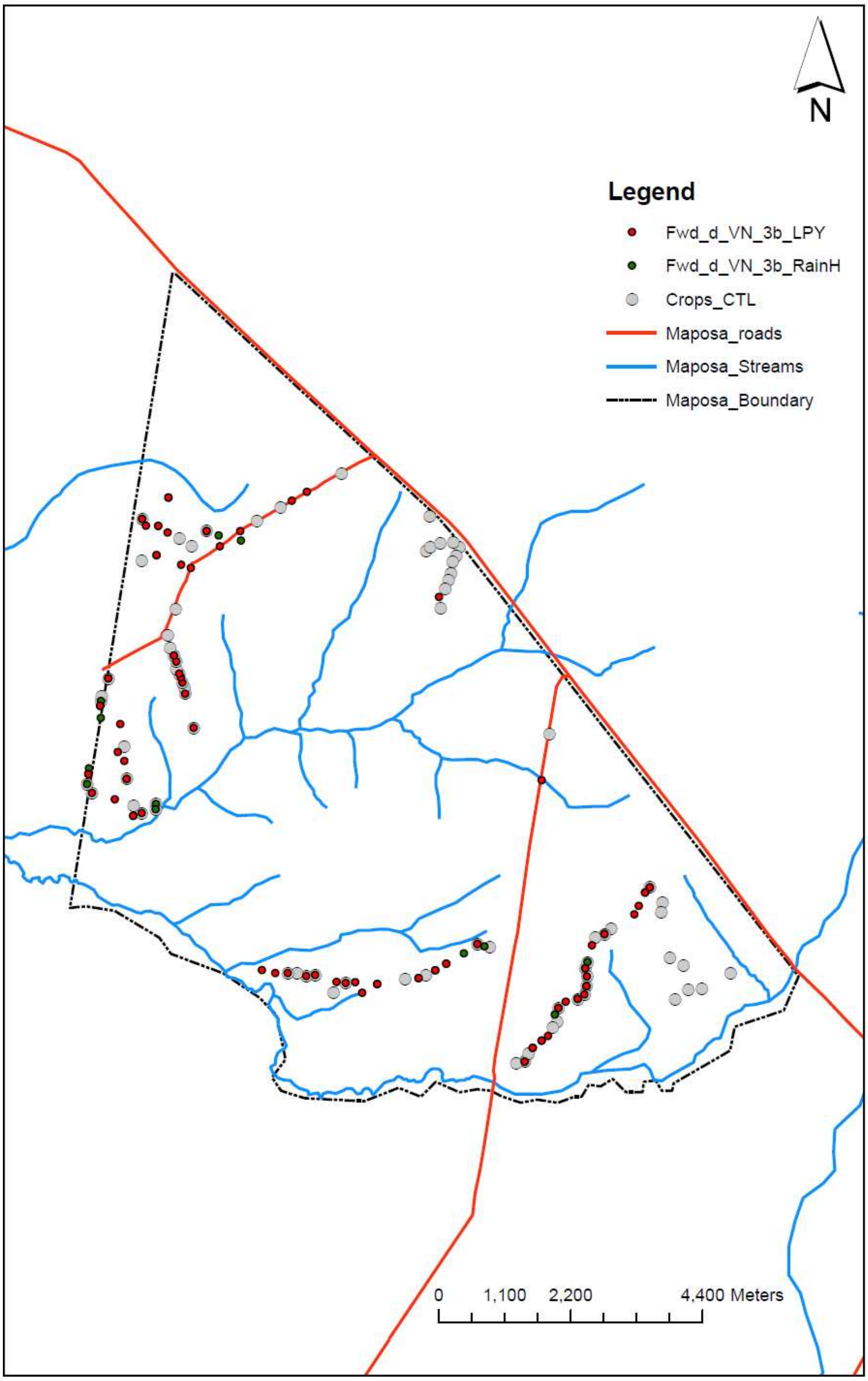

Figure 9.8: Land policy, rain and the main crop distribution. The red dots show where distance to firewood, D< 500m and Land Policy considerations are taken into account. The green dots show where distance to firewood, D< 500m and Rainfall is considered. The grey dots show the distribution of the crop combination CTL.

Figure 9.8 shows an overlay of instances where there is an awareness of land policy from classification tree 2 and instances where rain is perceived to be high. These are shown with the main crop combination CTL distribution as the background. Both trees become very difficult to interpret beyond this node level. Figure 9.9 illustrates the output for high rainfall, distance to firewood very near and without any policy considerations with the crop combination CTL in the background.

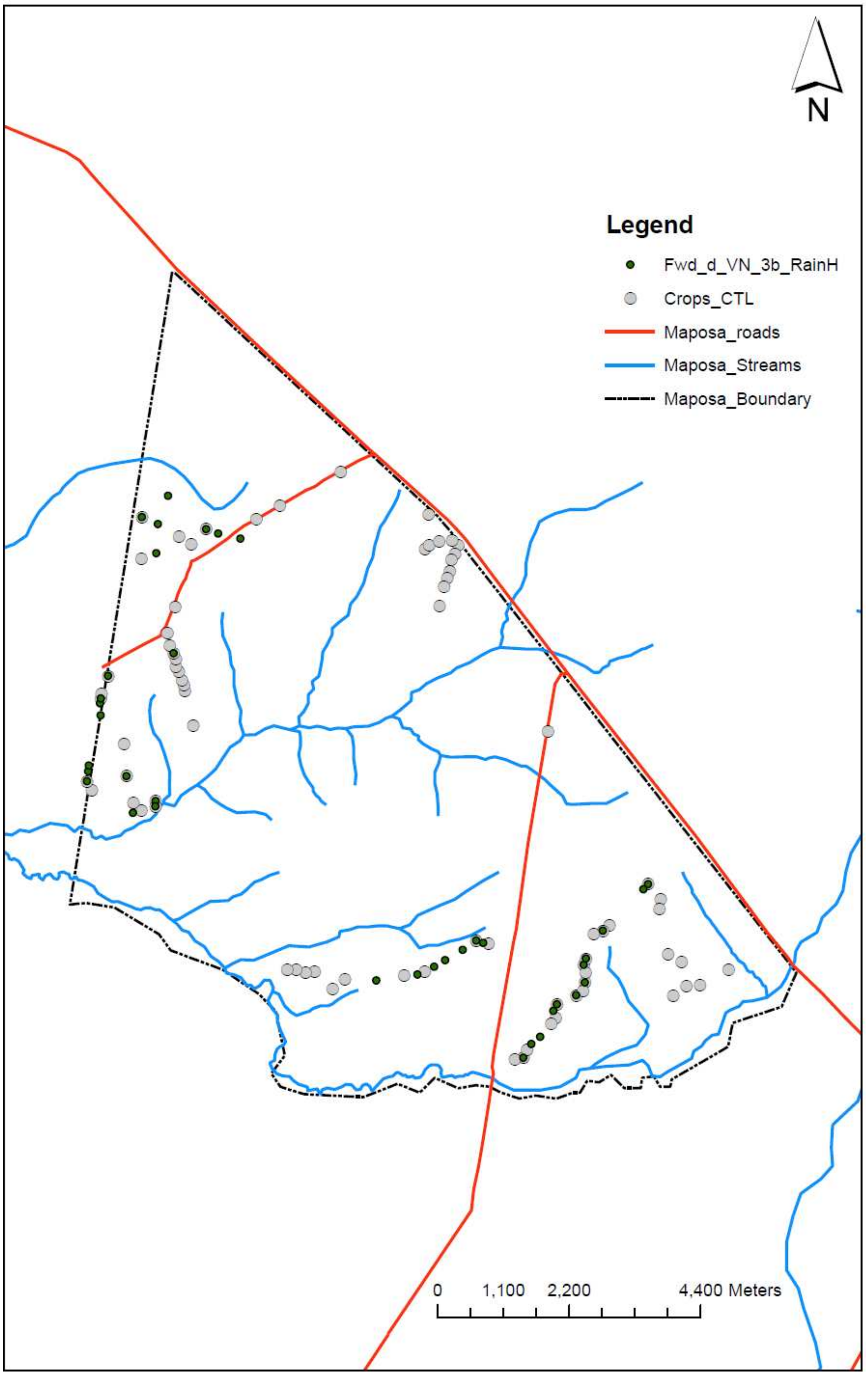

Figure 9.9: Rain and main crop distribution. The green dots show where distance to firewood, D< 500m and only change in Rainfall is considered. The grey dots show the distribution of the crop combination CTL.

Looking at the distribution of crop combinations in Figures 9.6 and 9.7, the influence of distance from the stream is not apparent. Distance to main road does not seem to influence the choice of crops either. Only access to firewood seems to affect the decisions, but even so, 86% of those sampled claim that they do not have to go far for firewood. These are widespread in the sampled locations. All the other factors seem to have minimal influence. Access to water was found to be an issue both when distance to firewood was far and was significant when distance to firewood was near and the crops grown were either partially or completely for sale.

The main implication from this comparison is that there seems to be no spatial variation in the activities of local stakeholders represented in this sample. What this implies is that geographic location was not important in influencing land use decision-making.

9.7 Classification tree using all data

What is immediately apparent is that the number of leaves has almost doubled compared to the other two trees. It has 42 leaves and the tree size is 75. The overall classification rate is at 38.8% and the rate of misclassification is at 61.14%. These accuracy rates are comparable to those obtained from the other two trees. Also, looking at the accuracy measures shown in Table 9.7, the tree identifies only 3 most common crop combinations grown in the study area and not 4 crop combinations as with the other two trees. The crop combination identified as being the most popular is CTL followed by CTLF and CTLV.

Table 9.7: Ranking of top 3 crop combination types

Rank	Crop Combination	Crop Types
1	CTL	*Cereal, Tuber, Legumes*
2	CTLF	*Cereal, Tuber, Legumes, Fruit*
3	CTLV	*Cereal, Tuber, Legumes, Vegetables*

The major discriminating factor was distance to firewood. When distance to firewood was far, i.e. *DIST. FIREWOOD = F*, that is more than 1km away, only rain was taken into consideration followed by how long one has lived at the plot of land. When access to firewood was near, that is between 500m and 1km, there was only one crop combination grown, CTL. However when access to firewood was within 500m, rain was the next major influence and this gave way to socio-economic considerations such as status of the villager in the village hierarchy, and the security of tenure as represented by fear of repossession of landholding. Environmental considerations were also taken into account using the attribute EPM_IND. The size of the tree made it difficult to interpret as more tests were carried out at the nodes approaching the terminal nodes (Quinlan, 1992).

9.8 Summary

This chapter investigated the possible application of machine learning to modelling land-use decisions by using decision trees to highlight the agricultural activity of local stakeholders. Two decision trees were built and were used in conjunction with ArcGIS to examine the spatial distribution of crops grown when there was an awareness of policy and when there was no awareness of policy.

The classification trees showed that there was no spatial variation in the crop-combinations grown and that access to firewood was the main consideration. This is illustrated by the considerations that the local stakeholders had to take into account depending on how far they had to walk to fetch firewood. The majority did not have to go far to collect firewood. This suggests that geographic location did not seem to play an important part in their choice of crop. Given the poor classification rates, it was not possible to build a reliable spatial model of the land-use decisions using this agricultural activity. It shows that land use decisions in the study areas are driven by factors other than agricultural activities alone.

A third classification tree was constructed using all data. This tree confirmed the outcomes of the first two trees. The classification accuracies for all three trees were comparable: tree 1 - 35%, tree 2 - 38% and 39% for classification tree 3.

The classification using all data suggests that the main factors influencing decision-making are

1. Distance to firewood
2. Rain

Most local stakeholders responded that access to firewood is within 500m of their landholding. For those who do not to go beyond that distance to look for firewood, rainfall is an important factor which influences their choices. Whilst *'Increased'* rainfall did not induce a lot of considerations, 'Reduced' rainfall induced social, economic and environmental considerations on the choice of crops to grow.

This method also highlighted the main crop combinations grown by the local stakeholders. Out of the 18 crop combinations, only 3 were significant: CTL, CTLF and CTLV. The 3 crop combinations show that the local stakeholders mainly grow basic food types largely for consumption.

The chapter has shown the possible application of machine learning to aid the understanding and development of land use decisions.

Chapter 10: Synthesis and Discussion

10.1 Introduction

The research has looked at the process of developing a model to help understand local stakeholder decision-making. This is relevant to the issue of environmental degradation which is impacting on human well being (MA, 2003) and is hampering the achievement of the UN MDGs in developing countries (UN, 2007). This chapter presents the results of the work done and seeks to address the issues arising from the work.

This chapter combines the results presented in Chapters 6, 7, 8 and 9 and also addresses issues raised in Chapters 2, 3 and 4 in the context of developing and examining a model of local stakeholder land use decision-making for the encroached forests in the Copperbelt Province of Zambia. The chapter also identifies and addresses the important aspects that contribute significantly to land use decision-making in these areas. Specifically, the discussion focuses on the research objectives:

(1) Can a model of the existing land use decision-making system be developed using SSM?

(2) Can a BN model of land use decision-making using agricultural activity as a basis for analysis be developed using stakeholder perceptions?

(3) Can a decision tree be used to model land use decision-making using agricultural activity as a basis for analysis?

(4) How does national policy relate to the access to and usage of land by local stakeholder?

(5) Can the relationship between the different types of tenure and their related land uses be identified from the existing situation in the Copperbelt Province?

10.2 Understanding gained

This section focuses on the first 3 questions identified for discussion. It looks at a brief description of what has been done, the outcomes and what they mean.

10.2.1 Can a model of the existing land use decision-making system be developed using SSM?

As has been reviewed in Chapter 6, SSM is a 7-stage process of enquiry which is used for the analysis of highly complex areas of real world activity by deriving useful models of purposeful activity in a system and to help structure that complexity (Bergvall-Karebon, et al., 2004; Checkland & Scholes, 1999; Wilson, 2001). Since it places special emphasis on people's perceptions and is iterative, it was considered ideal for use in a participatory context.

The application of SSM in the Copperbelt Province assumed a willingness by all stakeholders to take part in the process. However, the institutional stakeholders were reluctant to participate in the focus group meetings held to conduct the SSM data gathering exercises. This resulted in a modified approach of meeting each group of stakeholders separately and using the information collected as input into the SSM process to develop the root definition and subsequently the conceptual model of the land use decision-making. This process was outlined in section 6.5.

Section 6.5.1 expressed the problem situation of the area as being affected by severe encroachment attributed to a poor economic environment and the shortage of urban land A graphic form of representation, the rich picture, shown in Figure 6.2, depicted the complex processes operating in the encroached forest areas. It outlined the complex organisational structure, transformations that occur and the concerns of the various actors in the system. The rich picture in Figure 6.2 showed that the local stakeholders derive satisfaction from the use of the forest resources.

A root definition (RD), (Checkland & Scholes, 1999), of the problem situation was then derived. From the rich picture it can be inferred that the human activity of small scale agriculture was a problem relevant to the management of the Maposa Local Forest and Chibuluma National Forest areas. The main input for transformation selected in this research was the *'requirement for sustainable land use'*. The RD in this context for the observed problem situation was, therefore, defined as:

A system owned by the government and operated by the local authorities to ensure the sustainability of exploitation of resources in protected areas which have been encroached upon while considering the views and needs of local stakeholders in *consultation with NGO's and relevant policy and legislation.*

The RD was then tested using the CATWOE analysis as tabulated in Table 6.4 to enhance its coherence before the development of the conceptual model (CM) of the land use decision-making process.

The CM is a set of activities necessary to carry out the transformation process central to the RD. The CM that was developed is illustrated in Figure 6.3 and consists of 7-sub-models. Each of the sub-models was further analysed in Appendix B.7 and B.8. The CM outlined the process leading to the choice and implementation of a particular land use. The CM was compared to the real world by raising strategic questions about present activities. This was done by asking what features of the model differ from present reality and why. The comparative process helped identify how the 7 sub-models were conducted and the possible alternatives to improve the CM. This helped meet the requirements to achieve the transformation. Table 6.5 showed that all the sub-models of the CM were in existence but it is the effectiveness of how they were conducted that was at issue and alternatives were suggested. In light of this the changes for possible improvement of the existing land use decision-making system in the encroached forest areas of the Copperbelt Province were identified in section 6.5.6.

These can largely be seen as improvements of the data collection, storage and retrieval processes, better resource management, investment in technology and most importantly the development of a structured communication process between all stakeholders to allow for information interchange.

The CM that was developed allowed an insight from an institutional perspective: a system owned by the government and operated by the local government as land manager for the affected areas. A further simplification of the CM allowed it to be used as a basis for further analysis of the land use decision-making process using other systems and in the case of this research, Belief Networks.

The process of development CM of the land use decision-making model did not permit the final stage of actually taking action to implement the model. However, it provided an insight into the possible application of SSM in sparse data environments which reflect the situation in many rural and semi-urban areas of Zambia. The CM addresses the need to develop science-based environmental decision-making processes that are able to capture, understand and model local stakeholder perceptions for sustainable management of the environment as suggested by Gutrich et al., (2005).

The procedure adopted in conducting the SSM process raised questions of the accuracy and bias of the model outcomes. Clearly, this was a weakness that needed to be addressed. However, it was identified as a concern early in the research process but the situation on the ground showed that access to most of the encroached areas was restricted because of suspicions between the various stakeholder groups and it would not have been possible to conduct the SSM approach without modifying it. Although SSM has been used mainly for organisations, its application in a participatory context has also been used as shown by Bunch & Dudycha (2004).

Despite the criticism of SSM it is a useful method which allows the analysis of highly complex real world situations (Wilson, 2001). In order to improve the model, SSM exercises have to be conducted that include all stakeholders. This has provided an insight into the application of SSM and in this context has met objective (i) by developing a model of the land use decision-making process currently in use and suggestions to improve the model.

10.2.2 Can a BN model land use decision-making using agricultural activity as a basis for analysis be developed using stakeholder perceptions?

The construction, populating and testing of the BN model was an important aspect of the research. The use of BNs in environmental applications has been widely studied (Cain, 2001; Bacon et al., 2002; Ellison, 2004; Lynam et al., 2004; Marcot et al., 2001). The BN was developed from the SSM model developed to address individual stakeholder perceptions (Figure 6.4). Having identified the sub-models, the combination of different types of data for the construction of the BN model posed a challenge as some of the variables required extraction of data from different sources. A lot of variables were taken into account during the design process and this posed a problem in linking the relationships between the variables. This is a common problem acknowledged by Bashari et al. (2009). A way to address the challenge was to group the variables into themes. Choosing variable states was mainly done using the responses from the questionnaire. The CPTs were calculated using the CPT calculator developed by Cain (2001) and also applied by Bashari et al. (2009) in their work. After developing the basic structure of the BN model, it was populated with data from the Maposa area for further testing. Another model using the same structure but populated with data from the pilot study area in Kalulushi was also created for further testing

The BN models Maposa and Kalulushi, had error measure tests conducted on them as discussed in section 8.4. The Maposa model scored better than the Kalulushi model in all four tests. The most useful of the tests, the spherical payoff showed a good consistency of scores. They were between 1 and 0.6 for the Maposa model. Marcot et al. (2001), recommend a score of 0.8 as being good. Similar trends were observed for the other tests for both models. However, two nodes, U (access to forest food resources) and S (access to firewood), consistently show marked differences between the scores for both models in all tests, with the Kalulushi model scoring poorly in all tests. This could be attributed to the comments by the Director of Planning (DoP) in Kalulushi who observed that the Chamwanza and Icimpe areas in Kalulushi Forest were severely depleted (Appendix B.3). The local Chairman in Chamwanza also suggested that plot sizes were small and had little vegetation (Appendix B.6). Further analysis of the model behaviour was performed using a sensitivity analysis of the network to help shed some light on the findings. This was done by looking at the influence of model variables on the variable '*Satisfaction'*, the management objective, in relation to land use decision-making.

A sensitivity analysis of the network was done for the nodes of BN model Maposa, to identify which nodes have the most influence on the management objective. However, due to the sparse number of cases for the Kalulushi model, it was decided not to proceed further with sensitivity testing of the Kalulushi model.

Sensitivity analysis was carried out in two ways, firstly by carrying out an analysis of the network using all the data; by using partitions of the data divided into transects and by using sub-models of the BN model as depicted in Figure 8.10. This permitted the analysis of the impact of groupings of variables on the management objectives and the analysis of partitions of data subdivided according to the transects used in data collection. Table 10.1 shows a ranking from the comparison of the two approaches. The results do not show any direct matching since the transect approach looks at the impact from single nodes whilst the sub-model approach looks at the impact of groupings of nodes on the management variable.

Table 10.1: Comparison of two sensitivity analysis approaches

Ranking	**Sensitivity by Transect**	**Sensitivity by sub-model**
1	Current crop production	Location of landholding
2	Location of landholding	Access and productivity
3	Income	Properties of landholding
4	Distance to Road	Local interventions
5	Current land use	Land use restictions

Although cases with geographic coordinates were used for developing the network, the BN is not able in its current form to predict change at a specific location given data from another location. There is no explicit link between the predictions and location. This is an issue that requires further investigation. It has been alluded to by Aalders (2008) as well in an investigation to predict land use decisions in Scotland. It is an active area of current research (Uusitalo, 2007) and is important especially in areas without much data such as the study areas used in this research. The participatory application of BN modelling techniques has been used by Cain (2001) and Lynam et al., (2004) for environmental management applications, but have not been applied to informal settlements as was the case for this study.

Although access to firewood has been assumed to be a very important cause of deforestation, it does not rank highly in Table 10.1. This suggests that access to firewood is not an important consideration taken into account by local stakeholders in arriving at their individual land use decisions. This is both a puzzling and contrary observation to the trends observed by remote sensing. However, it could be an indirect factor arising from the desire to achieve a good crop production for instance. It is not immediately visible, but could be linked through clearing of land for larger fields. This link has not been established and needs further investigation.

An inspection of trends by transect could possibly be linked to a GIS holding land cover change data and could be used to gain more insight into the directions of change and then help a land manager at a village level rather than household level, decide on the appropriate management action. It is clear that individual perceptions provided input into the model but the model was not able to discern individual locations, though it was able to identify and rank the main influences on the management objective, Satisfaction.

It is in this light that the development of a BN model of land use decision-making using agricultural activity as a basis for analysis has been achieved although more work needs to be done to make the model output spatially linked to outcomes of land use decision making in informal settlements.

A key strength of the BN model is the inclusion of a wide variety of variables which encompass the physical, regulatory and social components which affect land use decision making. It is suggested by Pradhan et al. (1996) and Reckhow (1990) that error measures can be improved by using larger data sets. This may not always be possible. A weakness of the model is that few of the variables have a direct link to the management objective although they do have indirect influence. This is a reflection of the difficulty of modelling a multidimensional entity like satisfaction.

10.2.3 Can a Decision Tree be used to model land use decision-making using agricultural activity as a basis for analysis?

The principles of machine learning were used to help model land use decision making using decision trees. The flexibility of decision trees for handling data in the form of continuous and categorical variables and ancillary or missing data has made them useful in environmental management applications and especially for land cover classifications from remotely sensed data (Brown de Colstoun & Walthall, 2006; Garofalakis et al., 2003; Pal, 2006; McCarty et al., 2007; Otukei & Blaschke, 2010; Witten & Frank, 2005). They have not been applied to land use decision-making analysis in informal settlements. They were tested for their possible application to land use decision making.

This was done by using the J4.8 classification algorithm in WEKA. It was employed because of its capability of handling numeric and categorical data input. Two decision trees were induced from the collected data which had coordinate information. The results were analysed in conjunction with a GIS. One of the decision trees used awareness of policy as a factor whilst the other did not. The resulting trees are illustrated in Figures 9.4 and 9.5. A third decision tree using all data collected was induced to classify the main influences on land use decision-making.

For the first two decision trees the main discriminating factor that characterised the individual decision-making in the area is distance to firewood. The tree structure for the two trees is similar for the branches outside the area bounded by the two red arcs drawn onto Figures 9.4 and 9.5. This is where distance to firewood is far denoted by F and near denoted by N. The differences between the trees appear from the node Dist. Market in the area bounded by the two arcs on both figures.

Considering classification tree 1, individuals who are not aware of policy, consider rain to be the next influential factor. If the rainfall is perceived to increase, the tree shows that they tend to grow the most common crop combination, CTL. If however the rainfall is perceived to decrease then they tend to take into consideration other factors related to the security of their tenancy.

Classification tree 2, shows that individuals who are aware of policy, when the distance to the market, Dist. Market, is very near (VN) and distance to firewood, Dist. Firewood, is very near (VN), the influence of Land Policy, LP, is most influential and that those not aware of it are influenced by Forest Policy, FP, instead, in their activities. Geographical location did not seem to have an impact on the type of crop combination choices grown by the local stakeholders as there was no discernible pattern in the GIS plots for both trees. Awareness of policy seemed to have an impact on the choices but it does not show any spatial variation in the GIS plots.

Taking into account the number of cases at the nodes on the decision trees in Figures 9.4 and 9.5, it can be seen that the geographical factors of distance to market and distance to stream are less significant than the socio-economic factors in the choice of crops grown.

The third tree, illustrated in Appendix E.6, revealed a more complex structure in the considerations taken when making a decision. The tree however was used reveal the ranking of the most popular crop combinations in the study area.

An examination of the third decision tree confirmed the outcomes of the first two trees. The classification successes for all three trees were comparable: tree 1 - 35%, tree 2 - 38% and 39% for classification tree 3.

The classification output from the third tree using all data suggests that the main factors influencing decision-making are

1. Distance to firewood
2. Rain

Most local stakeholders responded that access to firewood is within 500m of their landholding. For those who do not to go beyond that distance to look for firewood, rainfall is an important factor which influences their choices. High rainfall did not induce a lot of considerations, but low rainfall induced social, economic and environmental considerations on the choice of crops grown.

Although the resulting error rates were poor, the decision trees provided an insight into the distribution of crop combinations in the study area. Out of the 18 crop combinations recorded in the study area, only 3 were most significant: CTL, CTLF and CTLV. They are tabulated in Table 9.7 and point to basic crop types which are grown largely for consumption thus indicating a subsistence type of agriculture.

This approach has shown the possible application of decision trees to aid the understanding and development of land use decisions. In this context, objective

(iii) was achieved but more needs to be done to improve the outcomes of the analysis.

10.2.4 A comparison of the Belief Network and Decision Tree approaches

A general comparison of the output from the BN model and the decision tree approach is shown in Table 10.2. It lists the main influences observed for the particular situation in decreasing order of importance. The ranking for the BN model uses all the data, while the decision tree approach uses a sequential ranking and uses the crop combinations grown by individuals as a basis to infer individual decision making.

Table 10.2: Comparison of influences of BN and Decision trees

BN model	Decision trees
Current crop production	Distance to firewood
Location of landholding	Distance to Market & Stream, Rain
Income	Access to water, Land Policy
Distance to Road	Forest policy
Current land use	Security of tenure

Looking at Table 10.2, the BN approach suggests that decision-making is influenced the most by agricultural activities as shown by the ranking of current crop production. However, with the machine learning approach, distance to firewood is the most influential characteristic. What is apparent is that distance to essential utilities ranks highly for the Decision tree approach while in the BN approach it ranked second to current crop production. The ranking shown does not take into account the number of cases where this occurs for the Decision tree approach. When that is taken into account, the geographic factors fall off and only the socio-economic factors have an influence on the decision making. This can be seen graphically in Figures 9.4 and 9.5 by looking at the area of the tree between the two arcs.

There is another possible interpretation when the influences are ranked as in Table 10.2. It is not immediately possible to observe that the two approaches seem to complement each other. Since the most influential factor in the BN approach is the current agricultural activities, a closer look at the decision tree approach shows that all the factors here are influences on the growing of different crop combinations and this is clearly related to ‘current crop production’ in the BN model approach.

The decision tree that was run using all data confirmed the result that distance to firewood was the major influence on the activities followed by rain. This is clearly an indication that the local stakeholders practise rain-fed agriculture.

The BN developed was only able to help make predictions at a village level and not the household level. The application of decision trees confirmed the lack of spatial variation in crops grown but most importantly highlighted the potential application of this method in conjunction with the BN modelling process.

It can then be concluded that the BN approach and the decision tree approach are complementary to each other and need to be used together to model and understand land use decision-making processes.

10.3 Policy Considerations

This section will now look at the policy considerations of the situation in the study area.

10.3.1 Evaluation of national policies with respect to access and usage of land

A review of the land and forestry policies in Zambia by Chileshe (2005) found that they were undergoing reform to make them participatory in approach. What was of concern was that the process of reforming the policies was not very transparent as only a few organisations and individuals participated in the process especially for the Land Policy review. The existing policies were not participatory. In his review, Chileshe (2005) also addressed the effect of changes in land tenure practices in Customary Land in Zambia. He found that land tenure reform must aim to secure land rights for individuals and households to ensure sustainable livelihoods through guaranteed access to and control of the usage of natural resources. This requires community participation in the planning and making of decisions for sustainable environmental management. Since the settlements in the study area did not have legal status, access to and usage of land was not guaranteed. What came out from the meetings with the local stakeholders is that they were anxious to have title to the land so that they could be able to make good use of their land (Appendix B.4, B.5 & B.6). What it implies is that before they have title they feel as if they are not obliged to use the land in a sustainable manner. The NGO, Bridge International, claimed that local stakeholders were generally surviving from one day to the next (Appendix B.2). They were of the opinion that the informal settlers were in 'survival mode' focussing on basic survival. According to the Provincial Forestry Office, steps to reassign the land use from forestry to agriculture have not been followed correctly (Appendix B.1) and political expediency has tended to overshadow the processes (Appendix B.2).

The confusion regarding whether the informal settlers can be assisted with development infrastructure is a source of concern and is alluded to by the Provincial Forestry Office (Appendix B.1). From the foregoing, it can be seen that more needs to be done to reform the national policies to address issues of access and usage. If this is not done, further encroachment into other protected areas may occur with an overall negative impact on the environment.

10.3.2 The identification of the relationship between the different types of tenure and land related uses

In the study area used in the research, there was only one form of land tenure and that is illegal informal tenure. This type of tenure is not a secure type of tenure as shown in Chapter 4 which looked at the evolution of land tenure in Zambia. The settlers in the encroached areas of forest do not have security of tenure. The land use that has been observed in the study area is that of subsistence agriculture. This has resulted in the extensive clearing of forest to make room for agricultural activity. The bordering areas were commercial farming lots but the owners did not avail themselves for the study. What has been observed is that with the informal type of tenure the sizes of the land lots vary and in most cases there are no clear boundaries between the land lots resulting in conflicts over boundaries. It had been assumed that the local settlers practised slash and burn agriculture, but the situation on the ground showed that they were settled and fiercely protective over their land lots. This resulted from the encroachment of the forest reserves by people moving from the surrounding towns. This is demonstrated by the mixed ethnic origin of the local stakeholders. The protective approach and suspicion of outsiders made it very difficult for the researcher to measure the sizes of the land lots, permission had to be sought to obtain GPS fixes from the locals.

There were no traditional power structures to support the assumption that the local stakeholders were indigenous people from the area. What were in place, however, were village committees with a chairman or villager leader and these were linked to the ruling political party structure. It was therefore not possible to compare the different types of land uses with the tenure because of the single type of tenure prevalent in the area. It was not possible to evaluate the effect of national policy on tenure because of the informal nature of the settlements.

10.4 The application of land use decision modelling methods investigated

This section addresses the practical relevance of the methods used to model land use decisions in the study area and Zambia in general.

10.4.1 Application of soft systems methodology

SSM has the potential to be useful in the context of Joint Forestry Management (JFM) in the study area as a tool to facilitate the joint management of natural resources. The Provincial Forestry Officer acknowledged the difficulty of evicting illegal settlers from the protected areas and actually suggested that it is easier to engage them in discussion on the way forward than to evict them (Appendix B.1). He further acknowledged that local people are best placed to understand issues on the ground. In this context, SSM allowed for the exploration of alternative ways to address the sustainability of exploitation of resources in conjunction with all stakeholders.

Furthermore, the advocacy role played by NGO's can benefit from the use of SSM through the provision of a communication channel between local stakeholders, NGO's and both Local and Central Government (Appendix B.2). In fact, Bridge International stated that *"...it is a matter of the government and the people to* work *together. We are doing our part as NGO's to help them and the people are accepting it..."* (Appendix B.2), suggesting that although they were suspicious, local stakeholders were willing to work with the government. The failure by government representatives to attend any of the meetings organised with the local communities is a sign of the lack of a direct communication channel between the various stakeholders.

The application of SSM enables different stakeholders to participate in the process and ultimately give them ownership of the decisions that may result from the solution of problems identified in the process. It is suitable for situations where eliciting of information about conditions prevailing in an area is required as demonstrated in Appendices (B.4, B.5 and B.6) and in helping find a way to address the various issues identified. Trained facilitators can work with the community focus groups to resolve local problems as well as with various institutional stakeholders from different organisations to address issues on a larger scale. They can assist stakeholders with the process of developing conceptual models.

SSM can therefore be considered suitable for application at community level with the help of trained facilitators. It is useful for identifying problems and can assist in helping to develop possible solutions.

The strength of SSM is that it encourages wider participation in community problem solving and helps address the complex real world situations which are not easily defined. This may lead to ownership of the process and solution by stakeholders. It however has the weakness of being susceptible to biases in the definition of problems and their solutions if not carefully done.

10.4.2 Application of belief network modelling

BN modelling has the potential for application to planning of land use. The capability of BN to taking both categorical and ordered data as input renders them very useful in areas such as the study area with complex issues and which can generate a variety of input variables to consider in the simulation of the decision-making process. The complexity of data that BNs can handle can be seen by looking at Appendix A.3 which contains the complex variables generated by the questionnaires in Appendix (A.1 and A.2).

BN's are the next logical step from SSM as they can help provide predictions of impacts of variables on the chosen management objective. Their ability to use different sensitivity tests to check the impacts of single variables or groupings of variables on the management objectives makes them ideal for use in addressing existing or potential problem areas in the land use of an area or region. Important, though, is the ability to use a phenomenon called back propagation to model the impacts given the probabilities of the potential causes in the belief network and also the modelling of the causes given the probabilities of the impacts within the BN. This feature of BN has enabled the modelling of complex decision situations.

BNs are best situated at either the local government level or central government level as land managers because of their high analytical and technical nature required to manipulate them. BNs are also useful for analysing land use decision-making in informal settlements where they can be used to model highly complex models. Their visual structure makes them easier to understand without necessarily understanding the complex mathematics on which they are based. However, at present, it is unlikely that the district councils in Zambia have the technical staff to run and maintain such a system. This is in light of the serious staffing shortages outlined by the Director of Planning (DoP) in Kalulushi (Appendix B.3) and the Provincial Forestry Office in Ndola (Appendix B.1). Once designed, it is however possible to train some people to maintain and run the system. Another option would be to work with the universities to help run the BN system. The strengths and weaknesses of Belief networks have already been addressed in section 10.2.2

10.4.3 Application of decision tree modelling

Decision tree modelling has shown that it is a useful classification method that can highlight land use decision-making trends. This approach can provide insight into the main characteristics of the decision-making process in the area for which data has been collected and when linked to a GIS can show the spatial characteristics of the decision-making.

In the study, the application of decision trees allowed the identification of the main crop combinations as well as the main influences leading to the crop choices grown. The decision tree approach in the study showed that geographical location in the study area such as the proximity to roads or streams did not influence the local stakeholder choices. They were influenced by two main factors: access to firewood and rain. This is confirmed in the outcomes of the meetings especially the one held at Kalulushi (Appendix B.6) where access to firewood was identified as a problem and that water was also a source of major concern as they only have a perennial stream which dries up for a short time of the year.

The decision tree approach is best suited for deployment at local government level as it can be used as a tool for rapid assessment of the main influences affecting land use in area by the councils. It can also be deployed at provincial level with central government to carry out rapid assessments of larger areas for planning purposes. As with the BN approach, they require some technical understanding and will therefore be faced with similar challenges of finding people who are technically qualified to operate the systems.

10.5 Limitations of the study

This study found the main limitation to be the data collection process. Although there is widespread deforestation in protected areas of Zambia, it was difficult to find a suitable study site that would allow the examination of land use decision making using SSM. This was largely due to the suspicions of local stakeholders who felt threatened that they would be removed from the areas. Once this was overcome, it was the institutional stakeholders instead who were reluctant to participate in the data gathering exercises. This limited the amount of information collected and the type of information gathered. The spatial data collection exercise was also hampered by the same problem because it involved measuring positions using a hand-held GPS. This unfortunately was more sensitive issue to the local stakeholders. So position fixes were only measured at the house and never in the fields.

Consequently this had an effect on the type of analysis that was carried out. Although the SSM process was done, it did not benefit from an active debate that would have allowed the model to be improved. This, however, is something to consider for future work.

10.6 Final comments

This now leads to whether the research questions have been answered. BNs can be used to model stakeholder perceptions with respect to land use decision-making but they clearly require more information sources in order to successfully model the behaviour. This was demonstrated by Aalders (2008); who used a number of different land data sources to complement the process used in developing the model. However in the case of the study areas there are sparse data. This is a common problem in developing countries and methods need to be developed that would allow for the creation of geographic data sets speedily to be used for purposes such as this.

The belief network tool that was developed reflected local stakeholder perceptions about how they view their environment and how they would respond to changes to it. It is a preliminary model and needs more testing using different data sets from different areas to improve its performance. The BN model in the research is a static model. It represents a static but interactive change process by giving the possible direction of change and is complemented by the Decision tree model.

The research has provided an understanding of the land use decisions of local stakeholders in a rural landscape under threat of alteration due to human settlement. The application of the BN and decision tree models has the potential to inform land managers on the directions of change and also lets them decide the appropriate management options to correct the problem situations in conjunction with local stakeholders. If proper management choices are taken, the application of the models has the potential to improve the well being of the local stakeholders in line with the human well-being indicators proposed by the Millennium Ecosystem Assessment (MA, 2003) and perhaps address the MDGs of the UN.

The research has also highlighted the potential of using BNs and decision trees in a participatory approach by simply using the perceptions of their environment by local stakeholders. It is conceivable that when complemented with actual measured data this can be a very useful approach to managing land use.

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Appendix A: Questionnaire employed in the field data collection

The questionnaires in this section were administered to stakeholders with an interest in the environment of, and land use in the Copperbelt Province.

Appendix A.1: Questionnaire for institutional stakeholders

The questionnaire in this section was administered to institutional stakeholders with an interest in the environment of the Copperbelt Province

The University of Nottingham
School of Geography

QUESTIONNAIRE

Towards a Decision Support System for Land and Land-use Allocation in the Copperbelt Province of Zambia.

This study is concerned with the development of a GIS-based Decision Support System that will [i] enable local authorities to perform better spatial decision-making operations for the development and planning of agricultural or forest-product activities and [ii] assist in the design or testing of appropriate mitigation measures and responses. The major challenges are thus twofold: [i] to encapsulate local stakeholder perceptions into a GIS digital decision-making process; and [ii] to produce a set of operational scenarios based on a local trust model. The research aims to addresses these challenges and also to model spatial decision making for land use in Zambia.

N.B. The data which will be provided through this questionnaire will be used ONLY for ACADEMIC purposes.

Date: ..../ August / 2005

Questions for discussion

1. What is the name of your organisation?

2. What is the function of your organisation?

3. What is the role of your organisation in Forestry management?

4. What is the role of your organisation in Land use allocation?

5. How does your organisation fit in to the Forestry Policy?

6. How does its function in relation to the application of the forestry policy?

7. What are the limitations faced in achieving the goals of your organisation with respect to the forest policy?

8. Was the organisation involved in the revision of the Forestry policy?

9. Was the organisation involved in the revision of the Lands policy?

10. What do you perceive to be the positive aspects of the policy?

11. What are your perceived deficiencies in the revised policy?

12. What needs to be addressed in the current policy to make it more effective?

13. To what extent are local stakeholders involved in the development of the policy?

14. To what extent are local stakeholders involved in the implementation of the policy?

15. Is there any supplementary information?

Appendix A.2: Questionnaire for local stakeholders

The questionnaire in this section was administered to local stakeholders in the Maposa Local Forest reserve, Luanshya District and in the Chibuluma National Forest, Kalulushi District.

The University of Nottingham
School of Geography
QUESTIONNAIRE

Towards a Decision Support System for Land and Land-use Allocation in the Copperbelt Province of Zambia.

This study is concerned with the development of a GIS-based Decision Support System that will [i] enable local authorities to perform better spatial decision-making operations for the development and planning of agricultural or forest-product activities and [ii] assist in the design or testing of appropriate mitigation measures and responses. The major challenges are thus twofold: [i] to encapsulate local stakeholder perceptions into a GIS digital decision-making process; and [ii] to produce a set of operational scenarios based on a local trust model. The research aims to addresses these challenges and also to model spatial decision making for land use in Zambia.

N.B. The data which will be provided through this questionnaire will be used ONLY for ACADEMIC purposes.

Date: ..../ August / 2005

1. Position of interviewee in village:

Chief ☐ Headman ☐ Ordinary subject ☐ Other ☐

2. Village name: .... Tribe name: ....

3. Rainfall conditions: High rainfall ☐ Medium ☐ Low ☐

4. How many fields (a) are held, and (b) are they contiguous or separate units?

(a) .... (b) ....

5. How were these fields acquired and when?

Chief or village head ☐ Parents ☐ Spouse ☐ Relatives ☐

Other

When acquired:……………………….

6. If you have not been using the fields for a long time can the Chief or headman give it another person? ☐ Yes ☐ No

7. How do you identify the edges of your fields?

...........................……………………………………………………………..

....

8. Can you erect a fence around your field(s). If not, explain why?

☐ Yes ☐ No

....

9. Have you had any problems before with your neighbours regarding the field boundaries, if so how were these resolved? Yes ☐ No ☐

....

....

10. Can you acquire land anywhere you like in the village? If not, why

Yes ☐ No ☐

....

....

Who restricts? ....

11. Are there any restrictions on the use of land, if yes, what are these restrictions?

Yes ☐ No ☐

....

....

Who restricts? ....

12. Have you heard about the Land Policy?

Yes ☐ No ☐

If yes, were you consulted in it's formulation? ....

Will you be involved in it's implementation? ....

13. Have you heard about the Forestry Policy

Yes ☐ No ☐

If yes, were you consulted in it's formulation? ....

Are you involved in it's implementation? ....

14. What crops do you grow? Do you sell any of your harvest?

....

15. How far do you go to fetch firewood for cooking?

....

16. Can other village members collect firewood or wild fruits or graze their animals in your field(s)? ☐ Yes ☐ No

17. Do you harvest any forest products?

....

18. How can you dispose of your land?

Sale ☐ Rent ☐ Gift ☐ Abandonment ☐ Other ☐

(specify) ....

....

19. Is the Chief or village headman always consulted when a village member wants to acquire or dispose of his land? If not, in which cases is he not consulted?

Yes ☐ No ☐

....

....

20. Do you interact with the district council? If so how? ....

....

....

21. Do you think there is an environmental problem in your area?

Yes ☐ No ☐

22. If your answer to '21' is YES, what is the problem?

....

....

23. How do you think the problem can be solved?

....

....

....

24. Do you think other members of your community are aware of the environmental problem in your area?

Yes ☐ No ☐

25. If your answer to '24' is YES, what have they done about the environmental problem?

....

....

26. Do you think the local Council is aware of the environmental problem in your area?

Yes ☐ No ☐

27. What do you think the Council must do to solve problem?

....

....

....

28. Should the law be changed to take care of the environmental problem in your area?

Yes ☐ No ☐

29. If your answer to '28' is YES, which law should be changed?

....

....

Appendix A.3: Coding of questionnaire administered in 2004 / 2005 field survey

Coding of Questionnaire administered in Aug/Sept 2005.

Heading	**Code**	**Coded Value**	**Coded Heading**
Reference No.	ID	-	**ID**
Group	1	1	**GRP**
Group	2	2	**GRP**
Date of Survey	DOS	-	NIL
Position in village			**STATUS**
Chief	C	1	
Headman	H	2	
Ordinary Subject	OS	3	
Other (Village Committee member etc…)	OT	4	
VILLAGE			**VILLAGE**
Mupundu		1	
Kabe		2	
Tashuka		3	
Buntungwa		4	
Twikatane		5	
Kabulanda		6	
Solwezi		7	
VJ Mwaanga		8	
Chiminwa		9	
Chilangwa		10	
Sekela		11	
Chibote		12	
Tubalange		13	
Natwange		14	
Kosapo		15	
Zambezi		16	
Mwaiseni		17	
Maposa		99	
TRIBE	***Tribe_code***	**Province_code**	**TRIBE**
LAMBA	*1*	1	
BISA	*8*	2	
LALA	*12*	2	
SHONA	*23*	2	
CHEWA	*14*	3	
KUNDA	*28*	3	
LUNGU	*7*	3	
NGONI	*6*	3	
NSENGA	*13*	3	
TUMBUKA	*4*	3	
CHISHINGA	*24*	4	
NG'UMBO	*22*	4	
SHILA	*26*	4	
USHI	*16*	4	
SOLI	*27*	5	
BEMBA	*2*	6	
MAMBWE	*5*	6	

MWACUSA	*19*	6
NAMWANGA	*3*	6
NYIKA	*18*	6
KACHOKWE	*25*	7
KAONDE	*21*	7
LUNDA	*9*	7
LUVALE	*20*	7
LOZI	*15*	8
MBUNDA	*17*	8
NKOYA	*11*	8
TONGA	*10*	9

***Province**	***Province Code**
CB (Copperbelt Province)	1
CP (Central Province)	2
EP (Eastern Province)	3
LP (Luapula Province)	4
LS (Lusaka Province)	5
NP (Northern Province)	6
NW (North Western Province)	7
WP (Western Province)	8
SP (Southern Province)	9

RAINFALL		**RAIN**
LOW	1	
MEDIUM	2	
HIGH	3	

No. of FIELDS		**FIELDS**
X	1	

FIELD SEPARATION		**PROX_F**
SINGLE	1	
CONTIGUOUS	2	
SEPARATE	3	

ACQUISITION OF FIELDS			**H_ACQ**
CHIEF/VILLAGE LEADER	C	1	
PARENTS	PA	2	
SPOUSE	SP	3	
RELATIVES	R	4	
OTHER (Usually PURCHASED)	OT	5	

WHEN ACQUIRED	**DOA**
X	

REPOSESSION BY CHIEF		**REP_VH**
Y	1	
N	2	

IDENTIFICATION OF BOUNDARY		**BDRY_ID**
TREE / VISUAL MARKINGS	1	
CONTROL RIDGE	2	
NATURAL FEATURES	3	
BEACONS / SIGNS	4	

DEMARCATION / BOUNDARY MARKINGS	4	
PATHS / LEAVE SPACE / FOOT STEPS	5	
NOTHING	6	

ERECTION OF FENCE		**FENCE**
Y	1	
N	2	
BLANK	99	

REASON FOR NOT ERECTING FENCE		**NOT_FENC**
AFTER DEMARCATION	1	
LAND NOT ALLOCATED/ DEMARCATED	1	
NOT YET EMPOWERED	1	
NO NEED / NO TIME	2	
NO LAND AVAILABILITY	3	
NO SPACE / LAND SHORTAGE	3	
AREA TOO BIG / IMPOSSIBLE	4	
BLOCKAGE OF ACCESS	5	
FINANCIAL LIMITATIONS / NO MONEY	6	
CAN'T MANAGE	7	
NO STRENGTH / POWER	7	
TOO OLD	7	
CAN ERECT (OR ALREADY ERECTED)	8	

BOUNDARY DISPUTE		**B_DISP**
Y	1	
N	2	

BOUNDARY DISPUTE RESOLUTION		**BD_RSLN**
DISCUSSION WITH NEIGHBOURS	1	
CHAIRMAN / COMMITTEE	2	
THROUGH COOPERATIVE	2	
UNRESOLVED	3	
JUST IGNORE	3	
NO DISPUTE / PROBLEM	4	

NEW LAND ACQUISITION IN VILLAGE		**MORE_AQ**
Y	1	
N	2	

REASON FOR NOT ACQUIRING LAND ELSEWHERE IN VILLAGE		**NOT_AQ**
NO FREE LAND / NO SPACE	1	
NO MONEY	2	
RESTRICTIONS / NEED PERMISSION	3	
ONE IS ENOUGH / CURRENT SIZE IS OK	4	
SATISFIED WITH ONE / NO NEED	4	
TOO OLD / CAN'T MANAGE	5	
HARDWORK / NO STRENGTH	5	
CAN ACQUIRE / ACQUIRED	6	

RESTRICTING AUTHORITY (for land acquisition)		**AQ_RST_A**
COUNCIL	1	
CHIEF / CHAIRMAN / COMMITTEE / COOP	2	
NONE	3	

DON'T KNOW	4	

LAND USE RESTRICTIONS?		**LU_RST**
Y	1	
N	2	
U	3	

TYPE OF LAND USE RESTRICTIONS		**LU_TRST**
NO HUNTING	1	
NO REARING OF ANIMALS	1	
NO QUARELLING	2	
NO USAGE OF LAND BELONGING TO OTHERS	2	
AGRICULTURAL USE ONLY	3	
NEED TO ROTATE CROPS	3	
USE FERTILISER	3	
NO BURNING OF GRASS	4	
NO TREE CUTTING	4	
NO CULTIVATION OF ILLEGAL CROPS	5	
UNAWARE OF / NO RESTRICTIONS	6	

RESTRICTING AUTHORITY (for land use)		**LU_RST_A**
CHAIRMAN	1	
COOP	1	
COUNCIL	2	
GOVERNMENT (Min of Agriculture / Forestry Dept)	3	
NONE	4	

HEARD ABOUT LAND POLICY		**LP**
Y	1	
N	2	
BLANK	99	

CONSULTED IN FORMULATION OF LAND POLICY		**LP_CONS**
Y	1	
N	2	
BLANK	99	

INVOLVEMENT IN IMPLEMENTATION OF LAND POLICY		**LP_INV**
Y	1	
N	2	
BLANK	99	

HEARD ABOUT FORESTRY POLICY		**FP**
Y	1	
N	2	
BLANK	99	

CONSULTED IN FORMULATION OF FORESTRY POLICY		**FP_CONS**
Y	1	
N	2	
BLANK	99	

INVOLVEMENT IN IMPLEMENTATION OF FORESTRY POLICY **FP_INV**

Y	1	
N	2	
BLANK	99	

CROPS GROWN **CROPS**

CTLF	1	
CTLV	2	
CTLVF	3	
CTV	4	
CFT	5	
CVFL	6	
CVL	7	
CTVF	8	
TLV	9	
TLF	10	
CTL	11	
CT	12	
CL	13	
CFT + FISH	14	
TF	15	
CLF	16	
C	17	
CV	18	
CTLV + FISH	19	

***Crop Classification**

Cereal	C
Fruit	F
Legumes	L
Tubers	T
Vegetables	V
Fish	Fish

***Crops**

		*Abbrev.
Cereal:	Maize	M, MA, MZ
	Sorghum	SG, SGM, SO, SR, SGH
	Rice	Rice
	Millet	MI, ML
Tubers:	Cassava	C, CA, CSV
	Sweet Potatoes	SP
	Potatoes	P
	Yams	YAM
Fruit:	Banana	BA, BAN
	Oranges	OR
	Lemon	L, LE
	Fruit	Fruit
Legumes:	Groundnuts	GN, G/NUTS, NUTS, NT
	Beans	B, BE, BNS
	Soya Beans	S, SY
Vegetables:	Cabbage	CAB
	Okra	O, OK
	Tomato	TM, TO

Rape	RA
Peppers	PP
Vegetables	V, VEG, VG

IS HARVEST SOLD?		CROP_SEL
DON'T SELL / NONE	1	
A LITTLE / SOME / IF HARVEST IS GOOD	2	
BEANS (Only)	2	
Cassava (Only)	2	
MAIZE (Only)	2	
NUTS (Only)	2	
SWEET POTATOES / POTATOES (Only)	2	
EVERYTHING	3	
VEGETABLES (Only)	4	
FISH (Only)	5	

HOW FAR TO COLLECT FIREWOOD?		FWOOD_D
IN FIELD / WITHIN FARM	1	
NEAR	2	
ACROSS VILLAGE / VERY FAR	3	

ACCESS TO RESOURCES IN FIELD BY OTHER VILLAGERS		FWD_CACC
Y	1	
N	2	

FOREST PRODUCT HARVEST?		FPR_HVST
Y	1	
N	2	

DISPOSAL OF LAND		LAND_DSP
SALE	1	
RENT	2	
INHERITANCE / GIFT	3	
ABANDONMENT	4	
OTHER	5	
CAN'T DISPOSE / NO DISPOSAL	6	
DON'T KNOW	7	

CONSULTATION WITH V/H FOR LAND DISPOSAL		LDVH_CONS
Y	1	
N	2	
DON'T KNOW	3	

HOW IS CONSULTATION DONE?		MODE_CONS
BY INFORMING VILLAGE HEAD (V/H)	1	
MUTUAL AGREEMENT	2	
CONSULT V/H	3	
DON'T KNOW	4	

INTERACTION WITH DISTRICT COUNCIL		DSTC_INT
Y	1	
N	2	
DON'T KNOW	3	

REASON FOR INTERACTION WITH COUNCIL		**MODE_IDST**
LAND ISSUES	1	
LAND RENWAL	1	
LAND SECURITY	1	
LAND USAGE	1	
SETTLEMENT ISSUES	1	
DEVELOPMENT / MAJOR ISSUES	2	
LEADERSHIP	2	
MEDICAL ISSUES	2	
AGRICULTURAL INPUTS	3	
NO INTERACTION	4	
MISSING	99	

ENVIRONMENTAL PROBLEM IN AREA?		**EPM_IND**
Y	1	
N	2	
DON'T KNOW	3	

WHAT IS THE ENVIRONMENTAL PROBLEM?		**TYPE_EPM**
INFERTILE LAND	1	
LAND POLLUTION	1	
SOIL DEGRADATION / SOIL NOT GOOD	1	
SOIL EROSION / DAMAGED SOIL / BAD SOIL	1	
LITTLE RAINFALL	2	
NOT ENOUGH WATER / DRY WELLS / WATER DRYING UP	2	
WATER POLLUTION	2	
AIR POLLUTION	3	
BAD POOR HARVEST	4	
FARMING METHODS	4	
LACK OF SEEDS	4	
PESTS	5	
NO ENVIRONMENTAL PROBLEM	6	

RESOLUTION OF THE ENVIRONMENTAL PROBLEM?		**PRSN_IND**
BETTER PLANTING SITE SELECTION	1	
CROP ROTATION	1	
USE ANIMAL MANURE	1	
APPLY FERTILIZER	2	
APPLY LIME	2	
BRING PIPED WATER	3	
DEEPEN WELLS / SINK BOREHOLES	3	
TREAT WATER	3	
PLANT TREES	4	
STOP BUSH FIRES	4	
STOP CUTTING TREES	4	
PEST CONTROL	5	
NOTHING	6	
DON'T KNOW	7	
NO ENVIRONMENTAL PROBLEM	8	

IS COMMUNITY AWARE OF ENVIRONMENTAL PROBLEM IN AREA?		**EPM_COM**
Y	1	

N	2	
DON'T KNOW	3	

RESOLUTION OF THE ENVIRONMENTAL PROBLEM BY COMMUNITY		**PRSN_COM**
BURN LEAVES FOR MANURE	1	
CROP ROTATION	1	
USE ORGANIC / ANIMAL MANURE	1	
USE FERTILISER	2	
DEEPEN WELLS FOR WATER	3	
STOP BUSH FIRES	4	
DISCUSS ISSUE WITH COMMUNITY	5	
NOTHING	6	
DON'T KNOW / NOT SURE	7	
NO ENVIRONMENTAL PROBLEM	8	

IS LOCAL COUNCIL AWARE OF ENVIRONMENTAL PROBLEM IN AREA?		**EPM_COL**
Y	1	
N	2	
DON'T KNOW	3	

RESOLUTION OF THE ENVIRONMENTAL PROBLEM BY COUNCIL		**PRSN_COL**
PROVIDE SEEDS	1	
SUPPLY ORGANIC MATTER	1	
SUPPLY FERTILISER	2	
CONNECT TO WATER SUPPLY	3	
DEEPEN WELLS / SINK BOREHOLES	3	
PROVIDE PIPED WATER	3	
HELP WITH TREE PLANTING PROJECTS	4	
ENVIRONMENTAL EDUCATION	5	
HELP WITH KNOWLEDGE, ADVISE PEOPLE	5	
NOTHING CAN BE DONE	6	
DON'T KNOW / NOT SURE / NOTHING YET	7	
COUNCIL NOT AWARE OF PROBLEM	8	

SHOULD LAW BE CHANGED TO SOLVE PROBLEM?		**LAW_CHG**
Y	1	
N	2	
DON'T KNOW	3	

WHICH LAW SHOULD BE CHANGED?		**NAME_LAW**
LAND USE LAW	1	
DON'T KNOW / NOT SURE	2	
KNOW NOTHING ABOUT LAW	2	
NO RESPONSE	3	

Appendix A.4: SPSS output

(File too large, put on CD).

Appendix B: Transcriptions of fieldwork interviews

Appendix B.1: Transcript of meeting with Deputy forestry Officer, Ndola

2 in attendance [DPFO and M. Akombelwa]
Meeting: Deputy Provincial Forestry Officer, Ndola10th August 2005

MA: You were saying the joint mgmt plans being in two districts?
DPFO: Yes the Joint Forestry management concept is being implemented only in two districts of the Copperbelt province, that is Lufwanyama district and Masaiti district. In Lufwanyama district 20,000ha of customary land has been earmarked for the JFM and this within the area of PFAPII which begun in 2000 and wound up in June this year (2005). We are trying to do the implementations in the same area. In Masaiti district this is being implemented in Katanino local forest reserve, with an area of about 4,552ha. So the biggest part is Lufwanyama. Within these two areas, the idea has been to develop management plans which we have formulated and we are now trying to smoothen them out. Besides that we have produced guidelines, that is the JFM guidelines which if we wanted to implement elsewhere, we can just follow the steps.

The steps are identifying the area, making the applications by the local people for joint management with government. Other steps are field verification and approving those steps by signing a MOU which lasts for two years. The documents which we have used are the JFM guidelines and the preparation of Management plans. Then within the same thing the biggest result areas for the project are capacity building for both forest Dept staff and the community since there are two partners, the community and forest dept. on the side of government. So both these categories of stakeholders have been given training to make sure that the concept is well implemented. Of course in terms of things on the ground we have a few things on the ground.

MA: So with the JFM guidelines having being drafted, does it mean you can go to any community on the Copperbelt now and apply them, that is if the community is on state land, can you use the model from the Katanino project?
DPFO: Exactly, that's what it means because it is now dependant on government that this concept is implementable because what we have seen is that the previous arrangement where the policing issue was done by government, there were a lot of problems. As a forester, as I speak, I am here in town while the forests are out there and within the perimeters of the forest there are people sitting there. Even before the forests were gazetted they were under customary tenure, the chiefs used to own that land and then government came in and gazetted the forests.
These people have indigenous knowledge which we need to tap and we can only manage [the resources] and it is also stipulated in the new (forestry) policy of 1998. It supports the concept of JFM. The problem has been implementing the same without the enactment of the new Act of 1999. What was done was to extract the relevant section from the Act and pass it as a statutory instrument just to make sure this concept is implementable. So under SI no 52, the JFM concept has been implemented. This is to ensure that what is suggested in the 1998 policy can be implemented. We are still using the forestry Act of 1973. The SI was to facilitate the implementation of the concept of JFM either in national forests or local forests and to some extent even plantations.

MA: Looking at the Copperbelt Province, there has been a lot of illegal settlement in national and local forests, what plans do you have to address this issue?
DPFO: For the illegal settlements, the first thing we must look at is the issue of what has brought about this massive encroachment. On the Copperbelt there have been a lot of retrenchments and massive structural adjustment programmes where people have lost employment. The policy was that of having a smaller effective workforce even in government. So many people have lost employment and the only way for people to survive is for them to help themselves to the forest resources which is a cheaper source of agricultural production. The problem is they open up forest land in the name of agriculture and yet they initially use the forest resource to produce charcoal and sawn timber which they sell off and they do not follow government guidelines on how to conduct such businesses and they don't pay anything to the state. Government in most cases does not collect any money from the activities that go on in the illegal settlements. So many of the people who have encroached on the forests are those who lost employment and their only way to survive is to cut trees produce charcoal and open up land for agriculture and sawn timber illegally. So the plan that we have in the Copperbelt is to make sure that these people are out of the forest areas, they are there illegally, BUT the workforce cannot sustain such operations because firstly we have been restructured removing the much needed workforce that was mandated to man the forests day in and day out, at the moment we don't have that workforce. The workforce we have is almost office-bound but since that cadre of forest officers have been laid off, the forest guards, we have the forest extension officers who have attained the level of certificate holder and they are not always in the field and

they are not even enough to cover all the areas of the forest reserves on the Copperbelt and secondly we have had a problem of transport. We don't have vehicles and operational funds are also a problem so you find that people are not on the ground to do what they are supposed to do because of the problems at hand of transport and not having enough staff. These have compounded the problem of supervision in the forests.

MA: So your position (Provincial Forest Office) is to remove the illegal settlers from the forests?

DPFO: Yes, to have them removed. And what we have been lobbying to Government is to have a strong political will on the Copperbelt because in most cases there have been those problems, you would not know how someone settled in a particular area maybe there was that political backing especially during campaigns like this year you find that people will use that to gain political mileage [to say, you settle here, you do what and what]. There are some cases we have even heard of, they would even tell [them], you have been given this (land), it is so political. So you find that it becomes a problem. Also the change of political leaders, you find that the post of PS and Minister are being changed now and then, so each one coming in will need to be reoriented to the situation and then there is a time lapse where things are left hanging and people will do whatever they want to do. That prolonged office tenure for our political leaders made things to have a different image as we speak, but now because of changing leaders, it is causing a lot of problems.

MA: How is your interaction with the Agriculture and Lands departments with respect to [land] tenure and agricultural expansion.

DPFO: At the moment, what I can say is that there are issues, really serious issues. We do meet with these people but in most cases when there is a problem not at policy level, I don't think much of thatt has been done but when there is a problem or conflict of ideas as you are implementing, you find that you summon each one of you to go and meet and then discuss to iron out problems. But I think issues of such nature should be handled at policy making level so that when you go out in the field you do not conflict with each other. What I have seen is a culture of meeting when there are problems and then you start saying, our policy says this and that you are not supposed to do this, our map is like this and then you start comparing maps in the field. So that has been a very big problem, but there is that arrangement of meeting and discussing problems and ironing them out as you meet.

MA: In my work I would like to find out from the local people in the areas I am going to [visit], to find out their involvement in the policy making process of the current policy whether they were involved and also in the implementation of the same whether they are aware or whether they are also involved in that. Do you have any work in that respect [directed] towards the communities or is it just something that was restricted to the two districts?

DPFO: Do you mean the JFM?

MA: No, that one aside, I mean the general policy.

DPFO: The general policy, I don't think it takes care of someone who is down there [on the ground] because what has been happening is that when those things are formulated, they come from ministerial level. It is something like a Top-Down approach. There are meetings at that level during that formulation and very little has been done to incorporate the person who is down there [on the ground], I am sure that is why we had problems. Now in the JFM concept, we are saying all those things should come from the bottom to say this is what is needed because we are co-managing the forests, so even during times of policy formulation all units need to come together and then formulate policy – together and find out what is applicable. So that is why you have seen all these changes in the current policy to say there should be JFM and within JFM matters of policy issues should also be handled by both stakeholders, rather ALL stakeholders. There is that change, but initially what I have seen is that the article is out and we need to implement it as it is, how it was generated whether there was that strong consultation or wide consultation, not to my knowledge, I can just speak for myself, I haven't seen much apart from us having arguments here to explain that we have just been directed to implement this.

MA: In the implementation process, how is your interaction with the District officers?

DPFO: The interaction is very good and well coordinated because all matters pertaining to forestry issues should first be relayed to the Provincial forestry officers [and] where they fail to handle them there should be consultation with the main office, the Provincial forestry Office, then a go ahead can be given. Besides that we have had circulars and even other issues which we are mandated to do. We know them, issues of regional regeneration, forest protection and management, rehabilitation of degraded areas all those things are known and people know what to do unless where there are issues that they cannot handle which crop in then they request the Provincial forestry office to interact [intervene?] and even when we are doing our monitoring trips we sit down and see that things are being done according to the way they have been planned so the coordination is there. Each month, [these people] they also write reports, monthly reports as well as quarterly reports and then we direct them into quarterly reports for the whole province and at the end of the year we have the annual reports which depicts what has happened in the previous period. So that kind of communication is there.

MA: So do they develop their own plans in the Districts, or do you advise them what to do, do they need to consult with you [at the Provincial Office]?

DPFO: No, what it is like I mentioned, we have got the core steps that we follow, like I mentioned forest protection and management, that every district knows and should make a program in relation to that step. Then revenue collection, they know that they are supposed to collect revenue on behalf of government and how it should be done. Is it from selling of poles or selling of any other forest produce, they will do that. Nursery management and establishment because we have to replant most of these depleted areas and areas that we are cutting which cannot regenerate or rejuvenate themselves, so we need to have nurseries throughout. Even through our extension work, we need to have nurseries so that we have those plants and then we can do our extension services very well. So there are those steps which we follow; so they make their own plans, submit them to the provincial office and then we have them approved when we synthesise them into the main document for the whole province. So we have district plans which come to the PFO and then the PFO incorporates everything in one document to represent the whole province and then the budgets are drawn up against the activities that we intend to undertake and then we submit them to the relevant authorities for funding, that is government per se.

MA: I read in the paper a couple of days ago something about 18 forests to be de-gazetted. Is it in the areas where we have squatters?

DPFO: On that one, I don’t know, because releasing information like that, us foresters we don’t comment on that [I cannot comment]. What our mandate has been is to protect and manage, we don’t give out land and all that we are supposed to do is to protect and manage and if possible, bring under reservation a number of forests because we have a target of 15% of what is forest in the country to fall under ‘vacated’ forest.

MA: 15% of total land area?

DPFO: No, 15% of forested area should be forest reserves but that has been difficult because of the same deforestation and other things that are making our trees diminish, so we may have about 9% or so as I speak we have failed to attain 15% because encroachment levels are quite high. So normally we don’t give out land and a forester won’t give me permission to say happily that we are de-gazetting so much forest. That does not come from this office, so if some people are saying that, that is an issue for a higher office to comment on. If there is anything, authority should come from the PS to say ‘can you give out that information’. I am sure that came from politicians, you would not find our director or a forester giving out such information. What we want is to achieve the 15% or even more. So it is protection and management that is the core task of Forestry department that’s all and not giving out land. There are other institutions like land resettlement, they can handle that so even in the media…

MA: I understand your position.

DPFO: There could be arrangements because that directive can come from government to say, can you de-gazette this and we have no say. What we do is just to facilitate the whole process. We do our own part. If we have to take inventories, we do that, if we have to mark lines, we’ll do that and we leave it to them. If the land is under government then we know who should handle it. If it is under the council, then the council will handle it, if it is the chief, the chief will handle that land and do the major demarcations, we will just say, our forest ends here and then we will do the boundary marking that’s all. What remains thereof will be handled by the respective land [holder?] owner, whether it is the government, council or local chief. Forestry dept will not be there to say this person will be given so much land [allocate land]. So such a directive comes from the Minister, they know the reasons why.

MA: I know I asked the position of the Forestry office concerning people encroaching into forest reserves. In the event that these people will not leave and since your workforce is depleted, what do you think is the solution [to this problem] going forward. They will not leave tomorrow or the day after and meanwhile the resources are being depleted and it is affecting the environment, what do you think needs to be done?

DPFO: In the first place, what government was supposed to understand is the nature of the work that we have. We really need these forests and we need to conserve them as much as possible or balance the issue of exploitation and replanting. Those are the two issues which we could have addressed but now we have this problem as you have said and we really need to do something otherwise our forests will finish, so what government has done, of course there is that willingness now to have all these happenings to be reversed. If we have to remove squatters, we have to remove them with strong political will. So what has happened is that this office has started receiving money under what is known as ‘eviction of squatters’. I was just looking at our allocation this month and there is a heading ‘Eviction of squatters’. What we need to do is to regroup ourselves, if we need people from agriculture or wherever, we need to formulate a task force and go out in the field and talk to these people and make them move out of these areas. But again it is mandatory upon government to find alternative land for these people because they are citizens of Zambia. You cannot just say out of these forests and where do they go. So our government should find alternative piece of land to resttle those people. I know we have so much land under different ownerships, like I talked of chief’s areas, council areas lying idle somewhere. What we need is these other institutions to help on part of government to resettle the people who should move out of the forest reserves because you cannot just do one operation without an alternative, that is the alternative. Without the alternative then you are asking for war, because where does someone go and take his family.

MA: Actually that was my worry because I am thinking, these people are not going anywhere, but is there a way of engaging [with] them to make them realise that what they are doing in that area, although they are there for a livelihood, has an effect down the road, that it maybe it affects someone who is 50 or 60km downstream. Is there such a process?

DPFO: The process is there, we do sensitise them and most of these illegal producers of charcoal and also of cutting of timber, if we get hold of them or if not if we find them, we try to sensitise them on the effects of what they are doing and most of them have that information but we are talking of a situation where they don 't have any alternative. Even if they have the information, they will still stick around and do the exact opposite of what you have told them. The only solution is for government, now that it has even started releasing money to have these people evicted, we are anticipating another step where they will have an alternative piece of land where they will resettle these people because I am sure we will have a very big problem to evict these people without alternatives where they will settle and that is the responsibility of government to do that under the respective institution of Land resettlement. So the problem is there like you are saying and this is what government intends to do to have it brought to levels which are acceptable, yes it is just too much.

MA: Yes I can imagine. Is there no will or direction to engage them into JFM, is that an option that can work?

DPFO: that is an option, if you follow the policy closely you'll find that it is an option because what we want is to co-manage, these people are already there and if they are , then maybe we need to incorporate the indigenous and technical knowledge together and maybe those areas which have been encroached so much get [become] de-gazetted, give them to people, then formulate new forest boundaries which we will manage together with them. So the concept of JFM entails people moving away from an area that has been earmarked for JFM to stay outside the forest reserve itself because no one would want to be inside the pot and eating from every angle. You should be outside and each one of you is getting a piece rather than you being inside, so even in the context of JFM, we want everyone to be outside and then manage that. That means there would be issues of training people and sensitising people within the periphery of the same area so that they know what we are doing and the benefits that will accrue to them. Within the same JFM concept there is an issue of income generating activities that should be addressed. People will be engaged in production both for non-timber and timber produce so that they can make money for their benefit. So the JFM theme for government now within forest dept is what is revolving around to address those issues you are mentioning that in the new policy if the Act is enacted then you will have that all local forests where we are supposed to do that in one or two within each province not all of course but we are just trying this or we will start by a few and then we can increase when we see that things are working out. That's all I can say for now.

Then for data, for information, this GIS thing you are talking about, I don't know what is happening when you talk of resources. Data of foresting, status of forests, the stocking levels, species diversity, I think that has been a little bit of a problem; a few documents can release that kind of information on a pilot basis like we are doing in Lufwanyama and Masaiti, we have information for those two areas but what about the rest (that) which fall even outside forest reserves is really difficult to have that information but as government we are supposed to have information on all areas, the stocking levels and all those things. The land use thing you are talking about, pick up one, we did that but we didn't go far, just in a few forest areas, the land use mapping and then it wasn't much. So if there is money for that then people will get to do the job and we will have a strong data bank. So, GIS, [go to] Management division, Lusaka. They will give you the information even these stocking levels that information will come out from there even the differences, the trends impressed in deforestation itself, you will see from different [satellite] images how that has progressed.

MA: Yes I am using two [satellite] images actually.

DPFO: Oh you have [satellite images] for Copperbelt [province]?

MA: Yes, for Copperbelt [province]

DPFO: For which year?

MA: One for 1989 I think and another for 1990.

DPFO: 1989 and 1990…just one year in between

MA: Oh it is 2000, almost 10 year between them

DPFO: So is there much difference between them [satellite images]?

MA: I am still working on them, I am trying to calibrate the images and then I can compare them.

DPFO: If you went to Lusaka, you can access those things.

MA: Actually, I got them from Mr xxxxx.

DPFO: Right now he is at Mwekera where he is doing his diploma. He has been in that unit since the project started. It is the one which initiated GIS for PFAP from the nineties up to June this year when the project wound up. So they have the machinery [equipment?] and expertise to handle that.

MA: So, I am trying to use [relate] the differences I will find to what people are saying on the ground and find out from the people on the ground possibly together with the local authorities and possibly the district forest officers, what they think should be the way forward and then put it into some kind of decision support system.

DPFO: In fact most of those things you are saying will come very correctly from the implementers themselves right on the ground because they will be seeing those things. They wouldn't be speaking from without, they will be speaking from experience. If you tackle the local leaders, the DFO's they will be in constant contact with PSP and they will give you what is right.

So now for the two areas, I don't know if you will change because you are talking of Maposa. If you could manage Kalulushi because these people are at Kalulushi: the DFO for Lufwanyama resides in Kalulushi and if you make contacts, you may meet at Kalulushi itself, then he tries to explain. It is quite a good and has a lot of information on these things I was talking about. He will give you serious details, I am so sure because I have been on off on off on this project. I went to school came back found it.

MA: What would be the DFO's name?

DPFO: Mr xxxx, DFO, Lufwanyama. He has been with the project from the start and he will tell you all the activities they are involved in especially the income generating activities to empower people with a little bit of money from their community projects. There are a number of them in different categories. He will be able to mention them to you.

End of Interview.

Appendix B.2: Transcript of meeting with Bridge International NGO

3 in attendance [BI-1, BI-2 and M. Akombelwa]
Meeting: Bridge International, Ndola 10th August 2005

MA: Good afternoon and thank you for this opportunity to ask you a few questions. Firstly, could you tell me what your organisation does.
BI-1: Bridge International (BI) is a Christian organisation dealing with Christian transformation development, we believe God doesn't only care about the spiritual [needs] but he also cares for the physical [needs too]. We are dealing in things that affect a person, the whole being of a person [that is], and our process is a community driven process. We do not go into communities with something in our mind, we go into communities to make relationships and the communities are the ones that come up with problems that are affecting them and in the process we help them identify and they prioritise the problems themselves (and come up with the most priority, the first thing they feel they can do) and together with us, they sit down and see how we can help with them playing a part and also us [BI] playing a part. The tools that we use are Appreciative enquiry, we don't just look at the bad side of the community, we also look at the good side of the community. It does not mean that in these communities they do not have good things, so we always try to help them identify good things that are in the community and if there are any resources in that community, we try to help them see if [how] they can use those resources and from the bad side also we help them to identify how they can contribute to build on those bad things so that they can bring them to the original intended purposes. That's what we do.
BI-2: Yes try to find their strengths that sometimes they don't even know that they have and empower them to use them [strengths] to help themselves. We are not an aid organisation, but we are about building up people before we are about building up communities and in this area of Maposa since they don't own the land, there is very little that we can do there as far as infrastructure, you know because we would be in violation of the law, so we had to go into an advocacy role for them to help them understand, first of all, that they could be put off this land at any time and ways that they can go about through legal channels to help themselves which is what we have been working on now for over a year and I think we are getting very close to having the politicians and the government turn, at least part of that forest area over to them but it's a long process. When we partner with a community we intend to be there between 15 and 20 years. Its a not short term, short fix kind of a thing because we want to build up the people to where they can sustain it on their own when we are gone and if they have a part to play in it, the more likely they are to care of it and pass it all on to their children, so that's basically what we are doing. We have a small team, we are relatively new in Zambia, but that's what we are doing and our vision is for all of Zambia and perhaps beyond but right now we have started in the Copperbelt and we are working in 4 communities.

MA: Yes, like I explained, my work is more towards trying to get the local people's views into policy development and implementation because we have got all these Land, Forestry and agricultural policies but the people at the bottom end, the people who impact on the land usually are not aware about those

BI-2: That's where we play the role of advocacy to inform them, like I said, we took a long time to go round to every single branch and put on almost an entire day's seminar and we brought in professionals to speak to them on the laws and different things. They were very well received to the point that they were very happy to be on a committee to form a local Board so that we could continue to work on issues at hand and we haven't been successful yet but like I said we are getting to that point.
BI-1: Actually, this is an issue in communities, they don't know about the policies, they don't know that there is an Act on forests, they don't know about the Land Acquisition Act, they don't know about anything, you know. What they just know is that there are forestry people who come to chase them when they are making charcoal, so that has developed enmity between the forestry [dept] and these communities because the communities do not know that what they are doing is affecting the environment, they

only know that what they are doing is affecting the forest officers because if there is no forest, they [forest officers] won't be employed. So they don't really know the real impact it has, they see it as something just bringing enmity between them and the forest officers and not with the environment.

BI-2: Well, the other thing is most of them are just in survival mode. They are just doing whatever they have to do to eat for the next day, so they can't be concerned with the far reaching acts of what they are doing because they are just focussed on eating today or tomorrow, so it takes a lot of teaching.

BI-1: Yes, even these people, the politicians, I don't think they understand the policies very much or if they even take time to go through them because you would find that an MP who doesn't even know anything about the Forest Act, he has never gone through it and when he goes to these communities, he is going to tell them 'this is your land, we have given you, don't worry'. It comes from a person who should give an insight to the community [yet] he doesn't understand it, so all these policies are not reaching the grassroots, they are just there in the offices and maybe they found in offices where they are not easily accessible. It is a difficult thing.

BI-2: It is very confusing period for the people right now because land is a big issue all over Zambia as well as many other African countries and they tend to believe what politicians tell them and this campaign time they are getting al these conflicting stories and they are trying to assess whose right and what's right and who to believe and all these things.

BI-1: It was just this week, I think it was on a Tuesday when I was listening to the radio, the Provincial Deputy Minister, was quoted as telling people in Kalulushi that 'from today you are no longer squatters, as a government we are going to de-gazette about 18 forests in the Copperbelt'. He is saying they are going to de-gazette 18 forests and the people are no longer squatters. To me he is saying: 'We haven't de-gazetted 18 forests and today you are squatters.' He is confusing them, he is telling them that they are not squatters but they have not de-gazetted the forests.

BI-2: They don't have a paper in their hands to prove that it is theirs.

BI-1: So these people are confusing them. What they know is that for a forest to seize being a forest, a politician has to come and tell them it is not a forest anymore, but the Act is saying it has to go through some channels and there should be a paper signed to say this is no longer a forest. So all this is confusing, because when we go there we try to explain to these people. We bring in [inform them of] a very long process which the local people fell cannot workout. It is so cumbersome. 'Last time the Minster came he told us this is our land, now you are telling us we have to go through this whole process, you are confusing us'. Already, these people have been told that to access land is so easy, it is just a matter of a minister coming to tell you and here comes a development worker to tell you that there all these processes: you have to apply to the council and it has to go to the chamber and it has to go this level and that level until the President signs. To the local people, they feel that the President has the Ministers and when they come here they represent the President. So if you ask them about these policies, you'll be lucky to hear anything.
[It was more like this meeting where the people in Maposa wanted to demonstrate, so the Minister came. He used the Land Act and the Land Acquisition Act to tell them the processes the government was doing and to inform them they were no longer squatters from that day. So when I took the same papers (Acts) that the Minister was reading to them, people said both of you are lying to us.]

BI-2: We need to arrange to meet up with you on Thursday. What time is the meeting?

BI-1: It's at 9:30. It's so confusing. I think it will be very interesting when you get to meet them.

MA: Roughly, how big is the area?

B1-I: In Maposa?

MA: Yes.

BI-1: It's about 8,000 sq km.

MA: Which District does it fall under?

BI-1: Under Luanshya, but there is a lot of confusion. Politically, they have divided it. One part falls under Kitwe and another falls under Luanshya. Geographically it falls under Luanshya district and it is Luanshya forestry section that is administering that but politically it is divided into two. So, administratively, it is Luanshya district that works in Maposa i.e. for health and other things but also the other side, people from Kitwe try to come in because the area is so big.

BI-2: It's been a very confusing place for us to work in.

BI-1: For proper information it falls under Luanshya district, because it has gone to Kitwe [council] chambers several times and has been rejected. The Council argues that they only go as far as Kamfinsa stream and the Kitwe forestry office does not work across the stream. It is only the politicians who claim that it falls under Wusakile constituency in Kitwe district because of votes. So that is their vote bank. They promise land in exchange for votes and no one votes against them because they want land.

BI-2: It's a can of worms.

MA: My idea is to try and develop this Land Use Allocation system, a digital one, which will be used by the local authorities and the local communities in that input comes from the local communities together with the local authorities, but in order to do that one has to understand what the local communities perceive as a problem. As an outsider, I would say deforestation is a problem but is it a problem to them, what do they think about it? What do they think is a problem to them? That is what I am trying to do.

BI-2: Well, I doubt that most of them understand the ramifications of deforestation. All they know is that they need more ground to farm and if they can make charcoal out of a few trees while they are doing that, they get a little more money, then that's what they will do.

MA: If you look at the questionnaire I have for them, when I had a meeting with the Kalulushi communities, I asked them about what they thought about deforestation, was it a problem to them, they said 'we don't think so'. I asked what they used for cooking and whether they thought the supply of trees would be there and how far they got their firewood from and what they thought needed to be done to sustain the consumption assuming they were not leaving the forest reserve. That in a way, got them thinking

BI-2: Yes, many of them just followed the trees. The trees are gone in one place, they just move to another place. Now they have started farming so they are not leaving.

BI-1: Many people that are in these communities that we will be seeing, if you look at their background, they are from a charcoal [burning] background and now they have gone into farming because the trees are gone. So, big trees as their capital are no more, so they replace big trees with farming. When they want soap, salt and other needs, they cut the small trees so that they can make charcoal and sell it and then buy the things they need. Where they come from trees are for charcoal. So to really understand about deforestation, one has to look to the government and find out what the government has to say about deforestation. Does what the government say reach the grassroots or does it just remain in the offices? The government is talking about the forests but have they gone back to the grassroots to tell them? They have not. We just hear about this on the radio and when we go to their offices (forestry offices) they do not know what it means either. All the District Forest officers tell us is they do not know about it except that some people will lose jobs and their waiting to get their pensions. The government has not explained it to their own officers so how can you expect the people in the grassroots understand it. It is a problem. Last time I was talking to a few local people, I asked them what they would do if the government was to give them the land on condition that they will leave a place (on each farm) where they will grow trees so that it works as a replacement for those trees which have been cut down. They responded that they could do that except that they need firewood and thought that they also could use it to make charcoal sometimes. So, for them, trees are just there for firewood and charcoal. They do not relate it to contribution to rainfall, drying of streams, to them those are the least things they would think of. To them, their priorities are firewood and charcoal so there is a lot of work that has to be done.

MA: In your advocacy work, have you been involved with some of the process going on such as the current work on the draft Land Policy?

BI-1: No. Last time I was talking to Mr ZZZZ of the Zambia Land Alliance, the problem is that they target the people they know. Like in the Copperbelt they have gone to places like Copperbelt Land rights center who then refer them to one community where they have discussion for a day and they go. The results depend on what type of people they met. Like in Maposa, they just went there once and it was only one side of it and they just met those people who were closer to the projects that Oxfam was funding, so for the Land policy that the Zambia Land Alliance is working on, I personally do not think there is much work that they have done in terms of consultation from the grassroots. Maybe they might have done it in Southern and other provinces but when it comes to the Copperbelt, I still feel people have not given their views.

MA: Any input to the forest policy?

BI-1: There is nothing.

MA: But I can see you are helping with the implementation in the communities.

BI-1: Yes, actually that is what we are doing. Anything like the Environmental policy which was rumoured to be about to be implemented, and we have not seen it and nobody seems to have a copy apparently as my research on it has revealed. The forest officers have only heard about it in seminars. My friend at the Coppperbelt land rights center in Mufulira, was lucky to have some insights as they discussed it at a seminar they had recently but he does not have any detailed information about it. The headquarters in Lusaka might have it and you would have to see the environment Permanent Secretary and this would mean making an appointment well in advance.

MA: In terms of the land tenure problems relating to deforestation what do you think is the way forward when you look at this? Firstly, do you think these people are going anywhere?

BI-1: That’s a very good question…

MA: The people are settled there and resources are being depleted and I was talking to the forestry people, they don’t have the manpower to move the people out even if they wanted to try to move them, but then what are we going to do because we can see that the environment is being degraded and the Copperbelt province being close to the headwaters you know the catchment areas for our main rivers, to me, is a sign of danger if nothing is done and we continue in this direction, soon we will have no rain

BI-1: Actually, in our advocacy, we have been looking at empowering them with land and then teaching them how they can start growing more trees. We teach them to not only look at growing food but also how to grow trees. We are also trying to teach them sustainable agriculture whereby they can look at the method of growing these [cece banyia] trees. Also we are looking at the environment, so we tell them it is good to own land but there is an also another important aspect of it, the land needs to be cared for, the land needs trees. [So how do you look at it?]. It is something we need to continue teaching them and I feel people need to be told because as I said [earlier], a politician will come and will not mention anything about the environment impacts, he will advise them to continue producing [more food since it is a], we are a government which supports agriculture and that since they came to power there hasn't been a problem with food. When a development worker goes there to advise them to look after the environment in addition to growing food, there is some resistance [to the acceptance of such concepts]. So it is political will which is needed whereby the Government has to train the MP's especially those with constituencies are in or have forests, in fact not only forests even other places too, so that they can teach local people how to grow trees. I remember in Kenya, the government came together with the local people. The people are good custodians of forests because they live with trees. The [Kenyan] government had to empower the local people. Every farm had to have a place were they grew trees [woodlots] and whenever the farmer decided to cut down trees on the farm, he had to make sure he started growing trees on another part of the farm to replace the ones he has cut. This has been followed. If you go to Nakuru [Tanzania and Kenya] you will find land is very scarce. Families have about 10 hectares and it doesn't change unlike here where vacant land can be found. People have trees on their land. It is a matter of the government and the people to work together. We are doing our part as NGO's to help them and people are accepting it but what about the people who are coming to alter what we are sowing, if they come in to uproot what we are sowing, then it won't have an effect. That is the major constraint that we are faced with in these communities but like in Maposa, we have tried to help them to understand the consequences of cutting trees along the streams and this has changed and at the previous meeting that we had, we were trying to come up with some rules whereby whenever they find someone selling [burning] charcoal, he has to be taken to the local crime prevention office where he will be fined or they grab the land from him. They are also looking at how they can protect trees but they are also looking to see if it can workout because if an individual who has cut trees is reprimanded has political influence or connections he might use the political influence to victimise the local enforcement committee. So, they were also giving reasons why it may be difficult to enforce at times because of the influence of outsiders who have an upper hand in that community.

MA: It sounds complex.

BI-2: It's a challenge

BI-1: Yes it's a challenge. I think when you go to talk to them you will get a lot information and you shall get the information. We are trying our best.

MA: Thank you for your time. I will go through the brochure. So how about Friday, what time do we meet?

BI-2: The meeting will be at the Catholic church along the road from the substation about 5 to 7 km from the dual carriage way.

End of interview.

Appendix B.3: Transcript of meeting with Kalulushi Council Director of Planning

2 in attendance [Director of Planning and M. Akombelwa]
Meeting: Kalulushi Municipal Council, Kalulushi 15th August 2005

MA: Good morning and thank you for this opportunity to ask you a few questions. Firstly, could you tell me what your organisation does?

DoP: We have two wards, Chembe ward and Ichimpe ward. Chembe has a projected population for Chembe is 4,131. Ichimpe has a projected population of 2,023 so we could say about 2000 people stay in that farming area we are talking about because Chamwanza is much more on the Ichimpe side than Chembe but they are bordering with Chembe.

MA: Roughly about how many households are there?

DoP: We are talking about 750 [households].

MA: 750 [households]?

DoP: Yes 750 households. It is quite a big area. In terms of what plans there could be [for the future], these areas are mostly in forest reserves and Council has identified that gap, the problem of people encroaching into the forest reserves and what has happened is that there has been a resolution in council to identify how many people there could be squatting in the forest areas and what the council can do to officially give them the land and ownership. You heard from the recent press newspaper statements that there are some areas earmarked for de-gazzetting on the Copperbelt, that is the area, Chamwanza and Mwambashi areas of Kalulushi. After the resolution sent some officers from agriculture and forest departments to go and identify the said areas, so they have done the work but the final report hasn't yet been given to the Council but what I can confirm is that they have identified some land which they will recommend for distribution to those that are seriously in the areas which council wants to protect in the future but some other areas where they can repatriate or relocate those people have been identified. I don't know how many plots exactly but we will get that fact as soon as we get the consolidated report from the officers who went to the ground from departments of Agriculture and forestry. So that is in terms of plans that council has put in place. There are other activities, of course, of charcoal burning in these areas perhaps that is why they have also found themselves there. But Kalulushi having suffered a lot of retrenchments that is job losses at [during] privatisation could be the underlying factor to why there are so many people {staying there to get a livelihood}.

MA: So, for instance, in the Chamwanza area is there anything that needs to be protected or is it all going to be given out?

DoP: Yes, that is the more the reason why the officer went on the ground to see how many people are classified as having encroached in forest areas and how much of non-forest area is remaining idle or unutilised for a long period of time and then they will come up with a criteria of distribution. So basically, there will be an area left out for future use as a forest reserve. So this one is more like a cleanup exercise to move people from where they shouldn't be to areas where they should be permanently at least for now.

MA: In the areas that are going to be protected, are there any plans for Joint Forestry Management?

DoP: Yes, there are [plans], in fact this sensitisation has been going on. The forestry department is doing some recommendable work, of course, in conjunction with other stakeholders like the schools and the communities themselves. They are forming these partnerships between themselves and the communities. In fact they are trying to avoid the term charcoal burning and instead use charcoal production, because charcoal is seen as a livelihood for some of the people and what is important is the sustainable way of producing charcoal so they are calling it charcoal production so that communities can be incalcated in some responsibilities because that is the area and if depleted, then it is them that are going to be affected. There are some joint management plans between forestry department even agriculture department is also joining in with the communities affected. So it is something that council has taken broadly to encompass every stakeholder that is in this problem.

MA: Does that go for the entire district?

DoP: That is not only restricted to the Chamwanza area, we have also the Chati area, Mwambashi areas where we suspect severe encroachment into the forest reserves, those programs are covering those areas as well.

MA: do you have any area maps?

DoP: The maps we have may not be covering everything but Agriculture have some and Forestry have some forest maps which show which forests have been encroached and if we talk about the Chamwanza area it shows which area has been encroached on and agriculture also have some maps which show the same areas we are talking about. At the council what we have are layout plans and maps for the areas that are viewed as State land as at the time before encroachment. These other areas which are forest which have been encroached, we do not have such maps. We are making plans to secure them from ministry of Lands and natural resources.

MA: So how soon will it be possible to access these reports for the work that has been done.

DoP: The officers have just recently come back from the field. So we are expecting in the next 3 weeks to have the report submitted to council and if it is ready, it is just a matter of calling for a special council meeting to look at the recommendations and the report itself. But we interact with them, we know they are back from the field, they have done some work, they have identified some land so they should be reporting officially to council because it is the one that sent them to the field.

MA: Thanks a lot Mr Chamoto for your time. I don't know if there is any other information you would like to add I would appreciate.

DoP: Thank you very much it has been a pleasure to talk to you. If there is any other information, we will still get back to you and give [it to] you. For now, this is the problem we are facing, that of encroachment in the forest reserves and the worry is not only for the department but for the district and council.

MA: I almost forgot, I do realise that some of the areas although they may be out of your district, but they actually close to the headwaters of the Kafue river, what is the position of Council in terms of natural resource conservation?

DoP: Yes we are very worried, of course, Kafue river is almost at the northern border of the district but these areas are actually the water resource base for most of the streams we depend on as far as agriculture is concerned so their deletion is a concern for the district. The conservation is: we are operating as a district we liase [work hand in hand] with the forestry and agriculture departments. Agriculture department is doing an independent program of sensitising on conservation farming, so those on the banks of these streams or rivers are taught on how to best conserve the river banks and generally the forest management itself because it is a big source of rainfall, so the plans as a Council since we do not have a department of forestry or agriculture we rely on our cooperation with those two departments. We hope that under a decentralised regime, these functions will come back to the council and we will operate from in-house, so generally we could say that we have plans to ensure that our communities do cultivate responsibly and conserve the environment.

MA: Thank you.

DoP: Thank you very much Mr Akombelwa. They also realise that trees are very necessary for their survival. They realise that they have cut enough and that if they cut more they will affect their living and that is why they are now talking about government coming in to electrify their areas because they have also sensed the danger of over-cutting the trees. We were just compiling the DSA and one of the inputs from ZESCO was that they are willing of course to go in the areas but the economic return from such ventures is what stopping them from embarking on those plans. Right now in Kalulushi, the amount of power we have available, they [ZESCO] have capacity to sustain Kalulushi upto 20 mega watts but we are only using 12 mega watts meaning that ZESCO is prepared, they just don't have customers for the power that they have. The Lufwanyama area has taken long on the same principle, the Lufwanyama electrification programme because the farmers who are the target are very few there and the amount of money they will spend on operations to sustain the line is more than what they expect to reap from the same programme. That is the problem we have. We need a good number of farmers coming together and supporting each other an being very committed before we can convince ZESCO to bring electricity to those areas and we have seen that the electrification programme is not only affecting farmers, its also affecting communities from a different angle. Take education for instance, I was just reading from the Education section in the DSA saying most of the peri-urban schools have power problems. So even when we are talking about teaching people in the modern way using computers, how do you start, where do you start from. It is also costly because when there is no electricity, there are multiplier effects because teachers are shunning such areas so we have low staffing levels, an artificial situation not because we have no teachers but because of the type of facilities offered in those areas. So, the problem as you can see goes from being only an environmental one, it goes into a social nature, it goes into a different angle, so we are glad that they are talking in that area because that will help us also convince the power suppliers that there is need and if there is need for political intervention, I think that is the angle we are going to take but to just convince government that Chamwanza or Chembe needs electricity is not enough. There must be evidence, proof from the communities themselves that this is what we are doing. If we have those voices loud enough, then as a district we will support them because we know they need electricity to sustain other economic activities. That is the point we can convince ZESCO as our local [electricity] supplier to install electricity. So it will be good because it will also boost other programmes that are electricity related, we can conveniently and effectively implement them.

Thank you, very much for coming.

MA: Thank you once again.

End of interview.

Appendix B.4: Transcript of meeting at Natwange village.

Meeting 1: Natwange and Twashuka Wards 8th September 2005

C/man Natwange: lands committee chairman and his guest called this meeting. I am not sure of the topic we are discussing today. As ch/man I receive everyone who comes here. We welcome our visitors today to tell us why they have called this meeting.
Before I hand over to the lands c/man to introduce our guest we wish to inform you that we have gathered 2 branches today and although we have quite a number of people today, a lot of people are still to join us. Our people are tired of these gatherings as we really want to get ownership of this land.

Lands C/man: thank you, as the c/man has explained I also received notice of this meeting last week and I made efforts to inform everyone and especially the ch/man to inform everyone in the branches. This the env. Surveyor, Mr Akombelwa and this is ZZZZ who works with Mr Akombelwa. He has come to teach you about how take care of your land, trees and your environment in general. He decided to come and meet you the local people after seeing the others who have been demarcating land with Mr Mulombwa the provincial forestry forest officer. I shall leave it to him to introduce what he has come for. I just want to introduce the chairman for Natwange, and the c/man for Twashuka.

MA: Thanks for your time. The reason we are here is to follow up the work we have been doing around Maposa trying to find ut how you use your land and what you grow. The reason of this meeting is for us to bring to your attention what I think is a problem that exists here and then we can discuss how we can address it togethor. I cannot tell you how to use your land but maybe we can all benefit from this dicussion. That is why we are here.

I have brought some maps and some and satellite images of this area which we shall all look at and then we can discuss from there. Firstly the lands c/man will draw a map of Maposa area showing all streams and roads and maybe even the branches in Maposa.
[Map is drawn and satellite images are circulated with an explanation of what is being represented]. Now that he has drawn the map. We can see that the tree cover is reducing over here in Maposa. It is beginning to look a bit like this area representing the town. You who live here must do something about it. If you recall, the quesyionnaire we had a question about where you get your firewood and I think most of you said you get it from your farms. It is true isn't it?
Mem: Yes.
MA: So if you try to look forward about 10 yrs from now do you think there will still be any firewood left?
Mem: No, we have stopped cutting down our trees from now on.
MA: Even if you say you have stopped cutting down trees, you still have to cook right?
Mem: Yes
MA: When it is cold you have to keep warm right?
Mem: Yes
MA: So you see you cannot stop all these activities, our challenge is for all of us to find a way forward to protect our environment whilst using it. What are we going to do? Maybe the women can give us a suggestion.
F Mem1: I think we shall be planting the trees from the plantation on our farms (conifers and eucalyptus).
MA: Thank you,let us give each other chance. Everyone will have a chance to express themselves. Another option? Yes over there plse
M Mem1: They say, young trees make the forest, so I think we should avoid cutting young trees but instead cut the older trees since they can last longer as firewood compared to the young trees. Also we should practice early burning around them so that wild fires do not destroy them in the hot season.
Clapping

MA: We have heard 2 options about the possible way forward. One from the lady there is for us to plant conifers and eucalyptus in our lots while the gentleman here suggests that we cut older trees instead and practice early burning to protect the smaller trees. Are there any more suggestions?
M Mem2: I think we should assign a small area in our farms where we shall grow trees for firewood.
MA: Is that what we all want?
M Mem3: I agree with the suggestion to plant trees. It is very important to plant trees but I think we should instead plant fruit trees such as mango and avocado which will also provide us with nutrition and fertiliser too and we can even use them for firewood. This will reduce the cutting of local forest trees. My friends, don't worry about planting eucalyptus, it does not mean that we shall attract forest wardens, no. Let us use re-fertilise this soil and also replace the trees we are cutting down.
Clapping
MA: thank you, that is very interesting. As you can see, the 4 suggested solutions we have heard are all different. Each of you may have different views on how to protect our environment. What we shall do now is split into 2 groups so that each group can discuss the best way forward and then we can all discuss them together and see if we can find a way forward. Let the groups be mixed. Can the chairman help with the making of the groups? Each group will have paper and pen to jot down your points. Also choose your own group leader.

[Selected Group discussions]

Resolutions of groups
Group A Leader: In our group we have agreed the following:

1. We should plant fruit trees and other types trees on the area we live
2. we should only cut older trees and leave the young trees
3. we should partition our farm to leave areas for agriculture and others for keeping trees for firewood
4. we should not burn vegetation anyhow
5. those with farms along the streams should not cut trees along the river banks
6. we should not plant the same crops every year in order to improve soil fertility
7. we should not burn trees to make charcoal
8. If the farms were permanently demarcated, we would know how to maintain our forests
9. If we cut all the trees, it does not rain properly
10. we should not uproot trees but instead trim the on the top so that they can grow again

This is what we agreed upon. Thank you.
MA: thank you, we shall now have the resolutions from Group B.
Group B leader: These are the solutions we have found as group B

1. we should not cut trees anyhow in our farms. This is what brings problems because once the trees are gone we shall not have anything left to use.
2. we should leave an area on one side of the farm for trees. We should not cut all the trees on our farms, these trees are the ones which bring rain and act as wind breaks
3. we should not burn trees to make charcoal
4. we should not cut trees on the banks of the streams because they help us. If we cut all the trees along the banks, the streams will dry up and even the Baluba stream will dry up too.
5. we should practice crop rotation for example after planting cassava, plant g/nuts next year and after that soya beans and then sweet potatoes. This will help maintain the fertility of the soil instead of planting maize year after year.
6. we should not cut young trees as this will cause problems for us in the future.
7. we should not burn fires on our farms anyhow. Grass also helps to keep the fertility of the soil. Even large commercial farmers do not burn grass anyhow on their farms.

8. we should plant fruit trees such as mangoes and guavas as they also help maintain soil fertility by holding moisture, their leaves can be used as manure and they help with fresh air and rain
9. same as number 5, practice crop rotation.

This is what we have discussed so far. Thank you.

MA:Thank you for your contributions. Let us give a big hand to both groups for the resolutions. However, I have observed that there seem to be some similar resolutions from both groups. May I suggest that we combine these suggestions into one set and the land c/man will help us write them down.

C/man land:

1. we should not cut trees anyhow. Only cut the older trees.
2. we should leave an area for keeping trees for firewood in our farms. We should not clear out trees in that area
3. there should be no burning of trees to make charcoal.

MA: Since we are agreed, I would like to find out something on this point. I overheard a discussion in group B about what to do when clearing an area for cultivation on the farms, the discussion was about what to do with the trees that are cut down during the process? Can you not make charcoal from this?

M Mem4: Yes you can make charcoal. This is because it is for domestic consumption. We are against bulk charcoal production for business.

C/man Natwange: Another way it can be answered is that we have already subdivided our farms into areas for cultivation, and for keeping trees for firewood. We really guard the trees on our farms jealously.

MA:I hear a suggestion from shi-Mwiche saying we should amend it to say 'we should not produce charcoal for business'. Is this agreeable to everyone?

Meeting: Yes it is

Group B leader: Continuing on,

4. For those who have farms along the streams, we should not cut trees along the river bank because they help keep moisture and bring rain.
5. To preserve soil fertility, we should practice crop rotation.
6. we should not cut young trees for firewood
7. we should not burn vegetation on our farms anyhow
8. We should plant fruit trees on our farms as they will provide firewood, manure and food.

Point 9: if the farms were demarcated to us we would know how to manage the land.

MA: Is this point necessary because it seems to me that we are discussing how to manage our environment?

M Mem5: Yes it is necessary but maybe we can leave it out for now.

MA:Can we continue with any other remaining points?

Group B leader: ok,

9. we should not uproot trees when clearing the land for cultivation in order to allow the trees to grow again.

M Mem6: I think the point you omitted about what to do with the land after demarcation is very important and maybe it should be included because some people tend to encroach on other peoples land and when queried, they respond that the land has not been allocated to anyone so they feel they can cultivate where they like.

MA:I take your point, we shall come back to it later as soon as we finish the other remaining points.

10. If we cut all the trees, there shall be no rain.

MA: Do you all agree with this one?

Meeting: Yes we do.

MA: Ok, we now have 9 points, but I would like us to get back to the point raised by our member. Sir, could you kindly tell us the point again so we can discuss.

M Mem6: Yes, I said that if we were allocated these farms, we would all learn how to take care of our land. This is true because some people encroach on the farms of their neighbours and begin to cut trees or even start producing charcoal and when approached, they claim that the trees do not belong to anyone because the farms have not been allocated to anyone yet. That is why I think it should be included there

MA: So what does the meeting think about this?

Meeting: The point is ok it should be included.

C/man Natwange: I think it should be there because if one knows the extent of your boundaries, you can easily protect your farm from intruders.

F Mem2: It is necessary because some people harvest the wild fruit trees in our lots without permission saying that they are God given and sometimes even cut the trees.

F Mem3: I think we should also preserve the grass and vegetation on the banks of our streams in order to protect them.

C/man Natwange: Oh, that point has already been mentioned and listed.

MA: OK, it shall be included. Are there any more comments or concerns?

Group B leader: I would like to emphasise the point about cutting down all the trees and that is, if we do not have any tree cover, wind will erode the top soil in our fields and it will all end up in the Baluba stream and in fact when it rains it will wash away all the fertile soil into the stream.

MA: So we have all heard, maybe we can add the aspect of erosion to point no 10. Is that agreeable?

Meeting: Yes it is.

MA: That is good. I shall now request the land c/man to read out the summary of the points we have been discussing.

C/man lands: The summary I have is as follows:

1. We should not cut trees down anyhow in our farms
2. We should each leave an area for keeping and growing trees in our farms
3. we should not burn charcoal anyhow and especially not for business. We can only do it for areas where we have cleared for cultivation.
4. We should not cut trees along the banks of our streams. If we cut all the trees we run the risk of drying up our streams and maybe even the Baluba stream may dry eventually.
5. In order to maintain the fertility of the soil we should practice crop rotation by changing the plants that we grow on our farms every year and leaving them fallow for sometime too.
6. We should not burn vegetation anyhow in our fields.
7. We should plant fruit trees on our farms such as mangoes, avocado etc
8. We should not uproot trees when clearing fields for cultivation. We should only cut them above ground
9. If we cut down all the trees, we may not have rain again and wind will erode the fertile soil
10. If we were allocated this land, we would learn how to take care of our farms.

My friends, this the summary of what we have discussed today and these resolutions have not been decided by anyone but ourselves isn't it?

Meeting: yes

C/man land: We have taught each other about what we think is important about preserving our environment. Thank you.

MA: Thank you mr C/man, now as you can see, at the beginning of our meeting I disagreed with your chairmen that I have come to teach you about the environment, actually all I came to do was to hear from you about what needs to be done given the problem I identified for you. Who made these resolutions?

Meeting: It is us.

MA: Did I say you should not cut trees, no. What has happened is that we have all educated each other about the problems we face here and how to deal with them. I think we all deserve a pat on the back and so we should all clap for ourselves.

[Clapping]

We have worked very hard on this today. As a reminder of what we have resolved, we shall print a copy of these resolutions and leave them with you for your future reference. You do recall in the questionnaire I asked about whether you knew about the Land and Forestry policies and whether you were involved in the process of creating the policies. Some of you said you had not heard about the policies and for those who have heard about them, mst said that you were not involoved in the process. However, these resolutions are your own and no one is going to come from the city to enforce them. This is how you feel you should take care of your environment. I just hope we can take the things we have discussed further and put them into practice and not just leave them today.

C/man land: We would like you to type and print copies of these resolutions and bring them over to the chairmen to distribute to everyone in the two branches.

MA: Thank you very much to you all for taking time from your busy schedules to come and discuss something very important to all of us. I will now call upon the c/man, to close the meeting.

C/man land: May I suggest that both chairman give closing remarks.

C/man Twashuka: Thank you all for taking time to come. It is very important that when we hear about a meeting, we make an effort to come for ther may be something important to be heard. We have learnt a lot of important things today for example on the issue of burning vegetation anyhow, I have been affected by fire which was set to some young trees and grass and this burnt most of the vegetation around my farm. My house is now exposed to the wind without protection and last month it actually got burnt. We should take what we have learnt today seriously. I hope we shall be allocated this land and if so what we protect today will benefit us tomorrow. Let us preserve and even improve the fertility of our soil so that we avoid hunger. With these words I wish to thank you all.

[Clapping]

C/Man Natwange: As my friend has has already said, I wish to extend my gratitude to the surveyor who has come from Kitwe because we didin't have the idea to meet and discuss in this manner. I therefore disagree with you and maintain that you came to teach us here because without you, we would not have gathered to discuss. Thank you. As it is said in the Bemba proverb, he who is summoned does not dress well. So everyone should come whenever there is a call for a meeting. These resolutions are important and we should make an effort to follow them and even teach them to those who have not been able to come along. I know that before you even reach where you are going, news of what we have discussed will spread in Maposa. Thank you very much to you all.

End of meeting.

Appendix B.5: Transcript of meeting at Kabulanda village.

Meeting 2: Kabulanda, Kosapo and Zambezi Branches, 9th September 2005

C/man Kabulanda: Hello everyone, I would like to welcome you to this meeting. Firstly I would like to thank our visitors for coming and to inform you that the reason for the apparent small number is because we had a funeral yesterday and as such most of our numbers had suspended their work and therefore may not be able to come for this meeting today.

To all of you gathered today, our visitors had told me they would come back to hold a meeting to discuss some things from that exercise after completing interviews, and for sure they have come. Although I am not very sure what the exact details are but I will leave it to our visitors to tell us. With that I now hand over to the land c/man.

C/man land: Thank you all. This is Mr Akombelwa from CBU and you all know me from around here. This is ZZZZ who works with Mr Akombelwa. We have come to educate each other. I now call upon Mr Akombelwa

MA: thank you all. As the chairman has stated, I requested for this meeting so that we could come and discuss how we can manage our land. If you recall on the questionnaire there was a question I asked you about whether you were aware of any environmental problems in your area and most of said you did not think there was a problem in your area. I have identified what I think is a problem and I would like to share it with you so that we may discuss how we can address this apparent problem together if it exists at all.

I have satellite images which I want to show you first of all and then I will explain what the problem I have seen is and then we can discuss. Thank you.

M Mem1: Before you go any further, how are going to know what the problem is?

C/man land: don't worry he will show you everything on the images that he has brought with him. You will all get a chance to see.

MA: Everyone has had a chance to see the images I have brought. Are there any questions? I noticed that some of you were saying that the problem I was showing you meant that I just wanted to devise an excuse to evict you from your farms. I want to assure you that is not what I have come here for. I have seen a problem that the tree cover in Maposa is diminishing. The reason I have come is for us to discuss what you think should be done about this problem. In the questionnaire, I asked about the source of your firewood and most of you said you kept woodlots on your farms. Now, I want us to imagine what it would be like 5years or even 10 years from now, will these woodlots still be able to provide enough firewood? Will they even be there at all?

M Mem2: The trees grow. They will be there.

MA: Your families are growing and demand is increasing, so isn't that a problem

M Mem3: Since you have seen the problem, what we are waiting for is for you to tell us what to do.

MA: But that is not what I have come to do. I have come to find out from you about what YOU think should be done about this situation.

M Mem4: You have seen the problem, we have not, and so what we are waiting for is for you to tell us what to do

M Mem5: We have been here for a long time since 1989 because we had problems living in town after we lost our jobs. The reason we are here is to grow food for us to eat because in town we cannot cultivate any food. Now you have come to tell us to stop growing food so that trees can grow again. I can see you just want to evict us from here. That is the problem I see.

MA: Your point is taken. Yes sir you want to comment, go ahead.

M Mem6: It is true we here cannot see the problem because, we here in Maposa do not produce charcoal. Nobody here produces charcoal for business. We only get firewood from the trees because we have no electricity for cooking. There is nothing we can do about that. We only burn charcoal in the areas we have cleared for cultivation. You are the one who can tell us about what to do about this problem.

C/man land: This man is your representative like an MP who will speak on your behalf concerning the problems you are experiencing with the environment, he wants to hear from you what suggestions you have to address the environmental problems you are faced with.

M Mem3: Mr xxxx, listen to us. We have been here long. When this man was going round the first time he told us he is not concerned with the issue of title deeds so how can you compare him to an MP?

C/man land: What I am talking about is like making laws, when you make laws you need to sit together and discuss, one person cannot make laws alone. So just like when the MP is going round getting information during tours, this is what this man is doing.

M Mem7: So why don't you tell him the answer yourself since you live here too.

MA: Allow me to explain again. I can see you do not want to talk. I asked you a question in the questionnaire about rainfall around here, those who have been here long said that initially it used to be heavy but now the rain seasons come late and they are getting shorter. Those are your words not mine. Yesterday we were at Natwange and Twashuka and we asked them the same things we are asking you today and the issue being evicted from the land did not arise. This meeting is a follow up to the questions I have been going round asking you.

C/man Kabulanda: What you have said is true. What we need is to teach other about what we can do about this problem that is affecting our farms.

M Mem2: Mr c/man you are not here to teach us anything, just leave it to them to explain to us what needs to be done to prevent Maposa becoming a place without trees.

MA: May I suggest that the best way forward is for us to break into 2 groups and discuss how we can overcome this problem and then compare the resolutions we come up with.

M Mem2: A long time ago we used to cultivate down the sides of hills until the agriculture department showed us the best way to cultivate, they were teaching people. Now we sent you to school to learn so that you can teach us. We have 2 universities and maybe even a 3rd is coming soon. The country is developing, so it is not for us to educate university students but for them to educate us, so you cannot expect us to teach you university students anything.

MA: I still think we can discuss this in groups if you are willing.

M Mem2: We are not squatters, no. Our mp told us we are now farmers. So we want the government to come and teach us about farming.

MA: Please do not put words in my mouth.

M Mem2: I do not see the relevance of this.

M Mem8: You see, we have small farms and we need to expand our food production and also get firewood, so if you look at last years images and compare them with this years image, you will see that the trees have reduced in number, so what do you want us to do about it aside from stopping to cultivate our crops or maybe even move out of here.

M Mem9: When we came here we found that there were no trees, charcoal burners had cut them down, and so the trees you see have grown under our care.

MA: I have already stated why I have come and cannot understand where the problem is. In fact it is not only here in Maposa that we have discussed this problem but in Kalulushi and Chembe as well and this problem did not arise, so please explain to me what the problem is.

M Mem3: We are different so that will not work here.

C/man Kabulanda: They have not come to talk about title deeds but about the environment so give them a chance.

M Mem2: Mr c/man if you have nothing to say, just sit down because we have had important meetings with ministers here from the time of President Kaunda to President Chiluba's time up to President Mwanawasa's time. The Ministers would stand on that anthill and declare that Maposa is ours for agriculture, now how can you come to tell us about cutting trees, go ahead and teach us now.

MA: Let me find out from the women, I think they have been very quiet. Ladies what do you think about all this?

F Mem1: In the questionnaire you asked us about whether we would be willing to follow the land and forest policies if we knew about them. I wonder why you asked

such a question when we do not know whether they are good or bad for us. I think it is just a way for you to try and get us out of here. Can you please explain this?
MA: Thank you before I answer that, I just wish to explain that in Kalulushi and Natwange we discussed what problems people are experiencing and what they think could be done about them.
C/man land: You see, that is what we have come to do, the problem you people have is that you keep thinking he has come to evict you from here. You are the ones who can tell him what problems you have experienced for instance after clearing trees along the river banks so that he can then go back and put these things together and maybe find a solution for all of us as opposed to him dictating to you what should be done. You the farmers are the ones who can tell him what problems you have experienced for example you may have problems with water on your farm and you need a well. He is a visitor.
M Mem2: What you are saying is like what the ministers promised us about coming to sink boreholes here, where are they now? Don't talk about water problems to us.
MA: You see, this relates to the question I asked you about whether you were involved in the process of developing the policies relating to how you use your land and the general response was that you were not involved, now I have would like to find out from you what you would like to see done in order to protect your environment, but you keep saying I should tell you. I do not see how we shall move forward if you are refusing to discuss this so that when I return to my school I can then put together your suggestions on how to respond to this problem I have brought to your attention.
However, I think we have dwelt for too long on the same point and would like to hear from you if you would like to proceed with the exercise or not. I appreciate that you have had to take time off your busy schedules just attend this meeting, kindly advise me if it is your wish not to continue with it.
M Mem11: It is alright for us to continue discussing. I came here a long time ago and I got permission from the forestry people to settle here after the charcoal burners had left, and I asked for seedlings of trees to plant on my farm. I think that is a solution to the problem of deforestation.
M Mem12: It is a good idea, we should get seedlings from the forestry dept and plant them around our farms for firewood and poles for construction.
M Mem13: Now that is a problem, not everyone will want to plant eucalyptus trees on their farms. My farm is small so I cannot afford to leave an area for cultivation. What are we going to do about it?
MA: Those are good suggestions but is it ok to discuss them in groups and then bring the resolutions for summary? Can we now break into 2 or 3 groups and discuss these issues?
M Mem14: I agree with that we shall just be wasting time like this, it is easier for us to break into groups because we can have several answers for one problem but it is easier to discuss them when we are in small groups.
[break into 2 groups fro discussion]
Group A leader: The resolutions for group A are as follows:

1. we should not cut all the trees on our farms
2. we should not burn vegetation anyhow
3. we should not burn charcoal for business
4. we should plant trees in our farms such as mango, guava and avocado which will give you food and shade when it is hot
5. Every household should have trees
6. we should practice crop rotation.

That is all we have from group A
MA: Let us give a hand to group A
Group B leader: As group B we have similar points to those read out by group A. and these are:

1. we should not cut trees anyhow along the banks of the streams
2. we should not cultivate large near the banks of streams as this will cause erosion of the soil when it rains and may even cause the stream to dry up.
3. we should plant trees near the stream such as fruit and eucalyptus trees

4. we should leave an area on the farm where we shall not cut trees
5. we should not burn vegetation anyhow, in fact we should practice early burning of the grass to protect our farms
6. we should not burn charcoal on our farms
7. we should practice crop rotation
8. we should use grass and animal manure as organic fertilisers because other types of fertiliser are destructive to the soil

This is what we discussed as group B.

MA:Thank you, we shall now use these two lists to combine into one list and I will ask Mr xxxx to help us with the writing down of the summary.

WS: The final resolutions are:

1. We should not cut trees anyhow within our farms
2. We should not cultivate large areas along the banks of the stream.

There is disagreement about whether this point should be included because the villagers feel that it is not representative of everyone since not everyone has the stream bordering their farms.

C/man Kabulanda: I feel cultivating along the banks of the stream causes the stream to dry up so It is in order to prevent the cultivation in such areas

Others felt that the banks are places best for cultivating vegetables as well as fruit trees since they do not have pumps to pump water up to the fields on high ground.

MA:Can I clarify that the point says that 'there should be no cultivation of large areas on the river banks' it does not say there should be no cultivation at all.

F Mem3: We are not commercial farmers so we do not clear all the area we have. Similarly, even those with farms by the waters edge do cultivate all the area along the bank.

MA:does this clarification help? Can we put down this point?

Meeting: Yes

M Mem13: I think this point is important because if we cultivate large areas, it will mean that eventually, those who are downstream will have no water in the future and I think that is selfishness.

F Mem4: The problem is that some of us here tend to divert water from the stream causing shortages for those who are downstream. This practice should stop.

M Mem14: We are not commercial farmers and our farms are quite small so we cannot afford not to cultivate any part of our farms. I do not think it is right for me not grow vegetables just because my neighbour downstream will not have any water. Why should I starve?

M Mem15: Our farms are small and I do not think we can afford not to cultivate. What I would like to suggest is that we should not cut the existing trees along the banks of the stream.

Meeting: Let us just skip this for now and we shall come back to it later.

MA:OK, let us move on to the next point.

C/man land:

3. We should plant trees in our farms
4. We should leave an area on the farm for trees to grow
5. We should practice early burning on farms before the grass dries to prevent bush fires and to protect the trees on our farms
6. We should not burn charcoal for business

M Mem15: I have a problem with this point can you please clarify.

WS: You can burn charcoal when you clear trees for cultivation but not solely for the purpose of selling the charcoal produced.

M Mem15: Oh that clarifies it thank you.

7. We should practice crop rotation
8. We should not use trees as a source of manure (as used in chitemene system – slash and burn) but we should try to use grass or animal manure

MA: Can the c/man land, give the summary he written down for us.

WS: the summary is as follows:

1. we should not cut trees anyhow on our farms

2. we should plant trees in our farms
3. we should leave an area on our farms specifically for keeping trees
4. we should practice early burning to prevent the loss of trees and top soil from bush fires.
5. We should not burn charcoal for business
6. We should practice crop rotation in order to maintain the fertility of the soil
7. We should use grass or animal manure and not trees as manure. Just like I overheard my colleague there say that for the gardens you only need chicken manure instead of urea fertiliser.

As you can see my friends, these are the resolutions you have made today. I can tell you today, that these are similar to what your colleagues in Natwange resolved yesterday. These will go for typing and I can assure you that I will distribute them personally to the chairman and all those I can find.

I hope you have seen that this discussion is linked to the questions in the questionnaire. He wants to know how you are using this land and how you intend to protect it for future use. He has not come to evict anyone at all as you can see he has no armed police escort to help him do that. Evicting someone is not a small matter. Thank you.

[clapping] + laughter

M Mem16: I just wish to add a comment on cutting vegetation along the banks of streams. There are some streams without trees but they have reeds, and some people tend to cut the reeds to make mats. Just like the trees, when we cut reeds, it also causes streams to dry up. It also creates a fire hazard after the reeds have been cut and are set on fire in the dry season.

F Mem5: I want to find out what will happen with these demarcations we have seen going on being carried out by the forestry dept. Are they going to give us this land or not?

MA: I am sorry I not able to answer your question as I have no information about the details of the process. Only the Forestry department can address your query. At this juncture I would like to thank you very much as we have educated each other. It is normal to disagree on certain points in a discussion. The important thing is you have recognised the different views that your colleagues have. The issues you have raised are very important and we shall give you copies of the summaries you have made. I refer to the c/man to close the meeting.

c/man Kabulanda: Thank you for the spirit you had to help us educate each other. Please do not tie to attend meetings. There is a lot to learn with every gathering. I am sorry about the poor attendance but nevertheless we are very thankful. I will ask Mr YYYY to close with a prayer.

End of meeting.

Appendix B.6: Transcript of meeting at Chamwanza village, Kalulushi.

17 in attendance
Meeting: Chamwanza Village Committee, Kalulushi November 2004

MA: Just to introduce myself, I am from CBU and I am carrying out this research to try and understand how you are using the land and to hear your views on how you would like to see improved and compare it with what the government thinks and then later use it to present a solution for the government to consider. In today's discussion, we may not find a solution but through discussion we might find a way forward.

C/Man: The biggest problem we have here is our situation concerning our stay here because we do not know if the Council will allocate these farms (land-holdings) to us. After the land is allocated to us, we will then be able to decide how we can take care of our livelihoods, build nice houses, and rear animals.

MA: Thank you very much for your time. Before we proceed further, I would like the chairman to draw a map of the area showing the most important features around here.

[Chairman proceeds to draw map with the help of his colleagues].

MA: Thank you for the map.

C/Man: I would like to say a few things. On the issue of water, this is central to this discussion. This has been discussed with the councillor at previous meetings with him. People here have complained about the lack of wells at their houses. They are afraid to spend money to dig wells in case the well is found to be in somebody else's land after demarcation of the land. This has caused a problem to people here as we find it difficult to build nice houses because we do not know how the demarcation will be done. It is even difficult for us to rear any domestic animals. For example even rearing chickens is a problem because during cultivation for example, my chickens can enter my neighbours' field and eat their crops. These are regularly occurring problems, in fact, we have had to resolve confrontations between neighbours at the Branch level over this and the issue of people competing for use of water in wells. This is because of not having clearly defined boundaries. These are very big problems for us in this area.

Concerning firewood, as I mentioned in the beginning it also causes problems here. There are some here who have small plots and they do not have firewood. Even if I have firewood on my plot, they cannot come to collect it without permission. Even that is a problem amongst us.

If we were to talk about what we can see on the map, you can see this stream shown here, it has water in the rainy season and in the hot season, it dries up except for one patch where it has water all year round. You saw my wife going to draw water yesterday, it was at the same place she went. It dries up along the way up to the bridge at the boundary and to have water, here, one has to dig a very deep well. Our friends across the boundary have water and some even have fish ponds. This causes a problem for us here as you saw, our women have to walk long distances to draw water especially during the time before the stream fills up in the wet season. The lack of properly defined boundaries also causes a problem. If people had title to land, they would try as much as possible to have their own wells on their land.

On the issue of firewood, anyone can have the power to cultivate plants because these plants can also be considered as firewood because when you prune the stalks and branches, they can be put aside as firewood. We can also plant some trees and when they grow that is firewood. The Forest [dept] also sell some tree saplings from the excess of what they plant. These trees are necessary on each person's lot as they can be very helpful in the future when they grow as they provide firewood.

Some other problems that we face are access to clinics. The hospital is very far from where we live, but the clinics should be near to us to allow for quick access to medical treatment even if it costs money to get the treatment. Lack of access to medical attention is a problem especially for expectant women in the night as you cannot predict when they will need to be admitted into hospital. We also have a problem with security in our area. Only recently a young man was robbed of his bicycle. So in a nutshell those are some of the problems we are faced with here.

MA: Is there anyone who would like to add anything that has been said by the C/man?

VLGR1: I would also like to say something. The problems the c/man has explained are the problems we are always complaining about in our area. We started in the past as charcoal burners invited by the forestry dept to help clear trees, but after sometime the firewood ran out and the forestry dept had nowhere to take us so we just had to begin cultivating food in order to feed our families. So our mainstay now is agriculture. The most important thing we want is for the government to demarcate this land because we are not free because as we are always wondering whether we will be allowed to stay or not. This affects our agricultural output because we have no security. We would be very grateful if the govt could look into this and demarcate this land so we could know where our boundaries are. This will stimulate economic activity as people will build better houses, dig deep wells and grow the crops they want to so they can support their families. This problem started a long time ago and we have tried to bring it to government's attention but they do not respond to our requests as they only say, *'we will look into it'* without any action. We would therefore like you to speak on our behalf and it will help bring security to us. Just like our friends in town, they were sold houses by the former president Chiluba at discounted prices, similarly, in line with the motto to 'go back to the land', we too would like to be considered similarly by giving us this land so we can be able to support our families. So we would like to urge the government to firstly give each one of us title to this land and secondly to come and help us with agricultural inputs. In some areas, the government through PAM (Program Against Malnutrition) supplies inputs to small scale farmers, we too would like to be considered like them. We would therefore like government to look into these issues so that we can be free to use the land without hinderance.

Concerning water, we cannot live without water. We would be most grateful if after demarcating the land, you could then assist us with the provision of wells. I went to a place in Ndola and I found that they were asking for water and electricity. They were given. So all we ask for here is for the land to be demarcated and for wells to be dug for us. This is all I have to say thank you.

MA: Thank you for your comments, I would like to advise that we have not come to demarcate land but to find out the problems you have in using this land. However, your views have been noted.

VLG2: So what exactly have you come to do here?

MA: The main purpose of this exercise is to understand the problems you have in using this land. This is for research purposes at university and not to demarcate land. The findings will then be presented to the government in future and they may consider using the findings to improve your livelihoods.

VLG2: I now understand. Thank you.

VLGR3: The government has a lot of departments, so which specific area are you focussing on?

MA: The research project is concerned with land use. In fact we have been administering a questionnaire which has a lot of different questions concerning how you live here, how you came here, what kind of challenges you face here, where you get your firewood and water from. Our task today is to find out from this committee what kind of challenges exist here and how you think they can be addressed.

VLGR4: Thank you for clarifying this since we missed the start of the meeting.

MA: We thought we should get started because of the threat of rain today.

VLGR2: I think you will have to understand us here because these are the problems we are facing and we cannot hide them. I heard from the other officer that you have not come to demarcate land. Yes, we can see that. We are just informing you of some of our concerns here.

VLGR5: You are right, it is said that he who feels the pain will move to find relief.

C/MAN: My friend here (VLGR1) mentioned projects [such as PAM]. The main issue concerning this is that we do not have these projects or cooperatives running here because we do not have proper tenure here. If we had title to land here, even 10 people can form a small cooperative or a club. Without these it is difficult to get anything going. For example, recently I had some people come to me with an idea to form a club to start fish farming. However, when I looked at the map I realised that fish farming needs a lot of water and that we do not have access to the kind of water resources required for this type of activity. If you look here you will see that the stream begins in one corner of the map and passes through two private farms. The suitable places for us to construct fish ponds along the stream are in private land. The only section of the stream available to us does not have sufficient water and we therefore came to the conclusion that we cannot carry out fish farming in this area. The only projects which we may be able to carry out are chicken farming and pig farming and with the support of projects such as PAM. I suggested this to my colleagues here and they did not seem to want to proceed with the suggestion as they were interested in fish farming.

I believe that given title to this land, we can run successful animal rearing projects in Chamwanza. We could request the government to designate an area within Chamwanza for the purpose of running cooperative projects.

MA: We have identified problems you are faced with here. To recap, the main problems you have identified are the title to land, access to water and access to firewood. Is there any other issue I have left out?

VLGR6: I think you need to include the problem of access to fertiliser

MA: That has now been included. Now concerning these four main problems you have identified, is it possible for us to identify the areas where these occur in Chamwanza? The first problem is that of title to land, but I would like us to first consider the issue of water. I would like you to show the areas on the map where access to water is a problem here in Chamwanza.

VLGR7: Before we proceed further, I just want to know what we are going to tackle after the issue of water. Here, water is a problem, we have had to dig deep wells and a lot of them are dry. To me land is a very important issue.

MA: After looking at water we will look at firewood. The issue of land affects the entire Chamwanza as none of you has any title to land here. We will look at it later. Concerning water, what I would like you as a committee to do is to identify places where water is a problem in Chamwanza and indicate these on the map. As you can see on the map, we have the stream running through here, so kindly indicate the areas where water is a problem.

[committee proceeds to show areas on map that experience scarcity of water]

MA: How do you get these wells prepared?

VLGR8: We dig the wells ourselves. In the dry season, (October, November) the water level is very low and the wells dry up until around January in the wet season when the water level rises.

C/Man: You see we do not dig wells in the same way one with equipment would dig. We use simple methods and stop when we find water. The sophisticated equipment used by the government helps them measure how deep they should dig and not just stop when they find water like we do. What we would like to see is for the government to come and dig wells for water for us here especially in the areas we have highlighted on the map since they have the expertise to do so.

VLGR9: Just to follow up on what the Chairman has said, the government should come and dig wells for us at certain places to cater for different locations [within Camwanza] so that people living in one area can draw from one well while other groups can draw water from wells nearest to them.

VLGR10: When we came here, there were trees but they are all gone now. We cannot find any firewood. If we venture into the [forest] plantation, we end up being arrested by the forest guards. So to reiterate, the shortage of firewood is a big problem for us as.

VLGR1: To help the v/cman, we mostly use the stumps that were left in the fields. We uproot them from the fields once they are dry since they have been in the ground for over 5years and use that as firewood. Sometimes we also use the stalks of our maize crops as well as the cobs (after shelling of the maize) as firewood.

MA: In administering the questionnaire which we began doing on Monday, we found that most people came here around 1987 and after. That's about 14yrs (upto 2004). Now looking forward, I do not see you moving away from here even if you were not to be given title to the land. Now, I don't think you will stop cooking as long as you are here. So where are you going to get firewood? What do you think can be the solution to this problem?

VLGR11: These same mango trees you see will be the solution. They will provide food, heating and lighting [energy] for us.

VLGR12: Look at the areas in Kitwe such as Chimwemwe, Buchi and Kamitondo. They used to be forest but are now built up areas, what do you think they use for cooking, isn't it electricity they use?

MA: Most of them use charcoal. But you see they get their charcoal from their local markets and the charcoal at the markets comes from very far. Now for you, you seem to rely on firewood from around here. But I have to ask you what you think you will be using in the future because with the passage of time even the small wood lots on your plots of land such as this one the C/Man has here are diminishing because of constant usage.

VLGR13: I would like to say something about that. Yes with diminishing wood lots, as a farmer, after harvesting, I will use the stalks and cobs as firewood because I have nowhere to get firewood and charcoal.

VLGR 14: I have followed this discussion and I think it is nice that we are talking openly. I think that after demarcation of the land in this area, we will have a legitimate right to go back to the government to provide electricity since we will be a recognised settlement then.

VLGR1: I like the answer you have given but I don't think we are actually addressing the question because even if electricity supply was extended here, not everyone will have access to it. I think what he is trying to find out is what we shall use once all our resources are gone in our area. I think what we should do is to plant more trees, both fruit and exotic trees such as avocado pear, mango trees, eucalyptus and so on. These will help bring rain and as we prune the trees they will provide us with firewood.

C/Man: Just to add to what has been said, looking forward, we may be fortunate to have the land demarcated for us soon and depending on the size of the plots we shall have, I do not believe that somebody can say they do not have enough space on their land to leave for a woodlot. This area is fertile and trees can grow easily.

As you can see on my woodlot, one section has larger older trees and another has smaller younger trees. The section with fresh growth was harvested recently and you can see it is regenerating. That new growth is firewood for the future. I am quite vigilant in guarding against fire and I burn off the undergrowth after the rains to protect against a major fire. If a fire was to breakout I would be the first one to protect the trees from fire. I harvested firewood last year and the growth shows me that I can be able to sustain my life here so I need to leave a place for the growth of trees on my land which will provide me with firewood for cooking and heating.

MA: How is it like for those who have cut all their trees?

VLGR14: You see every person learns from their experiences and prepares for the future. I am sure those who have cut all their trees will plant trees because they know they have to change.

MA: Thank you for this, so how can we summarise this point now?

VLGRS: Yes, we should plant trees in our woodlots for our own future.

MA: On this map, where can we show areas with problems of firewood.

VLGRS: It is everywhere in the area here.

VLGR15: Mr C/man, I have my concerns about all this. I don't think anything will come out of this. We should be talking about getting the land demarcated for us and not wasting time like this with these people. Once they go we will never see them again, so it does not matter whether we tell them anything or not because it will not help us here. Some other people will come another time and so on and we will not benefit anything at all.

C/Man: No, I disagree. You do not seem to follow what he is saying. He has come to find out what our problems are and what we think. It is not like the other people from the council and others. This is for school [research].

MA: This is a good discussion. I can see there are some among you who do not agree with this.

VLGR3: Yes clearly there are some who understand and some who do not understand what is going on.

MA: I am happy about this. Now, is the committee able to advise people here especially those who are at risk of using up or have used up all their firewood resources on their land about the dangers of such practices?

VLGR4: That is a bit difficult for us to do because of the needs that people face and each one makes their own individual decision. So we cannot tell anyone to leave trees on their land for future firewood usage.

MA: I do not mean individual committee members confronting members of the community about it. What I mean is whether the community can be brought to a meeting and advised about these dangers.

VLGR3: The problem we will face is that the size of plots differs and this affects how much land can be set aside for firewood by each person. This is why we need the demarcation so we can be very clear about the extents of our land because no one will be willing to give a part of their land to their neighbours for them to have a woodlot.

C/Man: My understanding of the question is whether we as a committee can advise members of the community who are at risk of depleting their firewood resources, is that correct?

The problem is this: the plot sizes [in Chamwanza] are small and so if we advise our community members who are at risk to leave some land for firewood, we feel we might be violating their desire to grow food on their land especially if they have large families. This is because part of the harvest is sold to raise money to pay for school and medical fees and other small things. So it can be difficult to urge people to set aside some land for woodlots on their plots as they need all the land to grow food.

I can give you an example of myself. If you look at these mango trees, they are not supposed to be here [near the house], but I made the decision early on about where to plant them because I needed the space to grow maize. I cannot plant maize under the mango trees as it will not produce any maize cobs. What we wish for is to have larger sizes of land when the demarcation is done so we can then be able to plan properly to grow crops and trees which will help us in the future.

MA: Thank you for your contributions. Is there anything else you would like to discuss?

VLGRS: No, we think we have covered everything. Maybe you have something more to add.

MA: No, that is all I wanted to find out from you. I would like to thank you for this discussion. Before we disperse can we pose for a picture?

End of meeting.

Appendix B.7:

Root Definitions and CATWOE Analysis of the Land-Use Decision-Making system sub-models

Table B.1: Root definitions of the land-use decision-making system sub-models

Gather Knowledge	*A government owned system, operated by local authority planning officers and technical staff to meet the need for knowledge, in order to allow for correct decisions while taking into account availability and accessibility of knowledge.*
Obtain Resources	*A government owned system, operated by local authority planning officers and technical staff, to meet the need for resources, in order to assure that sufficient and fully functional resources are available at local authority and regional levels, while considering insufficient amount and restricted availability of resources and lack of trained personnel.*
Collate Land Information	*A government owned system operated by local authority planning officers and technical staff, to acquire relevant land information, in order to support the decision-making process while considering quality, interoperability issues, existence of incorrect and contradicting information.*
Liaison with Stakeholders	*A government owned system operated by local authority environmental and planning officers, to ensure communication between local stakeholders, NGO's and government is in place, while considering issues of access to and use of natural resources, government policy, legislation and stakeholder views and perceptions.*
Land Use	*A government owned system operated by local authority planning and technical staff to meet the need for providing appropriate land-use advice to local stakeholders in order to encourage adoption of sustainable land-use practices, while considering lack of resources and trained personnel, accebility of areas, behaviour of local stakeholders.*
Decide	*A government owned system operated by local authority planning and technical staff to meet the need to determine the most appropriate land-use, in order to reduce progressive loss of natural resources, while considering quality and quantity of land related information, current state of natural resources in protected areas, negotiate balance between ideal and realistic outcomes and availability of resources to implement sustainable land-use practices, legislation and policy, stakeholder views and perceptions.*
Monitor and Evaluate	*A government owned system operated by local authority planning and technical staff to meet the need for monitoring and evaluation of the processes involved in the sustainable land-use system, in order to reduce the progressive loss of natural resources, identify issues and problems with current process, while considering problems related to operational constraints, access and lack of cooperation of local stakeholders.*

Appendix B.7:

Root Definitions and CATWOE Analysis of the Land-Use Decision-Making system sub-models

Table B.2: CATWOE Analysis of the land-use decision-making system sub-models

	Gather Knowledge
C	Local authority land-use decision makers
A	Local authority planning and technical staff
T	Need for knowledge => need met
W	Knowledge of good quality and quantity to allow for correct decision making
O	Local authority land-use decision makers
E	Availability and accessibility of knowledge; contradictory knowledge
	Obtain Resources
C	Local authority land-use decision makers
A	Local authority planning and technical staff
T	Need for resources => need met
W	Assurance that sufficient and fully functional resources are guaranteed and can be allocated as required
O	Local authority land-use decision makers
E	Insufficient amount of resources; restricted availability; lack of trained personnel
	Collate Land Information
C	Local authority land-use decision makers
A	Local authority planning and technical staff
T	Need for relevant high quality land information => need met
W	Assurance that sufficient quality and quantity of land information to support decision making process is available
O	Local authority land-use decision makers
E	Information quality; interoperability issues; existence of incorrect or contradictory land information
	Liaison with Stakeholders
C	Government agencies, local authority land-use decision makers, NGOs, local and institutional stakeholders
A	Local authority planning, environmental and other technical staff
T	Need for communication between stakeholders => need met
W	Facilitate inter-communication between all stakeholders
O	Local authority planning, environmental and other technical staff
E	Issues of access to and use of natural resources; policy and legislation; stakeholder views and perceptions
	Land Use
C	Local authority land-use decision makers
A	Local authority planning, environmental and other technical staff
T	Need to provide appropriate sustainable land-use advice => need met
W	Can encourage adoption of sustainable land-use practices by local stakeholders
O	Local authority land-use decision makers
E	Lack of trained personnel; accessibility of areas; behaviour of local stakeholders

Continued on next page…

	Decide
C	Local authority land-use decision makers
A	Local authority planning, environmental and other technical staff
T	Need to determine most appropriate land-use => need met
W	Can reduce progressive loss of natural resources
O	Local authority land-use decision makers
E	Quality and quantity of land related information; current state of natural resources; availability of resources; stakeholder views; legislation and policy
	Monitor and Evaluate
C	Local authority land-use decision makers
A	Local authority planning, environmental and other technical staff
T	Need for monitoring and evaluation of the process involved in sustainable land-use decision-making system => need met
W	Can reveal problems and issues with currently adopted practices; can improve land-use decision-making process; can reduce progressive loss of natural resources
O	Local authority land-use decision makers
E	Operational constraints; access to areas; lack of cooperation by local stakeholders

Appendix B.8:

Conceptual models of the Land-Use Decision-Making system sub-models

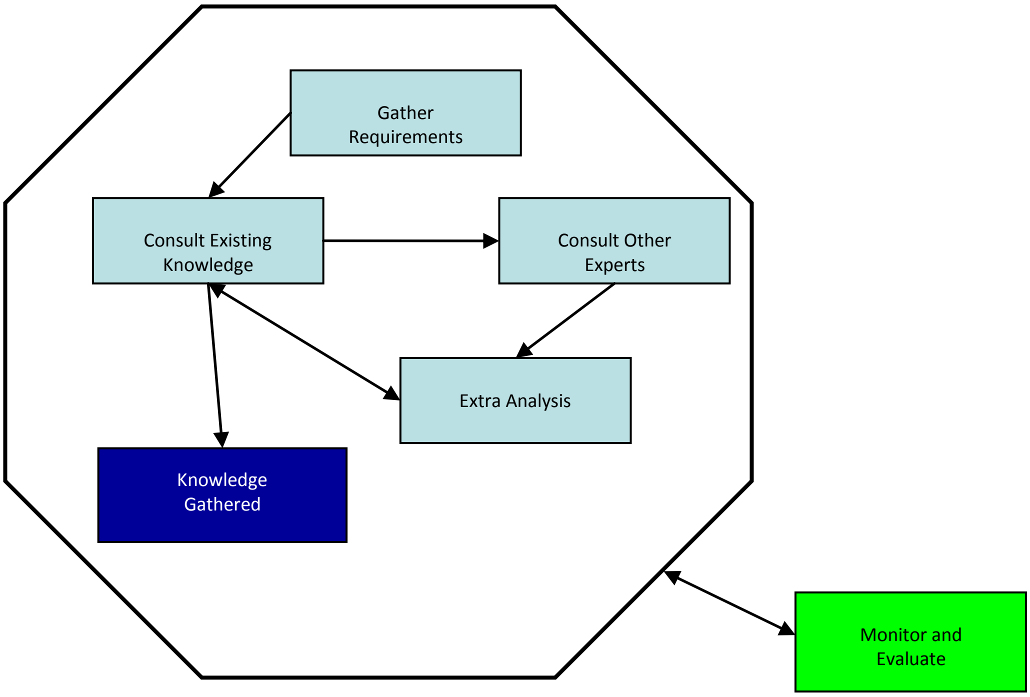


Figure B.1: Conceptual model of the sub-model Gather Knowledge

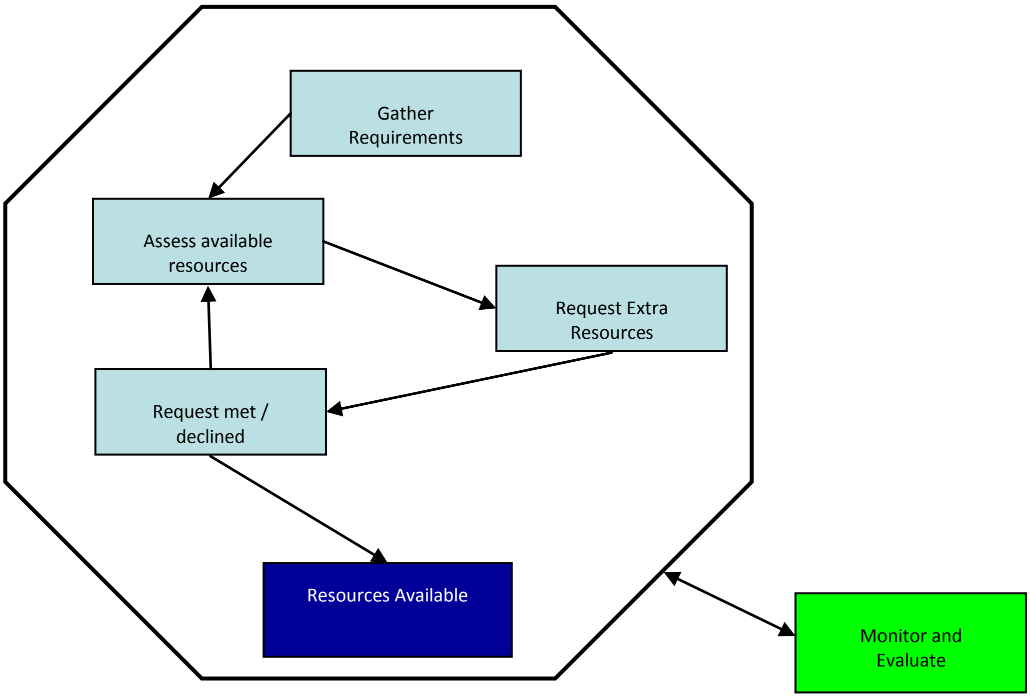


Figure B.2: Conceptual model of the sub-model Obtain Resources

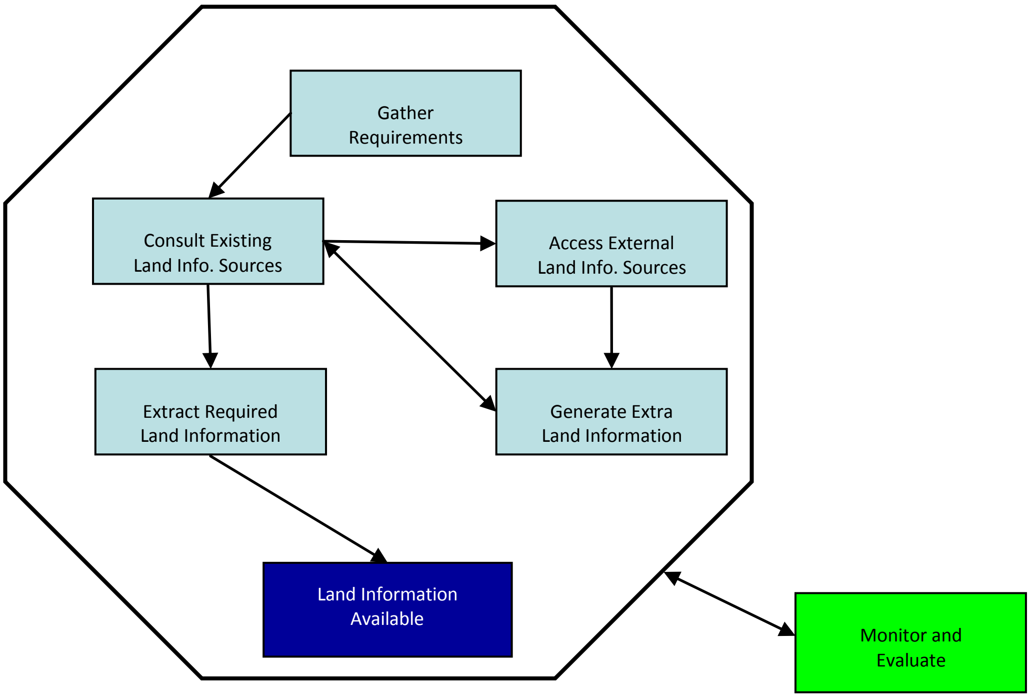


Figure B.3: Conceptual model representing sub-model Collate Land Information

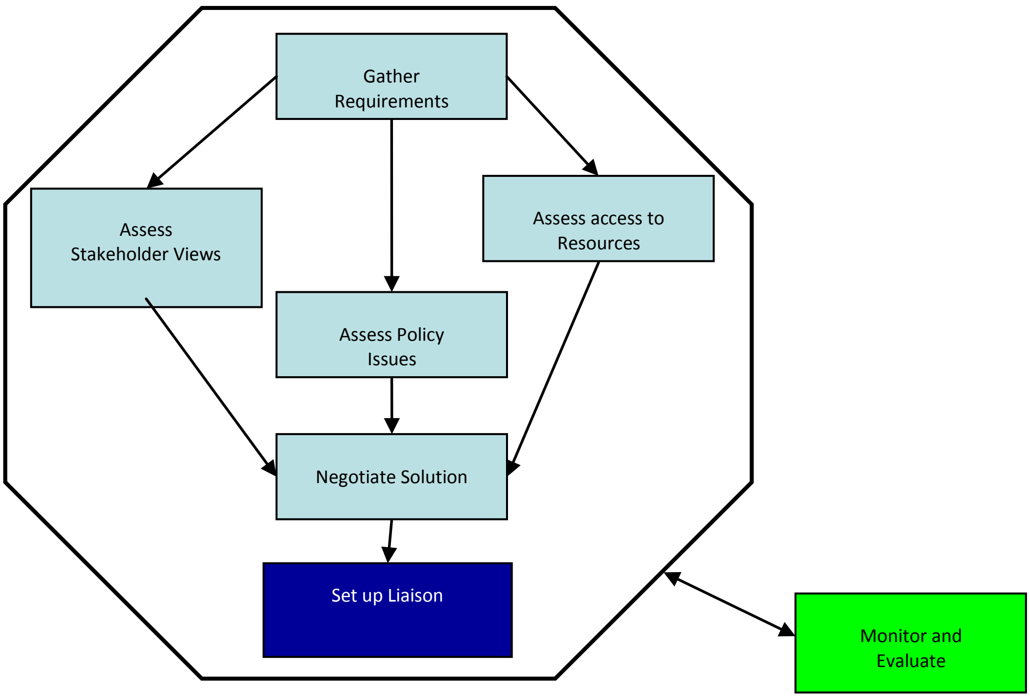


Figure B.4: Conceptual model for the sub-model Liaison with Stakeholders

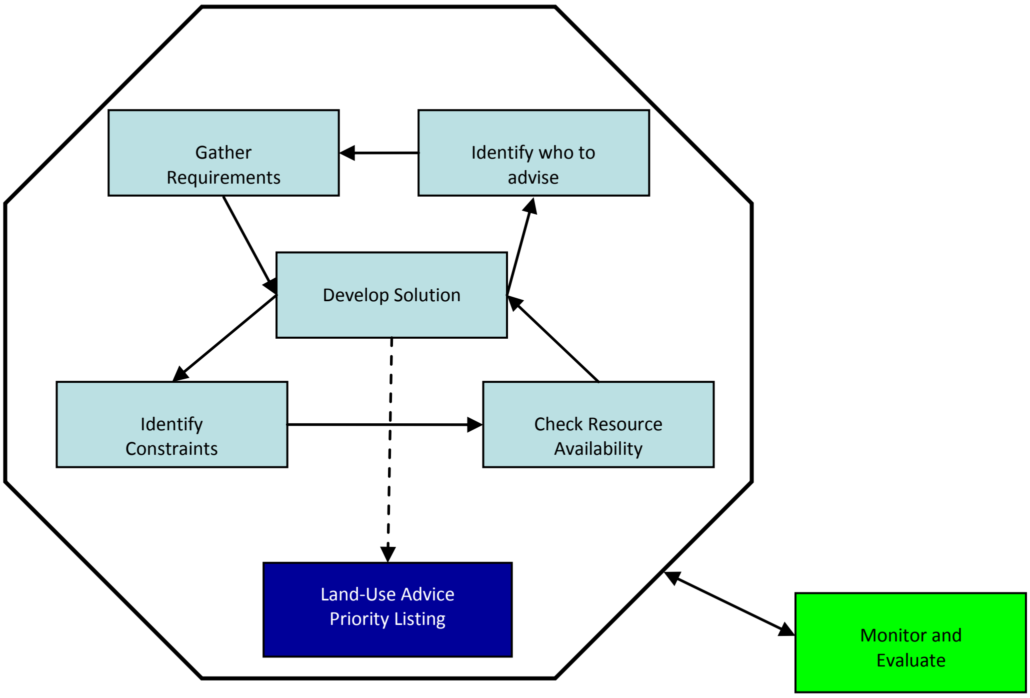


Figure B.5: Conceptual model for the sub-model Land-Use

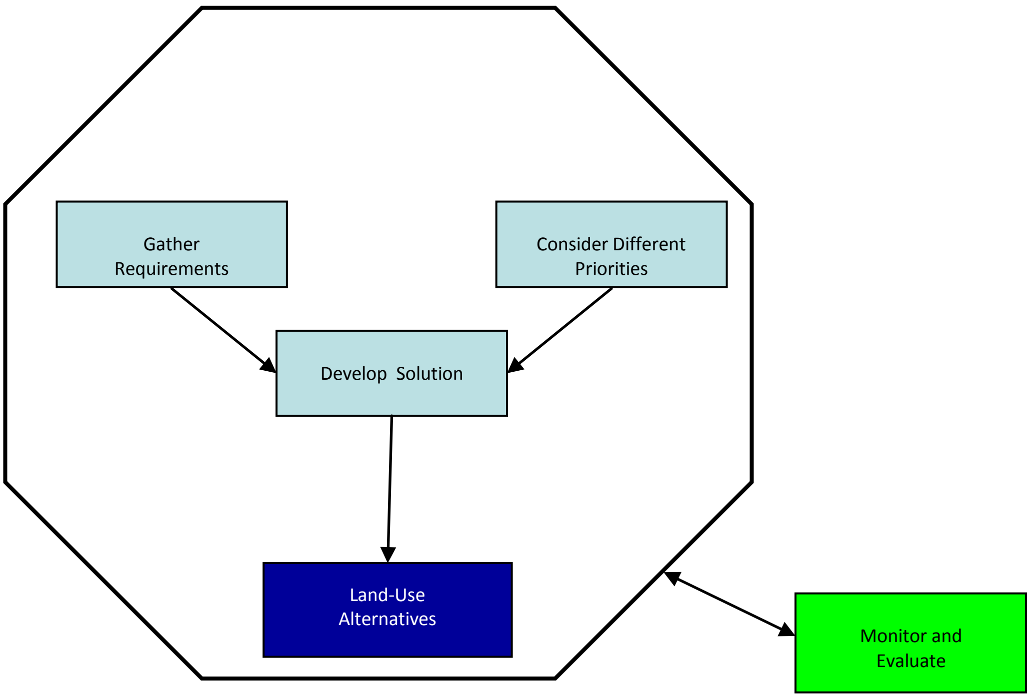


Figure B.6: Conceptual model for the sub-model Decide

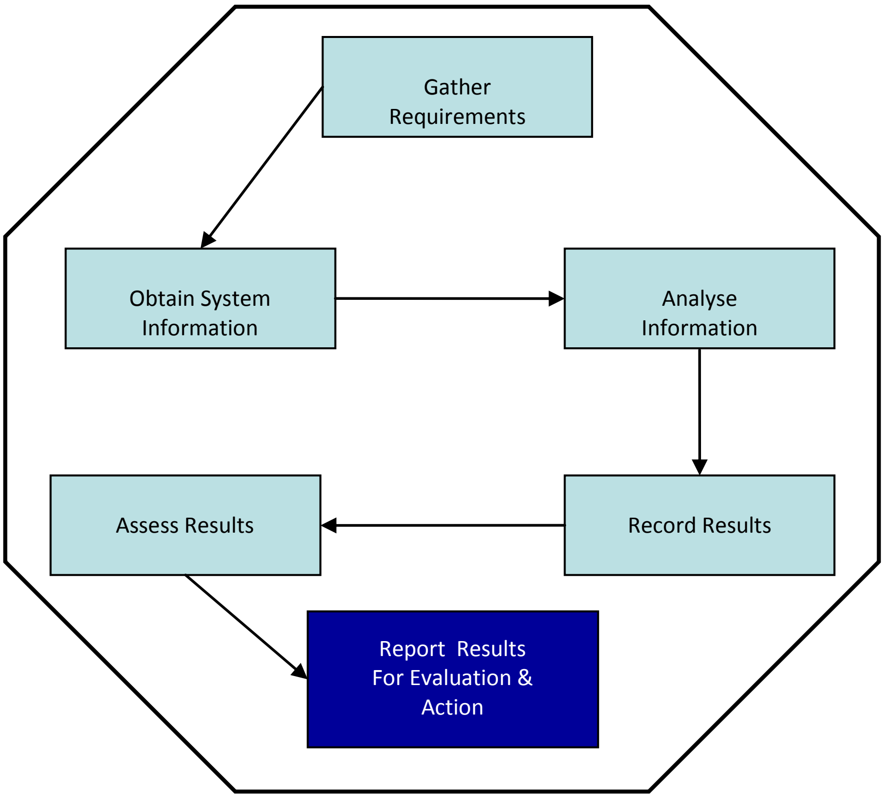


Figure B.7: Conceptual model for the sub-model Monitor and Evaluate

Appendix C: BN model output

Appendix C.1: Error measures

This section shows the scoring rule results for the nodes of the BN model for the Maposa and Kalulushi data. These are shown in Table C.1 which is spread over three pages

Table C.1(a): Scoring rule results for Maposa and Kalulushi

Node:	Maposa	Maposa Tr 2	Kal	Kal Tr 2
B: Distance to Market				
Error rate	0.9293	0.1566	0.9412	0.2941
Logarithmic loss	1.0990	∞	1.0990	∞
Quadratic loss	0.6667	0.2925	0.6667	0.5299
Spherical payoff	0.5774	0.8463	0.5774	0.7200
E: Distance from Road				
Error rate	0.7273	0.7831	0.7647	0.7647
Logarithmic loss	1.0990	1.7050	1.0990	1.5630
Quadratic loss	0.6667	0.9471	0.6667	0.8882
Spherical payoff	0.5774	0.3726	0.5774	0.4169
U: Access to Forest Food Resources				
Error rate	0.0657	0.0602	0.6471	0.6471
Logarithmic loss	0.2485	0.2364	1.5460	1.5460
Quadratic loss	0.1247	0.1159	1.0620	1.0620
Spherical payoff	0.9360	0.9408	0.4200	0.4200
S: Access to Firewood				
Error rate	0.1364	0.1386	0.4118	0.4118
Logarithmic loss	0.4923	0.4983	1.3970	1.2100
Quadratic loss	0.2442	0.2484	0.6938	0.6892
Spherical payoff	0.8694	0.8670	0.6116	0.6153
V: Distance to Stream				
Error rate	0.6414	0.3795	0.4118	0.5882
Logarithmic loss	0.6931	0.7046	0.6931	0.9339
Quadratic loss	0.5000	0.5045	0.5000	0.7132
Spherical payoff	0.7071	0.7087	0.7071	0.5767
	-	-	-	-
M: Rainfall				
Error rate	0.3939	0.3855	0.6471	0.6471
Logarithmic loss	0.9068	0.9043	1.0910	1.0960
Quadratic loss	0.5414	0.5370	0.7115	0.6975
Spherical payoff	0.6773	0.6809	0.5527	0.5586

Table C.1(b): Scoring rule results for Maposa and Kalulushi

Node:	Maposa_	Maposa_Tr 2	Kal_	Kal_Tr 2
G: Status in Village				
Error rate	0.2071	0.1747	0.1765	0.1765
Logarithmic loss	0.5101	0.5697	0.4693	0.5706
Quadratic loss	0.3284	0.3785	0.2928	0.3793
Spherical payoff	0.8195	0.7911	0.8413	0.7906
W: Land Policy				
Error rate	0.4747	0.5422	0.4706	0.5294
Logarithmic loss	0.6920	0.7059	0.6915	0.7034
Quadratic loss	0.4989	0.5127	0.4983	0.5103
Spherical payoff	0.7079	0.6982	0.7083	0.6999
X: Forestry Policy				
Error rate	0.4192	0.4096	0.8235	0.8235
Logarithmic loss	0.6845	0.6804	0.7395	0.7601
Quadratic loss	0.4913	0.4873	0.5463	0.5667
Spherical payoff	0.7132	0.7161	0.6744	0.6601
T: Local Authority Interaction				
Error rate	0.2778	0.2831	0.4706	0.4706
Logarithmic loss	0.5951	0.6047	0.8194	0.8355
Quadratic loss	0.4044	0.4125	0.6065	0.6179
Spherical payoff	0.7722	0.7675	0.6456	0.6401
Q: Land Use Restrictions				
Error rate	0.2576	0.3012	0.4118	0.4118
Logarithmic loss	0.5721	0.6135	0.7556	0.7204
Quadratic loss	0.3836	0.4223	0.5481	0.5215
Spherical payoff	0.7853	0.7602	0.6826	0.6962

Table C.1(c): Scoring rule results for Maposa and Kalulushi

Node:	Maposa_	Maposa_Tr 2	Kal_	Kal_Tr 2
D: Income				
Error rate	0.2273	0.2229	0.0000	0.0000
Logarithmic loss	0.5533	0.5339	0.1696	0.2984
Quadratic loss	0.3614	0.3489	0.0487	0.1331
Spherical payoff	0.8012	0.8072	0.9833	0.9445
Y1: Local Action				
Error rate	0.4192	0.4096		
Logarithmic loss	0.6821	0.6804		
Quadratic loss	0.4889	0.4873		
Spherical payoff	0.7150	0.7161		
Y2: Local Authority Action				
Error rate	0.1414	0.1325		
Logarithmic loss	0.4076	0.3943		
Quadratic loss	0.2429	0.2316		
Spherical payoff	0.8701	0.8769		
Y: Local Community Action				
Error rate	0.2475	0.2229		
Logarithmic loss	0.5638	0.5716		
Quadratic loss	0.3754	0.3813		
Spherical payoff	0.7908	0.7883		

Appendix C.2: Sensitivity analysis

This section shows tables for the output of sensitivity analysis calculations for the transects T1 –T7 for the BN model for the Maposa Local Forest.

Table C.2: Sensitivity output for satisfaction node for transect 1

Transect 1

Node	Mutual Info	Variance Beliefs
A	1.33044	0.336177
F1	0.37481	0.049324
A1	0.30986	0.054989
C	0.17148	0.025802
J	0.02736	0.004239
D	0.01657	0.002319
E	0.01469	0.002261
F2	0.00487	0.000744
K	0.00166	0.000248
U	0.00068	0.0001
L	0.00042	5.96E-05
F	0.00014	1.94E-05
H	0.0001	1.43E-05
Q	0.00006	9.1E-06
B	0.00006	9.1E-06
Y	0.00003	4.2E-06
N	0.00003	4.4E-06
G	0.00002	2.4E-06
T	0.00001	1.7E-06
Y1	0.00001	1.1E-06
M	0	6E-07
Y2	0	3E-07
R	0	2E-07
S	0	1E-07
W	0	1E-07
X	0	0
V	0	0

Table C.3: Sensitivity output for satisfaction node for transect 2

Transect 2

Node	Mutual Info	Variance Beliefs
A	1.51827	0.414293
F1	0.46038	0.072561
A1	0.35614	0.066466
C	0.21145	0.037126
D	0.05528	0.010378
J	0.05027	0.00917
E	0.01328	0.002439
F2	0.00832	0.001446
K	0.00353	0.000655
U	0.00172	0.000309
L	0.00103	0.00018
F	0.00043	7.39E-05
B	0.00018	3.36E-05
H	0.00017	2.95E-05
Q	0.00012	2.06E-05
Y	0.00009	1.52E-05
N	0.00005	0.000008
G	0.00003	5.1E-06
Y1	0.00003	0.000005
Y2	0.00002	3.2E-06
T	0.00002	0.000003
M	0.00001	1.5E-06
S	0.00001	1.3E-06
R	0	3E-07
W	0	1E-07
V	0	1E-07
X	0	1E-07

Table C.4: Sensitivity output for satisfaction node for transect 3

Transect 3

Node	Mutual Info	Variance Beliefs
A	1.37777	0.354879
F1	0.39809	0.05434
A1	0.32336	0.057548
C	0.19249	0.030246
J	0.0344	0.005571
D	0.02932	0.004259
E	0.02092	0.003354
F2	0.0051	0.000798
K	0.00188	0.00029
U	0.00073	0.000111
L	0.0006	8.94E-05
F	0.0002	2.94E-05
H	0.00009	1.33E-05
Q	0.00009	1.25E-05
B	0.00006	1.03E-05
Y	0.00004	6.5E-06
N	0.00002	3.6E-06
T	0.00001	2.1E-06
Y1	0.00001	1.6E-06
G	0.00001	9E-07
Y2	0.00001	7E-07
M	0	7E-07
S	0	2E-07
R	0	1E-07
W	0	0
X	0	0
V	0	0

Table C.5: Sensitivity output for satisfaction node for transect 4

Transect 4

Node	Mutual Info	Variance Beliefs
A	1.43151	0.376934
F1	0.42518	0.06151
A1	0.33857	0.06119
C	0.219	0.036323
J	0.04712	0.008018
D	0.04024	0.006152
E	0.0238	0.003945
F2	0.00644	0.00104
U	0.00255	0.000404
K	0.00243	0.000397
L	0.00076	0.00012
F	0.0003	4.77E-05
Q	0.00009	1.44E-05
H	0.00009	0.000014
Y	0.00007	1.17E-05
B	0.00004	7.5E-06
N	0.00002	0.000003
T	0.00001	0.000002
Y2	0.00001	1.8E-06
Y1	0.00001	1.7E-06
G	0.00001	9E-07
S	0.00001	8E-07
M	0	6E-07
R	0	1E-07
V	0	1E-07
X	0	0
W	0	0

Table C.6: Sensitivity output for satisfaction node for transect 5

Transect 5

Node	Mutual Info	Variance Beliefs
A	1.53167	0.420297
F1	0.48593	0.087055
A1	0.35779	0.071333
C	0.25625	0.047907
D	0.08262	0.015809
J	0.05177	0.010144
F2	0.00928	0.001887
E	0.00709	0.001508
B	0.00659	0.001406
K	0.00307	0.000663
U	0.00177	0.000363
L	0.00126	0.000272
F	0.00056	0.00012
H	0.00016	3.41E-05
Q	0.00013	2.64E-05
Y	0.0001	2.07E-05
N	0.00004	8.4E-06
Y2	0.00003	7.3E-06
Y1	0.00003	5.5E-06
G	0.00002	4.4E-06
S	0.00001	2.9E-06
T	0.00001	2.4E-06
M	0.00001	1.5E-06
R	0	5E-07
W	0	1E-07
X	0	1E-07
V	0	0

Table C.7: Sensitivity output for satisfaction node for transect 6

Transect 6

Node	Mutual Info	Variance Beliefs
A	1.47621	0.395926
F1	0.43379	0.063018
A1	0.34373	0.06206
C	0.18859	0.031888
J	0.04759	0.008378
D	0.028	0.005137
E	0.01936	0.003422
F2	0.00794	0.001286
K	0.00385	0.000675
L	0.00117	0.000186
U	0.0009	0.000156
F	0.0005	7.89E-05
H	0.00013	2.05E-05
Q	0.00011	0.000018
Y	0.0001	0.000015
Y1	0.00004	6.5E-06
N	0.00004	6.1E-06
Y2	0.00003	0.000005
T	0.00002	3.2E-06
G	0.00002	2.4E-06
B	0.00002	2.8E-06
M	0.00001	9E-07
S	0	5E-07
R	0	2E-07
W	0	1E-07
X	0	0
V	0	0

Table C.8: Sensitivity output for satisfaction node for transect 7

Transect 7

Node	Mutual Info	Variance Beliefs
A	1.36065	0.348063
F1	0.3872	0.051714
A1	0.31737	0.056317
C	0.17731	0.027323
J	0.03476	0.005538
D	0.01864	0.00273
E	0.00941	0.001511
B	0.00762	0.001234
F2	0.00523	0.000812
K	0.00241	0.000374
L	0.00025	3.68E-05
H	0.00009	1.32E-05
U	0.00006	9.1E-06
F	0.00005	7.9E-06
Q	0.00005	6.7E-06
N	0.00003	4.5E-06
T	0.00001	2.1E-06
G	0.00001	1.8E-06
Y	0.00001	1.6E-06
Y1	0	4E-07
S	0	3E-07
M	0	2E-07
R	0	1E-07
Y2	0	1E-07
V	0	0
W	0	0
X	0	0

Table C.9: Sensitivity output for satisfaction node for Kalulushi data using BN model conditioned on aspatial data.

K1 -(Aspatial)

Node	Mutual Info	Variance Beliefs
A	1.29529	0.322763
F1	0.35702	0.046169
A1	0.29951	0.05343
C	0.15442	0.022864
J	0.03831	0.005883
B	0.00893	0.001397
F2	0.00695	0.001012
U	0.00438	0.000645
E	0.00373	0.000581
K	0.00167	0.000249
D	0.00167	0.000229
L	0.00057	7.98E-05
F	0.00018	2.52E-05
Q	0.00008	1.09E-05
H	0.00004	5.2E-06
Y	0.00004	0.000005
T	0.00001	1.5E-06
Y1	0.00001	1.4E-06
Y2	0.00001	1.1E-06
S	0.00001	1.1E-06
N	0.00001	0.000001
G	0	6E-07
M	0	2E-07
R	0	1E-07
V	0	0
W	0	0
X	0	0

Table C.10: Sensitivity output for satisfaction node for Kalulushi data using BN model conditioned on spatial data.

K2 - (Spatial)

Node	Mutual Info	Variance Beliefs
A	1.34807	0.343142
F1	0.37757	0.04954
A1	0.31223	0.055389
C	0.16353	0.025243
J	0.04536	0.007286
E	0.01467	0.002405
F2	0.00777	0.001157
U	0.00423	0.000658
B	0.00423	0.000704
D	0.00312	0.000468
K	0.00216	0.000342
L	0.00077	0.000111
F	0.00028	3.95E-05
Q	0.0001	1.37E-05
Y	0.00006	8.9E-06
H	0.00005	6.8E-06
Y1	0.00002	2.6E-06
T	0.00001	1.8E-06
Y2	0.00001	1.7E-06
S	0.00001	1.3E-06
N	0.00001	1.2E-06
G	0.00001	8E-07
M	0	3E-07
R	0	1E-07
W	0	0
V	0	0
X	0	0

Appendix C.3: Sensitivity by transect

This section shows tables for the investigation of change state of the variables from transect to transect. Tables C.11 to C.14 show the belief values for each node and the variance from transect to transect.

Table C.11: Table for Income and future use theme

	T1	T7	T3	T4	T6	T5	Var.	% Change
Satisfaction - H	0.146	0.159	0.171	0.206	0.227	0.422	0.009	27.617
FCP - H	0.675	0.664	0.658	0.633	0.611	0.490	0.004	-18.567
CCP - H	0.290	0.334	0.304	0.341	0.506	0.638	0.019	34.749
FLU _ Cont	0.282	0.294	0.303	0.332	0.356	0.505	0.006	22.289
CLU - Crop	0.623	0.614	0.609	0.581	0.605	0.604	0.000	-1.89
Income (Insuff)	0.898	0.895	0.798	0.701	0.887	0.430	0.028	-46.851

Table C.12: Table for Location theme

	T1	T7	T3	T4	T6	T5	Var.	% Change
Satisfaction - H	0.146	0.159	0.171	0.206	0.227	0.422	0.009	27.617
D_Road (Far)	0.753	0.745	0.745	0.551	0.205	0.164	0.091	-58.918
D_Market (Far)	0.998	0.837	0.998	0.998	0.997	0.198	0.087	-80.055
D_Stream (Far)	0.711	0.637	0.089	0.573	0.938	0.990	0.088	27.906
Location (Poor)	0.795	0.715	0.773	0.669	0.383	0.169	0.064	-62.544

Table C.13: Table for Local authority and interaction theme

	T1	T7	T3	T4	T6	T5	Var.	% Change
Satisfaction - H	0.146	0.159	0.171	0.206	0.227	0.422	0.009	27.617
Extn. Serv (No)	0.922	0.974	0.875	0.807	0.748	0.824	0.006	-9.785
Ownership (Insecure)	0.687	0.751	0.779	0.782	0.742	0.767	0.002	7.991
F.Props (Poor)	0.541	0.590	0.556	0.525	0.547	0.486	0.002	-5.481
LUR (N)	0.793	0.879	0.678	0.668	0.659	0.772	0.006	-2.053
L Auth. Int. (N)	0.805	0.831	0.573	0.606	0.589	0.871	0.016	6.552

Table C.14: Table for water access and LUR theme

	T1	T7	T3	T4	T6	T5	Var.	% Change
Satisfaction - H	0.146	0.159	0.171	0.206	0.227	0.422	0.009	27.617
F.Props (Poor)	0.541	0.590	0.556	0.525	0.547	0.486	0.002	-5.481
Rainfall (H)	0.352	0.041	0.331	0.589	0.063	0.210	0.035	-14.149
Water Acc. (G)	0.614	0.505	0.657	0.701	0.417	0.491	0.010	-12.245
LUR (N)	0.793	0.879	0.678	0.668	0.659	0.772	0.006	-2.053
L Auth. Int. (N)	0.805	0.831	0.573	0.606	0.589	0.871	0.016	6.552

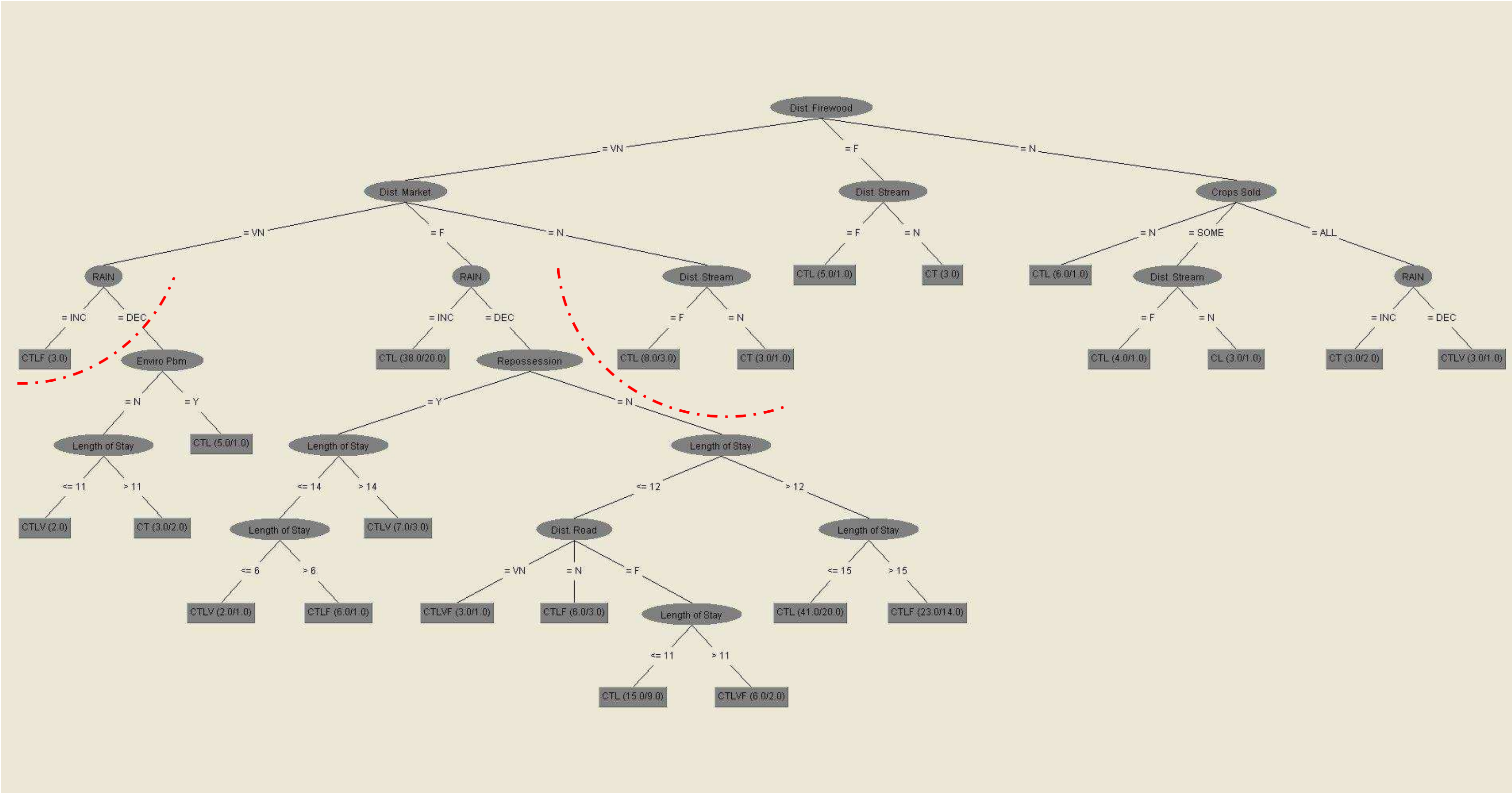
Appendix D: Accuracy assessment of 2002 satellite image

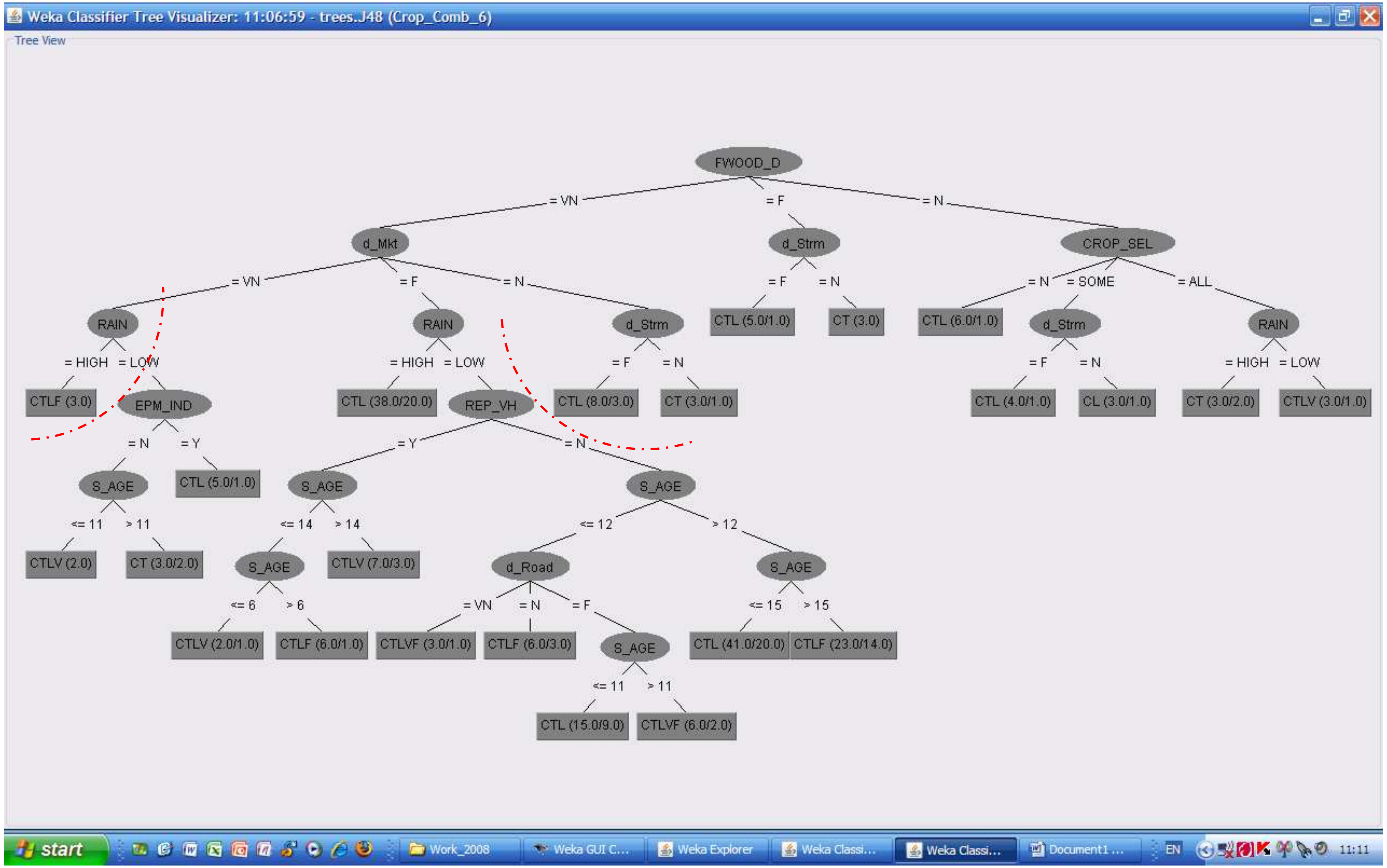
Classified Data	Unclassified	Grass	Water	Bright Surfaces	Forest	Soil	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
				Reference Data - 2002						
Unclassified	0	0	0	0	0	0	0	0	---	---
Grass	0	4	0	0	1	0	5	0	---	---
Water	0	0	0	0	0	0	0	0	---	---
Bright Surfaces	0	0	0	0	0	0	0	0	---	---
Forest	0	3	0	0	15	0	18	15	93.75%	83.33%
Soil	0	1	1	0	0	0	2	0	---	---
Column Total	0	8	1	0	16	0	25	15		

Overall Classification Accuracy = 60.00%

Appendix E: output from WEKA

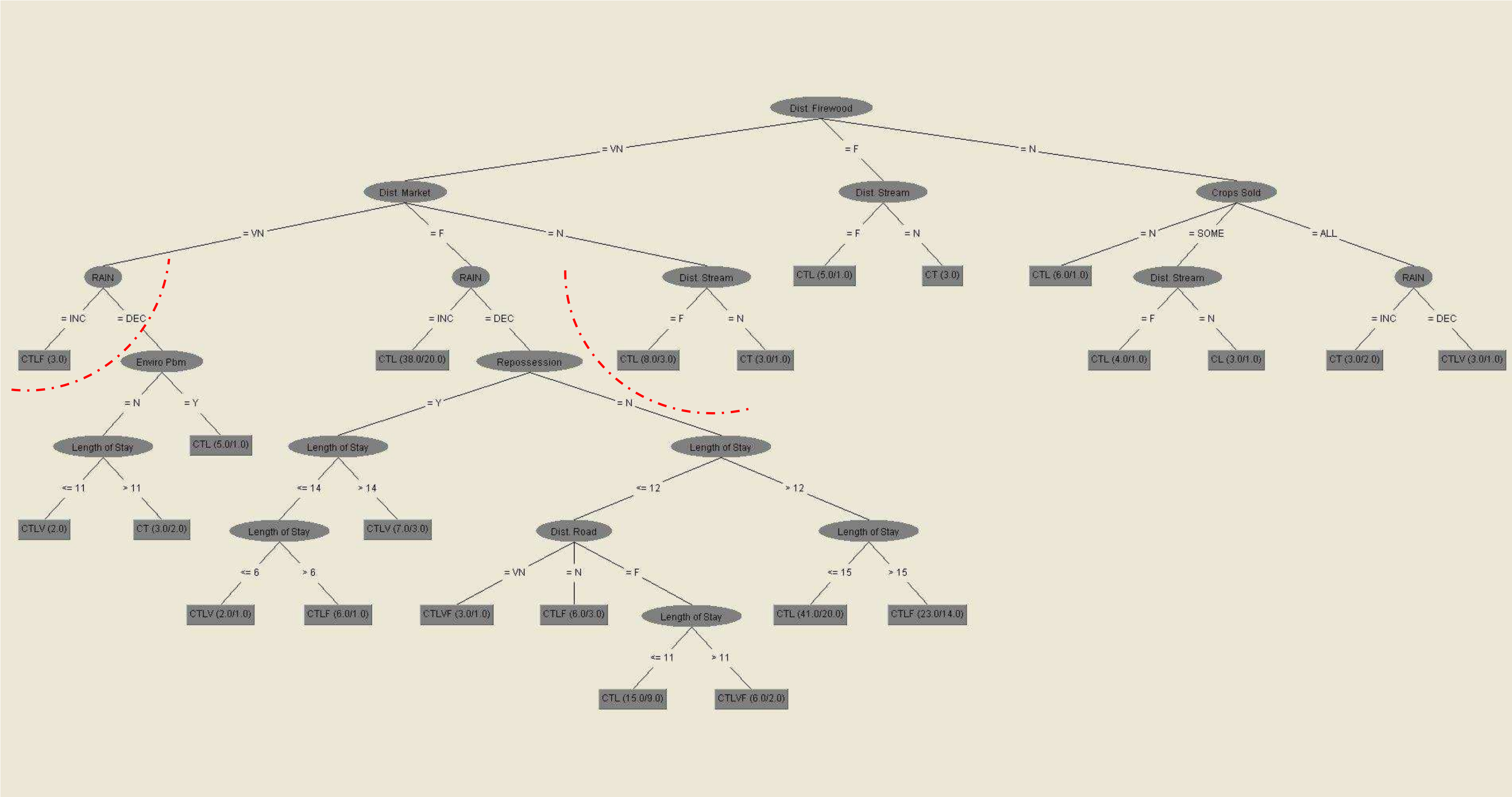
Appendix E.1: Classification tree 1: No policy considerations.

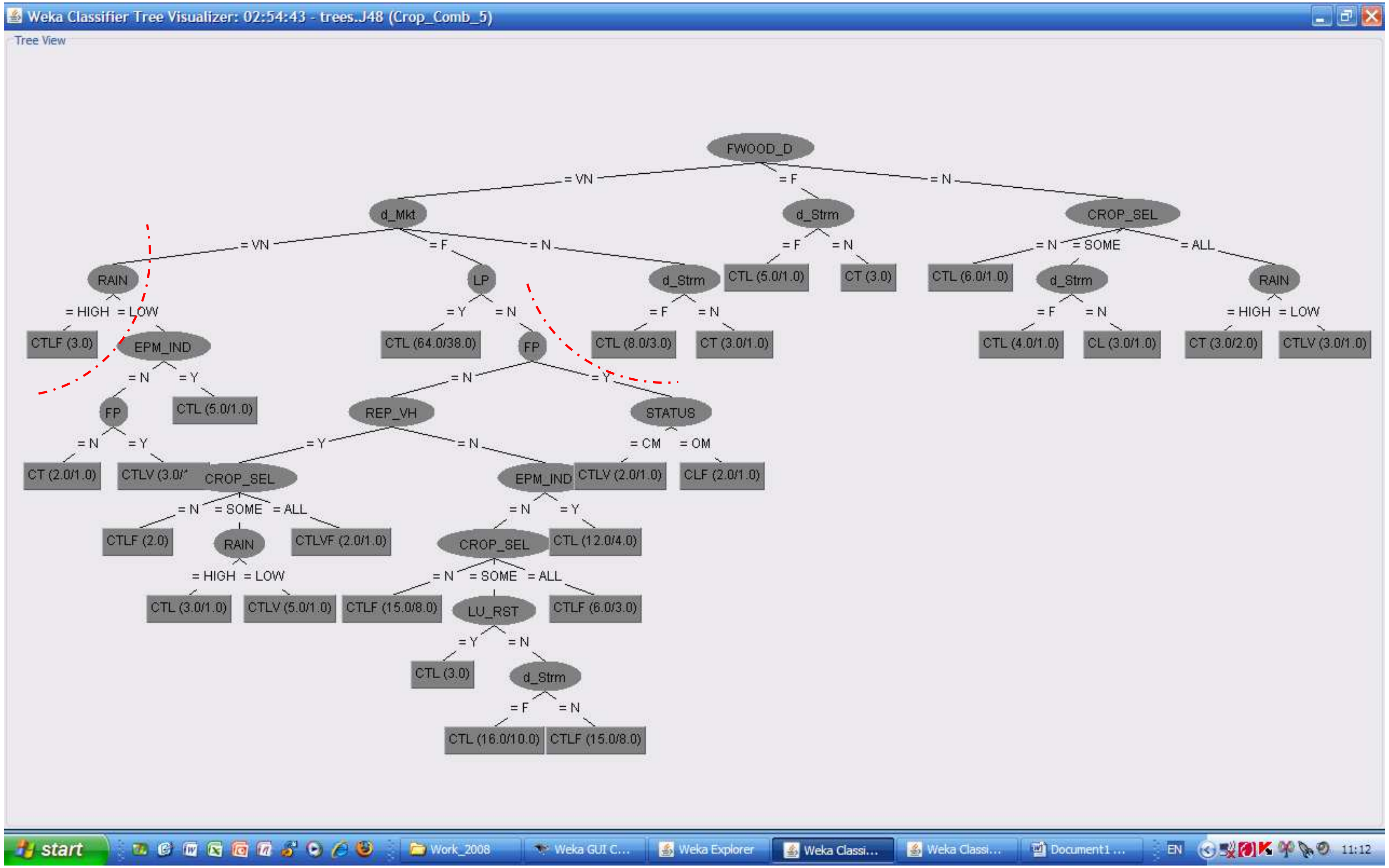




Weka Classifier Tree Visualizer: 11:06:59 - trees.J48 (Crop_Comb_6)
Tree View
FWOOD_D
= VN
= F
= N
d_Mkt
d_Strm
CROP_SEL
RAIN
RAIN
d_Strm
CTL (5.0/1.0)
CT (3.0)
CTL (6.0/1.0)
d_Strm
RAIN
= HIGH
= LOW
CTLF (3.0)
EPM_IND
CTL (38.0/20.0)
REP_VH
CTL (8.0/3.0)
CT (3.0/1.0)
CTL (4.0/1.0)
CL (3.0/1.0)
CT (3.0/2.0)
CTLV (3.0/1.0)
= SOME
= ALL
= Y
S_AGE
CTL (5.0/1.0)
<= 11
> 11
CTLV (2.0)
CT (3.0/2.0)
<= 14
> 14
S_AGE
CTLV (7.0/3.0)
<= 12
> 12
d_Road
<= 6
> 6
CTLV (2.0/1.0)
CTLF (6.0/1.0)
CTLVF (3.0/1.0)
CTLF (6.0/3.0)
CTL (41.0/20.0)
CTLF (23.0/14.0)
<= 15
> 15
CTL (15.0/9.0)
CTLVF (6.0/2.0)
start
Work_2008
Weka GUI C...
Weka Explorer
Weka Classi...
Weka Classi...
Document1 ...
EN
11:11

Appendix E.2: Classification tree 2: Policy considerations taken into account




Weka Classifier Tree Visualizer: 02:54:43 - trees.J48 (Crop_Comb_5)
Tree View
FWOOD_D
= VN
= F
= N
d_Mkt
d_Strm
CROP_SEL
RAIN
LP
d_Strm
CTL (5.0/1.0)
CT (3.0)
CTL (6.0/1.0)
d_Strm
RAIN
= HIGH
= LOW
CTLF (3.0)
EPM_IND
CTL (64.0/38.0)
FP
CTL (8.0/3.0)
CT (3.0/1.0)
CTL (4.0/1.0)
CL (3.0/1.0)
CT (3.0/2.0)
CTLV (3.0/1.0)
FP
CTL (5.0/1.0)
REP_VH
STATUS
= CM
= OM
CT (2.0/1.0)
CROP_SEL
EPM_IND
CTLV (2.0/1.0)
CLF (2.0/1.0)
= SOME
= ALL
CTLF (2.0)
RAIN
CTLVF (2.0/1.0)
CROP_SEL
CTL (12.0/4.0)
CTL (3.0/1.0)
CTLV (5.0/1.0)
CTLF (15.0/8.0)
LU_RST
CTLF (6.0/3.0)
CTL (3.0)
d_Strm
CTL (16.0/10.0)
CTLF (15.0/8.0)
start
Work_2008
Weka GUI C...
Weka Explorer
Weka Classi...
Weka Classi...
Document1 ...
EN
11:12

Appendix E.3: Classification Tree 1 Run information

=== Run information ===

Scheme: weka.classifiers.trees.J48 -C 0.25 -M 2
Relation: Crop_Comb_6
Instances: 198
Attributes: 12

STATUS	***Status in village***
RAIN	***Perception of rainfall in area***
S_AGE	***Length of stay in settlement***
REP_VH	***Fear of repossession of land by village head***
LU_RST	***Land use restrictions***
CROPS	***Crops grown***
CROP_SEL	***Crops sold***
FWOOD_D	***Distance to firewood***
EPM_IND	***Perception of environmental problem in area***
d_Mkt	***Distance to Market***
d_Strm	***Distance to stream / river***
d_Road	***Distance to main road***

Test mode: 10-fold cross-validation

=== Classifier model (full training set) ===

```
J48 pruned tree
------------------
Dist. Firewood = VN
|   Dist. Market = VN
|   |   RAIN = INCREASED: CTLF (3.0)
|   |   RAIN = DECREASED
|   |   |   Enviro Pbm = N
|   |   |   |   Length of Stay <= 11: CTLV (2.0)
|   |   |   |   Length of Stay > 11: CT (3.0/2.0)
|   |   |   Enviro Pbm = Y: CTL (5.0/1.0)
|   Dist. Market = F
|   |   RAIN = INCREASED: CTL (38.0/20.0)
|   |   RAIN = DECREASED
|   |   |   Repossession = Y
|   |   |   |   Length of Stay <= 14
|   |   |   |   |   Length of Stay <= 6: CTLV (2.0/1.0)
|   |   |   |   |   Length of Stay > 6: CTLF (6.0/1.0)
|   |   |   |   Length of Stay > 14: CTLV (7.0/3.0)
|   |   |   Repossession = N
|   |   |   |   Length of Stay <= 12
|   |   |   |   |   Dist. Road = VN: CTLVF (3.0/1.0)
|   |   |   |   |   Dist. Road = N: CTLF (6.0/3.0)
|   |   |   |   |   Dist. Road = F
|   |   |   |   |   |   Length of Stay <= 11: CTL (15.0/9.0)
|   |   |   |   |   |   Length of Stay > 11: CTLVF (6.0/2.0)
|   |   |   |   Length of Stay > 12
|   |   |   |   |   Length of Stay <= 15: CTL (41.0/20.0)
|   |   |   |   |   Length of Stay > 15: CTLF (23.0/14.0)
|   Dist. Market = N
|   |   Dist. Stream = F: CTL (8.0/3.0)
|   |   Dist. Stream = N: CT (3.0/1.0)
```

Dist. Firewood = F
| Dist. Stream = F: CTL (5.0/1.0)
| Dist. Stream = N: CT (3.0)
Dist. Firewood = N
| Crops Sold = N: CTL (6.0/1.0)
| Crops Sold = SOME
| | Dist. Stream = F: CTL (4.0/1.0)
| | Dist. Stream = N: CL (3.0/1.0)
| Crops Sold = ALL
| | RAIN = INCREASED: CT (3.0/2.0)
| | RAIN = DECREASED: CTLV (3.0/1.0)

Number of Leaves : 23

Size of the tree : 41

Time taken to build model: 0.02 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances	69	34.8485 %
Incorrectly Classified Instances	129	65.1515 %
Kappa statistic	0.0607	
Mean absolute error	0.1093	
Root mean squared error	0.2608	
Relative absolute error	95.8587 %	
Root relative squared error	109.8471 %	
Total Number of Instances	198	

=== Detailed Accuracy By Class ===

TP Rate	**FP Rate**	**Precision**	**Recall**	**F-Measure**	**Class**
0.243	0.168	0.25	0.243	0.247	CTLF
0.231	0.038	0.3	0.231	0.261	CT
0.048	0.051	0.1	0.048	0.065	CTLV
0.727	0.636	0.421	0.727	0.533	CTL
0	0	0	0	0	CFT
0	0.005	0	0	0	CFTFSH
0	0.033	0	0	0	CL
0	0.005	0	0	0	CTLVF
0	0	0	0	0	CTV
0	0.005	0	0	0	CLF
0	0	0	0	0	CVL
0	0	0	0	0	CVFL
0	0	0	0	0	CV
0	0	0	0	0	CTLVFSH

=== Confusion Matrix ===

a	b	c	d	e	f	g	h	i	j	k	l	m	n		<-- classified as
9	0	5	22	0	0	0	0	0	1	0	0	0	0	|	a = CTLF
1	3	0	8	0	0	1	0	0	0	0	0	0	0	|	b = CT
5	0	1	14	0	0	1	0	0	0	0	0	0	0	|	c = CTLV
10	4	2	56	0	1	3	1	0	0	0	0	0	0	|	d = CTL
3	0	0	5	0	0	0	0	0	0	0	0	0	0	|	e = CFT
1	0	0	0	0	0	0	0	0	0	0	0	0	0	|	f = CFTFSH
1	0	0	13	0	0	0	0	0	0	0	0	0	0	|	g = CL
4	0	0	6	0	0	0	0	0	0	0	0	0	0	|	h = CTLVF
0	2	2	2	0	0	0	0	0	0	0	0	0	0	|	i = CTV
0	0	0	2	0	0	0	0	0	0	0	0	0	0	|	j = CLF
2	0	0	1	0	0	0	0	0	0	0	0	0	0	|	k = CVL
0	0	0	2	0	0	1	0	0	0	0	0	0	0	|	l = CVFL
0	0	0	1	0	0	0	0	0	0	0	0	0	0	|	m = CV
0	1	0	1	0	0	0	0	0	0	0	0	0	0	|	n = CTLVFSH

Appendix E.4: Classification Tree 2 run information

=== Run information ===

Scheme: weka.classifiers.trees.J48 -C 0.25 -M 2
Relation: Crop_Comb_5
Instances: 198
Attributes: 14

STATUS	***Status in village***
RAIN	***Perception of rainfall in area***
S_AGE	***Length of stay in settlement***
REP_VH	***Fear of repossession of land by village head***
LU_RST	***Land use restrictions***
CROPS	***Crops grown***
CROP_SEL	***Crops sold***
FWOOD_D	***Distance to firewood***
EPM_IND	***Perception of environmental problem in area***
LP	***Land policy awareness***
FP	***Forest policy awareness***
d_Mkt	***Distance to Market***
d_Strm	***Distance to stream / river***
d_Road	***Distance to main road***

Test mode: 10-fold cross-validation

=== Classifier model (full training set) ===

J48 pruned tree

```
------------------

Dist. Firewood = VN
|  Dist. Market = VN
|  |  RAIN = INCREASED: CTLF (3.0)
|  |  RAIN = DECREASED
|  |  |  Enviro. Pbm = N
|  |  |  |  Forest Policy = N: CT (2.0/1.0)
|  |  |  |  Forest Policy = Y: CTLV (3.0/1.0)
|  |  |  Enviro. Pbm = Y: CTL (5.0/1.0)
|  Dist. Market = F
|  |  Land Policy = Y: CTL (64.0/38.0)
|  |  Land Policy = N
|  |  |  Forest Policy = N
|  |  |  |  Repossession = Y
|  |  |  |  |  Crops Sold = N: CTLF (2.0)
|  |  |  |  |  Crops Sold = SOME
|  |  |  |  |  |  RAIN = INCREASED: CTL (3.0/1.0)
|  |  |  |  |  |  RAIN = DECREASED: CTLV (5.0/1.0)
|  |  |  |  |  Crops Sold = ALL: CTLVF (2.0/1.0)
|  |  |  |  Repossession = N
|  |  |  |  |  Enviro. Pbm = N
|  |  |  |  |  |  Crops Sold = N: CTLF (15.0/8.0)
|  |  |  |  |  |  Crops Sold = SOME
|  |  |  |  |  |  |  LU Restrictions = Y: CTL (3.0)
|  |  |  |  |  |  |  LU Restrictions = N
|  |  |  |  |  |  |  |  Dist. Stream = F: CTL (16.0/10.0)
|  |  |  |  |  |  |  |  Dist. Stream = N: CTLF (15.0/8.0)
|  |  |  |  |  |  Crops Sold = ALL: CTLF (6.0/3.0)
|  |  |  |  |  Enviro. Pbm = Y: CTL (12.0/4.0)
```

| | | Forest Policy = Y
| | | | STATUS = CM: CTLV (2.0/1.0)
| | | | STATUS = OM: CLF (2.0/1.0)
| Dist. Market = N
| | Dist. Stream = F: CTL (8.0/3.0)
| | Dist. Stream = N: CT (3.0/1.0)
Dist. Firewood = F
| Dist. Stream = F: CTL (5.0/1.0)
| Dist. Stream = N: CT (3.0)
Dist. Firewood = N
| Crops Sold = N: CTL (6.0/1.0)
| Crops Sold = SOME
| | Dist. Stream = F: CTL (4.0/1.0)
| | Dist. Stream = N: CL (3.0/1.0)
| Crops Sold = ALL
| | RAIN = INCREASED: CT (3.0/2.0)
| | RAIN = DECREASED: CTLV (3.0/1.0)

Number of Leaves : 26

Size of the tree : 46

Time taken to build model: 0.45 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances	75	37.8788 %
Incorrectly Classified Instances	123	62.1212 %
Kappa statistic	0.1371	
Mean absolute error	0.1039	
Root mean squared error	0.2569	
Relative absolute error	91.1164 %	
Root relative squared error	108.184 %	
Total Number of Instances	198	

=== Detailed Accuracy By Class ===

TP Rate	FP Rate	Precision	Recall	F-Measure	Class
0.486	0.224	0.333	0.486	0.396	CTLF
0.308	0.022	0.5	0.308	0.381	CT
0.048	0.085	0.063	0.048	0.054	CTLV
0.675	0.471	0.477	0.675	0.559	CTL
0	0	0	0	0	CFT
0	0	0	0	0	CFTFSH
0	0.054	0	0	0	CL
0	0.005	0	0	0	CTLVF
0	0	0	0	0	CTV
0	0	0	0	0	CLF
0	0	0	0	0	CVL
0	0	0	0	0	CVFL
0	0	0	0	0	CV
0	0	0	0	0	CTLVFSH

=== Confusion Matrix ===

a	b	c	d	e	f	g	h	i	j	k	l	m	n	<-- classified as
18	0	3	16	0	0	0	0	0	0	0	0	0	0	a = CTLF
3	4	0	5	0	0	1	0	0	0	0	0	0	0	b = CT
9	0	1	8	0	0	3	0	0	0	0	0	0	0	c = CTLV
15	1	4	52	0	0	5	0	0	0	0	0	0	0	d = CTL
1	0	1	6	0	0	0	0	0	0	0	0	0	0	e = CFT
0	0	1	0	0	0	0	0	0	0	0	0	0	0	f = CFTFSH
0	0	2	12	0	0	0	0	0	0	0	0	0	0	g = CL
6	0	1	3	0	0	0	0	0	0	0	0	0	0	h = CTLVF
0	2	1	2	0	0	0	1	0	0	0	0	0	0	i = CTV
1	0	0	1	0	0	0	0	0	0	0	0	0	0	j = CLF
1	0	2	0	0	0	0	0	0	0	0	0	0	0	k = CVL
0	0	0	2	0	0	1	0	0	0	0	0	0	0	l = CVFL
0	0	0	1	0	0	0	0	0	0	0	0	0	0	m = CV
0	1	0	1	0	0	0	0	0	0	0	0	0	0	n = CTLVFSH

Appendix E.5: Classification Tree 3 run information

=== Run information ===

Scheme: weka.classifiers.trees.J48 -C 0.25 -M 2
Relation: Crops_Comb.csv
Instances: 404
Attributes: 9

STATUS	***Status in village***
RAIN	***Perception of rainfall in area***
S_AGE	***Length of stay in settlement***
REP_VH	***Fear of repossession of land by village head***
LU_RST	***Land use restrictions***
CROPS	***Crops grown***
CROP_SEL	***Crops sold***
FWOOD_D	***Distance to firewood***
EPM_IND	***Perception of environmental problem in area***

Test mode: 10-fold cross-validation

=== Classifier model (full training set) ===

J48 pruned tree

```
Dist. Firewood = VN
|   RAIN = INCREASED
|   |   STATUS = CM
|   |   |   LU Restrictions = Y
|   |   |   |   Crops Sold = N: CTLF (4.0)
|   |   |   |   Crops Sold = SOME: CTL (4.0/1.0)
|   |   |   |   Crops Sold = ALL: CTLF (0.0)
|   |   |   LU Restrictions = N
|   |   |   |   Crops Sold = N
|   |   |   |   |   Repossesion = Y: CTLV (2.0)
|   |   |   |   |   Repossesion = N: CTL (9.0/4.0)
|   |   |   |   Crops Sold = SOME
|   |   |   |   |   Length of Stay <= 18
|   |   |   |   |   |   Length of Stay <= 8: CL (2.0/1.0)
|   |   |   |   |   |   Length of Stay > 8: CTL (6.0/2.0)
|   |   |   |   |   Length of Stay > 18
|   |   |   |   |   |   Length of Stay <= 21: CTLF (2.0)
|   |   |   |   |   |   Length of Stay > 21: CTLV (2.0/1.0)
|   |   |   |   Crops Sold = ALL: CFT (1.0)
|   |   STATUS = OM: CTL (54.0/27.0)
|   RAIN = DECREASED
|   |   Repossesion = Y
|   |   |   STATUS = CM
|   |   |   |   Length of Stay <= 11: CTLV (5.0/2.0)
|   |   |   |   Length of Stay > 11
|   |   |   |   |   LU Restrictions = Y: CTLV (2.0/1.0)
|   |   |   |   |   LU Restrictions = N
|   |   |   |   |   |   Length of Stay <= 12: CTLF (3.0/1.0)
|   |   |   |   |   |   Length of Stay > 12: CT (4.0/2.0)
|   |   |   STATUS = OM
|   |   |   |   Length of Stay <= 15
|   |   |   |   |   Enviro. Pbm = N: CTLF (4.0/2.0)
|   |   |   |   |   Enviro. Pbm = Y: CTL (13.0/7.0)
```

```
|   |   |   |   Length of Stay > 15
|   |   |   |   |   Crops Sold = N: CTLVFSH (1.0)
|   |   |   |   |   Crops Sold = SOME
|   |   |   |   |   |   Length of Stay <= 18: CTL (3.0)
|   |   |   |   |   |   Length of Stay > 18: CTLV (3.0/1.0)
|   |   |   |   |   Crops Sold = ALL: CTLV (5.0/3.0)
|   |   Repossesion = N
|   |   |   Enviro. Pbm = N
|   |   |   |   LU Restrictions = Y: CTL (12.0/3.0)
|   |   |   |   LU Restrictions = N
|   |   |   |   |   Crops Sold = N
|   |   |   |   |   |   Length of Stay <= 20
|   |   |   |   |   |   |   Length of Stay <= 6: CTL (2.0/1.0)
|   |   |   |   |   |   |   Length of Stay > 6: CTLF (29.0/15.0)
|   |   |   |   |   |   Length of Stay > 20
|   |   |   |   |   |   |   Length of Stay <= 21: CTLV (7.0/4.0)
|   |   |   |   |   |   |   Length of Stay > 21: CTL (2.0/1.0)
|   |   |   |   |   Crops Sold = SOME
|   |   |   |   |   |   Length of Stay <= 15
|   |   |   |   |   |   |   Length of Stay <= 11
|   |   |   |   |   |   |   |   STATUS = CM: CT (2.0/1.0)
|   |   |   |   |   |   |   |   STATUS = OM
|   |   |   |   |   |   |   |   |   Length of Stay <= 5: CT (4.0/2.0)
|   |   |   |   |   |   |   |   |   Length of Stay > 5: CTL (17.0/8.0)
|   |   |   |   |   |   |   Length of Stay > 11
|   |   |   |   |   |   |   |   Length of Stay <= 12: CTLF (6.0/3.0)
|   |   |   |   |   |   |   |   Length of Stay > 12: CTL (28.0/20.0)
|   |   |   |   |   |   Length of Stay > 15: CTLF (16.0/8.0)
|   |   |   |   |   Crops Sold = ALL
|   |   |   |   |   |   Length of Stay <= 15: CTL (15.0/9.0)
|   |   |   |   |   |   Length of Stay > 15: CTLV (3.0/2.0)
|   |   |   Enviro. Pbm = Y: CTL (77.0/30.0)
Dist. Firewood = F
|   RAIN = INCREASED
|   |   Length of Stay <= 10: CTL (2.0/1.0)
|   |   Length of Stay > 10: CT (3.0/1.0)
|   RAIN = DECREASED: CTL (7.0/2.0)
Dist. Firewood = N: CTL (43.0/14.0)
```

Number of Leaves :   42

Size of the tree : 75

Time taken to build model: 0.03 seconds

=== Stratified cross-validation ===

Correctly Classified Instances	**157**	**38.8614 %**
Incorrectly Classified Instances	**247**	**61.1386 %**
Kappa statistic	**0.0538**	
Mean absolute error	**0.0808**	
Root mean squared error	**0.2163**	
Relative absolute error	**94.8137 %**	
Root relative squared error	**105.3546 %**	
Total Number of Instances	**404**	

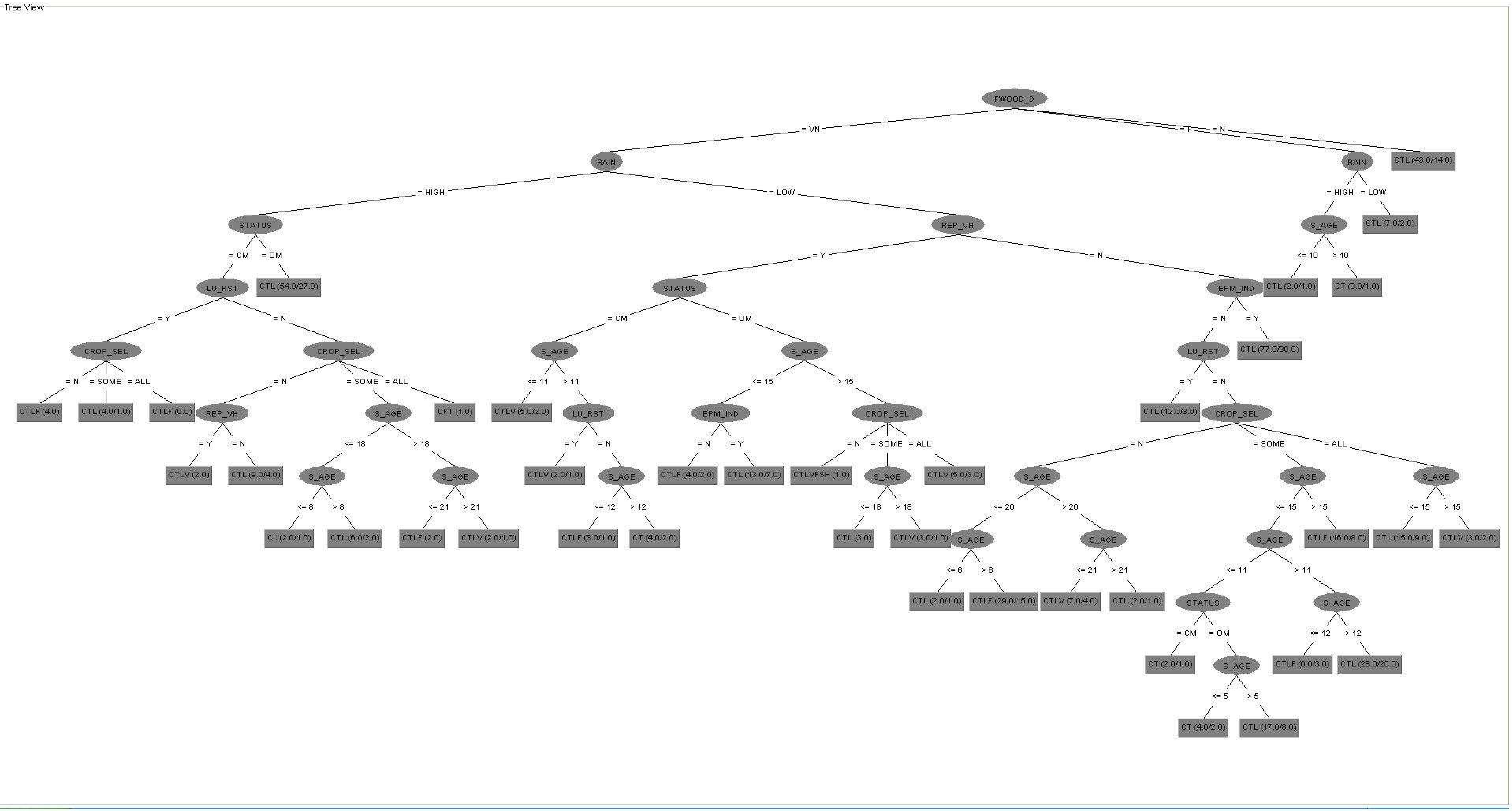
=== Detailed Accuracy By Class ===

TP Rate	FP Rate	Precision	Recall	F-Measure	Class
0.243	0.147	0.258	0.243	0.25	CTLF
0	0.021	0	0	0	CT
0.047	0.078	0.067	0.047	0.055	CTLV
0.784	0.68	0.471	0.784	0.588	CTL
0	0	0	0	0	CFT
0	0	0	0	0	CFTFSH
0	0.008	0	0	0	CL
0	0	0	0	0	CTLVF
0	0.003	0	0	0	CTV
0	0.008	0	0	0	CLF
0	0	0	0	0	CVL
0	0	0	0	0	CVFL
0	0	0	0	0	CV
0	0	0	0	0	CTLVFSH
0	0	0	0	0	TF
0	0	0	0	0	C
0	0	0	0	0	CTVF
0	0	0	0	0	TLF

=== Confusion Matrix ===

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	<-- classified as
17	0	7	44	0	0	1	0	1	0	0	0	0	0	0	0	0	0	a = CTLF
3	0	3	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	b = CT
11	1	2	28	0	0	0	0	0	1	0	0	0	0	0	0	0	0	c = CTLV
20	6	11	138	0	0	1	0	0	0	0	0	0	0	0	0	0	0	d = CTL
2	1	1	12	0	0	1	0	0	0	0	0	0	0	0	0	0	0	e = CFT
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	f = CFTFSH
1	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	g = CL
6	0	1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	h = CTLVF
3	0	1	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	i = CTV
0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	j = CLF
0	0	2	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	k = CVL
0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	l = CVFL
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	m = CV
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n = CTLVFSH
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	o = TF
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	p = C
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	q = CTVF
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	r = TLF

Appendix E.6: Classification Tree 3- all data



Tree View
FWOOD_D
= VN
= F
= N
RAIN
CTL (43.0/14.0)
= HIGH
= LOW
STATUS
REP_VH
= CM
= OM
LU_RST
CTL (54.0/27.0)
= Y
= N
CROP_SEL
CROP_SEL
= N
= SOME
= ALL
CTLF (4.0)
CTL (4.0/1.0)
CTLF (0.0)
REP_VH
= Y
= N
CTLV (2.0)
CTL (9.0/4.0)
= N
= SOME
= ALL
S_AGE
CFT (1.0)
<= 18
> 18
S_AGE
S_AGE
<= 8
> 8
CL (2.0/1.0)
CTL (6.0/2.0)
<= 21
> 21
CTLF (2.0)
CTLV (2.0/1.0)
= Y
= N
STATUS
= CM
= OM
S_AGE
S_AGE
<= 11
> 11
CTLV (5.0/2.0)
LU_RST
= Y
= N
CTLV (2.0/1.0)
S_AGE
<= 12
> 12
CTLF (3.0/1.0)
CT (4.0/2.0)
<= 15
> 15
EPM_IND
= N
= Y
CTLF (4.0/2.0)
CTL (13.0/7.0)
CROP_SEL
= N
= SOME
= ALL
CTLVFSH (1.0)
S_AGE
CTLV (5.0/3.0)
<= 18
> 18
CTL (3.0)
CTLV (3.0/1.0)
EPM_IND
= N
= Y
LU_RST
CTL (77.0/30.0)
= Y
= N
CTL (12.0/3.0)
CROP_SEL
= N
= SOME
= ALL
S_AGE
<= 20
> 20
S_AGE
<= 6
> 6
CTL (2.0/1.0)
CTLF (29.0/15.0)
S_AGE
<= 21
> 21
CTLV (7.0/4.0)
CTL (2.0/1.0)
S_AGE
<= 15
> 15
S_AGE
CTLF (16.0/8.0)
<= 11
> 11
STATUS
= CM
= OM
CT (2.0/1.0)
S_AGE
<= 5
> 5
CT (4.0/2.0)
CTL (17.0/8.0)
S_AGE
<= 12
> 12
CTLF (6.0/3.0)
CTL (28.0/20.0)
S_AGE
<= 15
> 15
CTL (15.0/9.0)
CTLV (3.0/2.0)
= HIGH
= LOW
S_AGE
CTL (7.0/2.0)
<= 10
> 10
CTL (2.0/1.0)
CT (3.0/1.0)