STATISTICAL APPROACHES FOR CLASSIFYING AND DEFINING AREAS IN SOUTH AFRICA AS "URBAN" OR "RURAL"

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DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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(Signature of candidate)

_____ day of _____ 20_____

ABSTRACT

The purpose of this research report is to utilise appropriate statistical (both non-spatial and spatial) techniques to classify areas in the country into urban and rural. These areas, as derived by means of each statistical method, are profiled and common characteristics amongst them are summarised for classification and definition of urban and rural areas. Population data for these areas were aggregated to determine the overall urbanisation for the country.

The methodology utilised was that of supervised classification. Two sample data sets of areas that are known with certainty to be urban or rural were derived and used consistently throughout the study. The importance of utilising areas of known urban and rural status was firstly to identify essential patterns or predominant characteristics from areas that are known, and thereafter to apply similar characteristics to areas that are not known or are ambiguous, in order to classify them as either urban or rural. Sample 1 comprises all areas in the country with formal and informal urban settlements, as well as formal rural areas, i.e. farms. Sample 2 is similar to sample 1, but in addition it includes areas falling under the jurisdiction of traditional authorities, known as tribal areas, which were classed as known rural. Non-spatial techniques, namely linear logistic regression, classification trees and discriminant analysis, as well as spatial techniques, namely straight-majority-rule and iterated conditional modes (ICM), were researched, applied and analysed for both samples, for each province and for South Africa as a whole, using the 2001 South African population census data. Comparisons were made with the 1996 census information.

All three non-spatial statistical methods gave insight into those census variables and their combinations that best describe the subject under research, i.e. urban and rural. All three methods identified significant variables that clearly separate urban and rural areas. The results of all three non-spatial statistical methods showed similarities within each sample, but differences were noted between the two samples. All three non-spatial statistical methods applied to sample 1 classified the majority of the tribal EAs (Enumeration Areas) as urban, whilst the results from sample 2 are very similar to those obtained from both censuses, since both censuses and sample 2 predefine tribal settlements as rural.

Of the two spatial statistical methodologies, ICM performed best. In general, ICM, performed better than the non-spatial statistical methodologies. Thus for this problem, applying the Bayesian spatial methodology does improve the classifications.

Comparing the results of the analyses across the two samples yielded the conclusion that the various statistical methods do not impact as much on the study as the constitution of the two samples. Thus, including tribal areas as known rural, instead of allowing them to be classified by the statistical methodologies, has influenced the results far more strongly than have the differences between the methodologies themselves.

DEDICATION

To my ever-loving children

Mishka and Yarika Laldaparsad

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1.1 Introduction

Statistics South Africa[1] (Stats SA) conducts population censuses at regularly defined intervals. This is a mammoth exercise with the aim to count all South Africans. In order to cover the entire country in a specified period, Stats SA divides the country into manageable units called Enumeration Areas[2] (EAs). For the 2001 population census, South Africa was divided into approximately 80 000 EAs. These EAs form the basis for dividing work by assigning an enumerator to each EA to administer the census questionnaire. Nowadays, the EA as a unit has become more than an administrative workload to conduct the census. Being the smallest unit against which information is collected, the EA is aggregated to other administrative units such as provinces, municipalities, electoral wards, etc. to produce meaningful information for planning and decision-making.

Stats SA has for several censuses now, published data on the classification of South Africa in terms of urban and rural or non-urban (We will use rural for ease of writing.) The definition or classification for urban and rural came from attribute information attached to each EA, namely the classification of EAs into *EA-types*. EA-types were, and still are, based on town planning concepts such as proclaimed town area (i.e. cadastral information). Each EA has a unique EA-type. There are ten EA-types defined for the 2001 population census. Assigning EA-types to each EA, can become very subjective. Based on a rule set, an operator assigns the EA-type. Sometimes this decision is very difficult, due to the nature of the area.

Currently, in South Africa, the classification of the country into urban and rural has changed radically due to the implementation of the new demarcation of municipal

[1] Statistics South Africa (Stats SA) is a national Government department accountable to the Minister of Finance. The activities of the department are regulated by the Statistics Act (6 of 1999). Stats SA's tasks are to coordinate, collect, process, analyse and disseminate official statistics in support of economic growth, socio-economic development and the promotion of democracy and good governance.

[2] An Enumeration Area (EA) is defined as a manageable area consisting of approximately 120 households to be visited by an enumerator during the period of the census.

areas as defined by the Municipal Demarcation Board (MDB)[3]. The new demarcation has moved away from classifying the municipality in terms of urban and rural but rather to an all-inclusive municipality.

However, the concept of urban and rural is still in the minds of South Africans who want to know how much of the country is urban, or how much urbanisation is taking place as urbanisation or urban areas are most frequently associated with having improved service delivery, more institutional facilities and infrastructure, thus better living standards. On the other side of the coin, these areas are also associated with higher levels of unemployment, high levels of crime, etc.

The problem, and thus the research contained in this report, is around the *classification of areas in the country into urban and rural, as well as determining appropriate definitions for urban and rural.* To elaborate further, definitions of urban and rural have traditionally followed the aggregations of EA-types from previous censuses to the 1996 population census. For the 2001 population census, owing to the redemarcation of new municipal areas and the subjectiveness of the EA-types, together with the EA-type definition, an attempt was made by Stats SA to investigate the use of *population density* as a proxy for conceptually defining urban and rural.

This research report's main focus is to follow scientific approaches (a move away from subjective definitions) by utilising non-spatial and spatial statistical methods to classify and define urban and rural in South Africa.

1.2 Objectives of the study

The main objective of the study is to *classify areas using appropriate statistical methods to determine urban and rural areas in the country*. These areas, as derived by means of each statistical method, are profiled and common characteristics amongst them are summarised for classification and for the definitions of urban and rural areas. Population data are aggregated to determine the overall urbanisation for the country.

[3] The Municipal Demarcation Board (MDB) is responsible for the redetermination of municipal boundaries in South Africa.

1.3 Motivation for the study

The *first* motivation for this study comes from the need to know by South Africans, Government and various other planners and decision-makers, in their everyday life and in their attempts to redress inequalities of the country's past, just how urban (or rural) South Africa is. In the recent 2005 budget speech by the Finance Minister, Mr. Manuel said "*this social intent also embodies our commitment to build a more just, more equal society, in which steady progress is made in reducing the gulfs that divide rich and poor, black and white, men and women,* ***rural and urban***".

The *second* motivation comes from the need for evidence-based statistical information required by users of official statistics. The methodological statistical techniques that are investigated in this study and applied for defining urban and rural, will in the first place reduce the subjectivity associated with such definitions. The approach can be extended to various other concepts and definitions that are needed by users of statistical data.

The *third* motivation comes from the approaches this study takes with respect to definitions and classifications for official statistics. The study incorporates both non-spatial and spatial methodologies. The study introduces new perspectives and new ways of thinking that incorporate the spatial side to defining concepts used in official statistics. In this way, the close links between South Africa's spatial frameworks and its statistics become evident.

1.4 Background of South Africa's spatial framework and its impact on definitions for urban and rural

1.4.1 Impact of apartheid legislature on South Africa's urban landscape

Historically, South Africa's urban and rural classification is impacted by the country's apartheid past. As a result of this, South Africa's urban and rural classifications are different from such classifications of other countries. In fact it has resulted in characteristics that can be considered as classically South African and not shared by other countries. Such characteristics have also emerged in the results of this study. Smit (1979) states, "Without homeland urbanisation many cities and towns in the White sector would have a far larger Black urban population."

SPP (1983) reports on the mass forced removals or population relocation in South Africa since the early 1960s. These relocations were a result of farm removals, clearance of informal areas, removals under the Group Areas Act and influx control. Large scale removals were that of Africans. They were relocated out of cities, towns and farming areas falling in the 87% of the country designated for white ownership into the 13% allocated for African occupation.

Smit (1979) reported on the "suggestion that 'rural villages' be established for Blacks employed in industry and other sectors, which was accepted for the first time in 1945 by the General Council of the Ciskei and the Transkei (Rogers, 1949, in Smit, 1979)." SPP (1983) mentions about the Bantu Authorities Act of 1951 which provided for the establishment of tribal, regional and territorial authorities. This Act coopted tribalism and traditional institutions of Government, such as chieftainship into the administration of apartheid. In 1959 eight national units were demarcated under the Promotion of Bantu Self-Government Act, and the Bantustan (or homeland or independent national states) era in South African politics was launched.

Fair (1982) talks about the 1913 Land Act which " … in particular sought to underdevelop the African peasantry by inhibiting its productive capacity and by limiting its access to land and to markets. Moreover, the Native Reserves to which the peasantry was then largely confined, became a '*vast reservoir of migrant labour*' – '*a sponge that absorbs, and returns when required, the reserve army of African labour*' (Bundy, 1979, in Fair, 1982). Production in the reserves was preserved at a low, mainly subsistence, level which '*conferred direct benefits upon urban employers – particularly in the mines in the form of low wages, cheap housing, the avoidance of welfare considerations for workers' dependents, and a brake on the growth of an urban proletariat*' " (Bundy, 1979, in Fair, 1982).

Yawitch (1982) discusses the schedule attached to the 1913 Land Act listing all existing native reserves, locations and African-owned farms as areas that were reserved for African land-holding only. A trust fund, administered by the South African Native Trust, was set up to buy land, hence the term 'trust land'. According to Yawitch (1982) even before 1936 these areas had a substantial African

population, which "… included 'black spots', land already owned by Africans, already carrying a huge African population."

Yawitch (1982) talks about the betterment schemes, which can be traced to the Glen Grey Act of 1894, "… even through betterment schemes, Government was seeking the most convenient way in which to organise the reserves so that they could ultimately feed themselves, govern themselves and still provide the labour base to the functioning of the central South African economy. … Betterment had come to actually mean control. … The South African working class was divided in a fundamental way into an urban privileged group and a poor and unemployed rural group. The way that the entire system of labour control operated was to export these 'excess' rural people out of urban areas to places where their unemployment and poverty was not visible. This was the main reason for the non-workability of betterment schemes."

"The first Black 'town' was laid out in the forties at Zwelitsha (in the Ciskei) near King William's Town where the Industrial Development Corporation established a textile factory. At more or less the same time Temba was laid out in Bophuthatswana to accommodate squatters from the PWV complex. … In about 1950 the notation began to gain ground that towns in the homelands 'should not only become dumping grounds for the surplus rural population but should also provide accommodation for those working in adjacent White areas' (Henning, 1969, in Smit, 1979). Umlazi was the first Black town established in a homeland (in 1949 - 50) to alleviate the housing shortage in a large White city (Durban)." (Rogers, 1949, in Smit, 1979)

Murray (1987) states that "what has happened, in summary, is massive 'urbanisation' in the Bantustans, in terms of the sheer density of population now concentrated there. … 56% of the population of the Bantustans are now 'urbanised'. … Some of the concentration has taken place in 'proclaimed' (officially planned) towns in the Bantustans, whose population was 33 500 in 1960, 595 000 in 1970 and 1.5 million by 1981. But most of the concentration has taken place in huge rural slums which are 'urban' in respect of their population densities but 'rural' in respect of the absence of proper urban infrastructure or services."

"In the 1980s the South African Government made a number of significant changes, both constitutionally and with respect to urban development policy. … Another significant change in the 1980s was the abandonment of policies designed to prevent Blacks from migrating to the towns. … Bureaucratic momentum, effective segregation and racial discrimination are but part of the inheritance of urban apartheid" (Christopher, 1992).

1.4.2 Historical classifications of urban and rural in South Africa

The discussion that follows is intended to give some understanding of the country's historical classifications of urban and rural. It also provides the context with respect to the evolution of South Africa's spatial frameworks and space economy, and the role it played in urban and rural areas in the country.

Davies (1967) and Davies and Cook (1968) postulated an urban hierarchy for South Africa. The hierarchy refers to conditions in 1960. It was based on an index method using a series of twelve index central functions, which was considered significant for different degrees of urban importance. Data were extracted from various sources such as government and provincial departments, commercial and financial institutions, and newspapers, supplemented by reference to commercial and telephone directories and by field checks. Davies (1967) describes how data for the 601 places classified as urban in the 1960 population census was used. He further describes "all places without an independent post office, which was the baseline of central functions in South African towns, were excluded from the analysis. These included places such as isolated collieries and other small mining settlements and resorts. Punctiform settlements not listed in the 1960 census had also been excluded. … No exact nomenclature to describe the status of urban places had yet evolved in South Africa beyond the use of such terms as metropolitan area, city and town in English and *metropolitaanse gebied*, *stad*, *dorp* and *dorpie* in Afrikaans. Terms such as village, hamlet or sub-town have never formed a part of customary usage." Davies (1967) suggested that South African urban areas be classified under the following eight orders of towns:

Order 1: Primate Metropolitan Area (The Witwatersrand concurbation)

Order 2: Major Metropolitan Areas (Cape Town and Durban)

Order 3: Metropolitan Areas (Pretoria, Bloemfontein, Pietermaritzburg, East London, Kimberley)

Order 4: Major country towns
Order 5: Country towns
Order 6: Minor country towns
Order 7: Local service centres
Order 8: Low-order service centres

Davies (1967) then tested the validity of the classification of using the twelve index functions against a hierarchy based upon fifty central functions. These included aspects such as administrative, educational, financial, professional, commercial, service industry, accommodation, social services, transport, newspaper, entertainment and utility services. Davies and Cook (1968) concluded that there " … is a high degree of correlation between the index hierarchy and the hierarchy based on more comprehensive methods. This has obvious benefits in that an urban hierarchy may be established rapidly using simple methods with a considerable degree of reliability, and may be easily updated periodically."

According to Fair (1982) South Africa's spatial system then was regarded as comprising three main elements:
The core – comprising the major metropolitan areas of the PWV, Cape Town and Durban-Pinetown, the minor metropolitan areas of Port Elizabeth, East London, Pietermaritzburg, Bloemfontein and Kimberley all considered together as the non-contiguous *urban core* of the South African space economy
The inner periphery – comprising the rest of South Africa in White, Coloured and Asian ownership
The outer periphery – comprising the African homelands or Black national states

1.5 Research methodology

The study also covers the *geographer's perspective* with regard to classifications and definitions for urban and rural. However, a recent trend amongst geographers is a move away from the concept of urban and rural. This is due to the difficulty in practically separating the two, due to movement on the ground and the existence of rural areas within urban areas. Rather, the concept of regional geography is being pursued again. According to Hoekveld (1990) "regional geography is about places, which means areas; it is not about objects, which have spatial attributes." Regional geography refers to classes of areas with common attributes and therefore can be

compared to other areas in the same class. The concepts of urban and rural from the geographer's perspective are covered in Chapter 2.

Non-spatial and *spatial statistical methodologies* are investigated for solutions to our classification problem, in particular that of supervised classifications. Supervised classification techniques best suit this study since we want to classify into two groups, i.e. urban and rural, using sample data sets of areas that are known with certainty to be urban or rural. Supervised statistical techniques, i.e. *linear logistic regression*, *discriminant analysis* and *classification trees,* were applied to sample data sets of known urban and rural areas for each province and for South Africa as a whole. The unknown areas were thereafter scored with the results obtained from the sample. The methodology and results are presented in Chapter 3.

While the non-spatial methodologies provide information as to how combinations of input variables contribute to the classifications, it nevertheless also is important not to neglect their spatial association, i.e. the association between variables distributed over space. Since EAs are adjacent to one another, this aspect cannot be ignored. The subject under research is most definitely a spatially affected phenomenon and it might be wrong to apply only non-spatial statistics to spatial data. Owing to this, some spatial techniques for grouping, based on conditional probabilities and adjacency, are researched and applied as a means to label an EA as either urban or rural, based on its spatial distribution.

Spatial methods researched and applied to EA level data are *straight-majority-rule* and *iterated conditional modes (ICM).* In the case of straight-majority-rule, each unknown status EA, namely an EA where the urban or rural status is not known, is classified according to the majority classification rule, based on its neighbours. The process is iterated throughout the province (or in the case of South Africa as a whole, throughout South Africa) until stability is reached. The initial classification is taken from the best results as determined by the non-spatial methodologies, i.e. logistic regression, discriminant analysis or classification trees. The methodology and results are discussed in Chapter 4.

For ICM, which is based on Markov random fields, a *prior* and *posterior* probability per EA is calculated and applied, in order to determine the urban/rural status of an unknown status EA. The prior probability is based on the number of urban and rural EAs in the neighbourhood of the unknown status EA. The posterior probability is the prior probability multiplied by the density function from the non-spatial discriminant analysis, using the significant census 2001 variables. The process is iterated until stability is reached. The initial classification is based on the urban/rural classifications as obtained for discriminant analysis. The methodology and results are discussed in Chapter 4.

The selection of the sample *data sets* of areas where the urban/rural status is known is important to this study. All statistical methods made use of the same sample data sets so that outcomes can be compared. The selection of the sample data sets of knowns is explained in Chapter 3. The chapter explains why and how two sample data sets (per province and for South Africa as a whole) were selected, i.e. *Sample 1 (urban-farm)* and *Sample 2 (urban-farm-tribal)*.

The attribute data from the 2001 population census was used.

1.6 Structure of research report

This research report consists of five chapters.

Chapter 1: ***Introduction and Problem Statement***

In this introductory chapter an explanation of the problem under research is presented, i.e. ***classifying and defining areas in South Africa as urban or rural through statistical approaches***, as well as details of the objectives and relevance of the research. In order to put some context with regard to urban and rural in this country, a background review with respect to South Africa's spatial framework and the influence it has on urban and rural, are also discussed in this chapter. Also included is an overview of the research methodology used in the study, as well as the research report structure.

Chapter 2: ***Methodology and Literature Review***

The chapter provides a theoretical literature review of the statistical methods used, and also discusses the concepts urban and rural from the geography discipline point of view.

Chapter 3: ***Non-spatial Data Application and Results***

In this chapter the non-spatial statistical techniques, i.e. linear logistic regression, classification trees and discriminant analysis, are applied to selected census 2001 demographic and household data. The application methodology is described. The rationale and selection of the two sample data sets are explained. The methodology for weighting the data with prior information from census 2001 for each statistical method is described. The selection of census 2001 variables is also discussed and results for each method are presented and analysed. Confusion matrices are also presented and the results are spatially presented on maps.

Chapter 4: ***Spatial Data Application and Results***

In this chapter the spatial statistical techniques, i.e. straight-majority-rule and iterated conditional modes (ICM) are explained and applied. Results from each method are presented and analysed. Confusion matrices are presented, and the results are spatially presented on maps.

Chapter 5: ***Discussion, Recommendations and Conclusion***

This chapter discusses the results from both the non-spatial and spatial methodologies holistically and makes final recommendations and conclusions to the study.

CHAPTER 2 - *Methodology and Literature Review*

2.1 Introduction

2.1.1 Statistical methods

This chapter contains a theoretical discussion of the various statistical techniques selected for classifying the country into urban and rural areas. Its purpose is to provide the theoretical understanding needed before applying the methodology to data in the following chapters. The selected statistical techniques incorporate both *non-spatial* and *spatial* techniques.

The following non-spatial statistical techniques are discussed in this chapter:

- Linear logistic regression
- Classification trees
- Discriminant analysis

These non-spatial statistical techniques are also referred to as *supervised* classification techniques. Hastie, Tibshirani and Friedman (2001) describe supervised classification as predicting the values of one or more outputs or response variables for a given set of input or predictor variables. Supervised classification techniques are applicable to this study since we want to classify into two groups, i.e. urban and rural, using sample data sets of areas that are known with certainty to be urban or rural.

Regression tells us how one variable is related to another – or to several others (Wonnacott & Wonnacott 1981). Regression models are used for several purposes, including the following: data description, parameter estimation, prediction and estimation and control (Montgomery & Peck 1992). Hosmer and Lemeshow (2000) discuss logistic regression, where the outcome variable is binary or dichotomous. *Logistic regression* is appropriate for this study, since the outcome variable is either urban or rural.

Classification trees were chosen as an alternative strategy for selecting appropriate variables that can describe the features of urban and rural. This is mainly due to its non-linear approach, i.e. ‘instead of using the complete set of features jointly to make a

decision, different subsets of the features are used at different levels of the tree' (Webb 1999).

McLachlan (1992) argues that *discriminant analysis* has to do with the assignment of the entity to one of a number of possible groups on the basis of its associated measurements, where the group membership of the entity is unknown. Thus this technique was selected to assign enumeration areas (EAs) based on the outcome of the sample data set of known urban and rural areas into two groups, i.e. urban and rural.

The following spatial statistical techniques are discussed:

- Straight-majority-rule
- Markov Random Fields (i.e. ICM and the Gibbs Sampler)

While the non-spatial methodologies described above provide more information as to how combinations of input variables contribute to the classifications, it is nevertheless also important not to neglect their spatial association, i.e. the association between variables distributed over space. Since EAs are adjacent to one another this aspect cannot be ignored. The subject under research is most definitely a spatially effected phenomenon and it might be wrong to apply only non-spatial statistics to spatial data. According to Besag (1989) nearby values (he uses pixels, we can link to EAs) tend to be similar, adjacent labels are usually the same, and boundaries around objects are generally continuous. Thus the spatial contribution to this study is important.

2.1.2 The geographer's viewpoint on urban and rural classifications

The other key aspect of this chapter is a discussion of urban-rural as defined traditionally by statistical agencies and by selected geography researchers and specialists. The relevance of this section is to get an understanding of current classifications, definitions and possible variables that describe urban and rural which can be used in the statistical analysis that follows in the next chapter. As Clarke (1972) says, the distinction between urban and rural is a "thorny problem for the population geographer."

Statistics South Africa (2003), identifies possible reasons for the differences in urban and rural figures for census 1996 and census 2001 by means of

- Reclassification of the 1996 EA-types in terms of urban and rural to correspond with the cadastral features on which census 2001 was based
- Reclassification of specific EAs from urban to rural in 2001 for comparison purposes between census 1996 and census 2001

Statistics South Africa (2003), further applies international definitions for urbanisation based on population density. The methodology employed, comprises calculations and comparisons of population densities for main places and sub places in South Africa at density cut-offs of 500 per km^2 and 1000 per km^2. The results showed that many urban informal areas (squatter areas) with a high population, concentrated in smaller areas, have a high population density. Interestingly some of the larger tribal areas of South Africa, which are regarded as rural are, based on this definition, actually urban. The older smaller so-called *white dorpies* (towns), as classified on the basis of a cadastral definition, are no longer classified as urban. The implications of some of these findings are profound and will require a change in the mindset of many people and leaders of the country. However, it is clear that a definition for urban and rural cannot be based on population density alone, and further investigations are needed to include other social, economic and institutional attributes such as number of public facilities, e.g. schools, police stations, health care, etc. in a given area to determine functionality or even human activities that can classify an area as urban or rural.

2.2 Linear Logistic Regression

2.2.1 Introduction

Christensen (1997) says that all of logistic regression can be viewed as an extension of standard regression analysis. In logistic regression, there is a binary or dichotomous response of interest, and predictor variables are used to model the probability of that response.

The specific form of the logistic regression model according to Hosmer and Lemeshow (2000) is

$$\Pi(x) = \frac{e^{\beta_0+\beta_1 x}}{1+e^{\beta_0+\beta_1 x}}. \qquad (1)$$

The quantity $\Pi(x) = \mathrm{E}(Y/x)$ represents the conditional mean of Y given x when the logistic distribution is used, where Y denotes the outcome variable and x denotes a value of the independent variable.

A transformation of $\Pi(x)$ that is central to logistic regression is the logit transformation. This transformation is defined, in terms of $\Pi(x)$, as

$$g(x) = \ln\left[\frac{\Pi(x)}{1-\Pi(x)}\right] = \beta_0 + \beta_1 x.$$

The importance of this transformation is that $g(x)$ has many of the desirable properties of a linear regression model. The logit, $g(x)$, is linear in its parameters, may be continuous, and may range from $-\infty$ to $+\infty$, depending on the range of x.

2.2.2 Fitting the logistic regression model

To fit the logistic regression model in equation *(1)* to a set of data requires that we need to estimate the values of β_0 and β_1, the unknown parameters. *Maximum likelihood* is the method that forms the foundation for estimation with the logistic regression model. The likelihood function is essentially the joint density of the data, expressed as a

function of the unknown parameters. The likelihood is based on the Bernoulli distribution.

2.2.3 Multiple logistic regression

According to Hosmer and Lemeshow (2000) multiple logistic regression generalises the logistic model to the case of more than one independent variable. Consider a collection of p independent variables denoted by the vector $x' = (x_1, x_2 ..., x_p)$. Let the conditional probability that the outcome is present, given x, be denoted by $P(Y = 1 | x) = \Pi(x)$. The logit of the multiple logistic regression model is given by the equation

$$g(x) = \beta_0 + \beta x_1 + \beta x_2 + ... + \beta x_p,$$

in which case the logistic regression model is

$$\Pi(x) = \frac{e^{g(x)}}{1 + e^{g(x)}}.$$

2.2.4 Interpreting the fit and the odds ratio

In the logistic regression model the *link* function is the logit transformation

$$g(x) = \ln\left[\frac{\Pi(x)}{1 - \Pi(x)}\right] = \beta_0 + \beta x_1 + \beta x_2 + ... + \beta x_p .$$

In the logistic regression model, the slope coefficient (β) represents the change in the logit corresponding to a change of one unit in the independent variable $\left[i.e. \beta = g(x+1) - g(x)\right]$.

Hosmer and Lemeshow (2000) explains *odds* using a dichotomous independent variable, x, coded as either zero or one. The possible values of the logistic probabilities may be conveniently displayed in a 2 x 2 table as shown in table 2.2.4. The *odds* of the outcome being present among individuals with $x=1$, is defined as $\left[\frac{\Pi(1)}{1-\Pi(1)}\right]$. Similarly, the odds of the outcome being present amongst individuals with $x=0$, is defined as $\left[\frac{\Pi(0)}{1-\Pi(0)}\right]$. The *odds ratio*, denoted by *OR*, is defined as the ratio of the odds for $x=1$ to the odds for $x=0$, and is given by the equation

$$OR = \left[\frac{\frac{\Pi(1)}{1-\Pi(1)}}{\frac{\Pi(0)}{1-\Pi(0)}}\right]. \qquad (2)$$

Table 2.2.4 Logistic probabilities

Outcome variable	**Independent variable** $x=1$	**Independent variable** $x=0$
$y=1$	$\Pi(1)=\frac{e^{\beta_0+\beta_1}}{1+e^{\beta_0+\beta_1}}$	$\Pi(0)=\frac{e^{\beta_0}}{1+e^{\beta_0}}$
$y=0$	$1-\Pi(1)=\frac{1}{1+e^{\beta_0+\beta_1}}$	$1-\Pi(0)=\frac{1}{1+e^{\beta_0}}$
Total	1.0	1.0

Substituting the expression for the logistic regression model shown in table 2.2.4 into *(2)* we obtain

$$OR = e^{\beta_1},$$

which shows the relationship between the odds ratio and the regression coefficient for logistic regression with a dichotomous independent variable coded 1 and 0.

2.3 Classification Trees

2.3.1 Introduction

Webb (1999) says that classification trees or decision trees are capable of modelling complex non-linear decision boundaries. A classification tree or a decision tree is an example of a multistage decision process. Instead of using the complete set of features jointly to make a decision, different subsets of features are used at different levels of the tree. Classification trees break up the decision into a series of simpler decisions at each node. Associated with each internal node of the tree is a *variable* and a *threshold*. Associated with each *leaf* or *terminal node* is a *class label*. The top node is the *root* of the tree. The number of decisions required to classify a pattern depends on the pattern. Generally the outcome of a decision could be one of $m \geq 2$ possible categories.

Fatti (2003) discusses Automatic Interaction Detection (AID). AID comprises a family of methods for reducing a large data set consisting of

1) a dependent variable Y which is either categorical or continuous
2) a (possibly large) number of predictor variables

into relatively homogeneous (in Y) subsets defined by different combinations of categories of the predictor variables.

The strength of an AID analysis is that it imposes little structure on the data (such as the linearity required by multiple regression), and the categorical dependent variable version (CHAID: χ^2- AID) requires few distributional assumptions. The continuous dependent variable version (XAID – extended AID) is based on normality of Y.

2.3.2 Tree method of SAS

Since SAS Enterprise Miner Tree Node was used in the study, a brief description of the Tree Method follows.

The SAS implementation of decision trees finds multiway splits based on nominal, ordinal and interval inputs. There are options to include features such as CHAID (Chi-squared automatic interaction detection). The criterion for evaluating a splitting rule may be based on either a statistical significance test, namely an F test or a Chi-square test, or on the reduction in variance, entropy or $gini$ impurity measure.

SAS Enterprise Miner Tree Node differs from the CHAID algorithm, in that the Tree Node seeks the split minimising the adjusted p-value, whereas the original KASS algorithm does not. CHAID discretises interval inputs, while the Tree Node sometimes consolidates observations into groups.

2.3.3 Splitting rules and pruning

Webb (1999) mentions that the construction involves three (3) steps:

1. Selecting a *splitting rule* for each internal node. This means determining the features, together with a threshold, that will be used to partition the data set at each node.

2. Determining which nodes are terminal nodes. This means that for each node, we must decide whether to continue splitting or to make the node a terminal node and assign a class label to it. If we continue splitting until every terminal node has pure class membership (all samples in the design set that arrive at that node belong to the same class), then we are likely to end up with a large tree that overfits the data and gives a poor error rate on an unseen test set. Alternatively, relatively impure terminal nodes (nodes for which the corresponding subset of the design set has mixed class membership) lead to small trees that may underfit the data. Several *stopping rules* have been proposed in the literature, but the approach suggested by Breiman, Friedman, Olshen and Stone (1984, in Webb, 1999) is to successfully grow and selectively prune the tree, using cross-validation to choose the subtree with the lowest estimated misclassification rate.

3. Assigning class labels to terminal nodes. This is straightforward and labels can be assigned by minimising the estimated misclassification rate.

A splitting rule, according to Webb (1999), is a prescription for deciding which variable, or combination of variables, should be used at each node to divide the samples into subgroups, and for deciding what the thresholds on these variables should be. A split consists of a condition on the coordinates of a vector $x \in \Re^p$.

Webb (1999) explains pruning as follows: Let $R(t)$ be real numbers associated with each node t of a given tree T. If t is a terminal node, i.e. $t \in \tilde{T}$, then $R(t)$ could represent the proportion of misclassified samples – the number of samples in $u(t)$ (where $u(t)$ is a subspace of $\Re^p$) that do not belong to the class associated with the terminal node, defined to be $M(t)$, divided by the total number of data points, n

$$R(t) = \frac{M(t)}{n} \qquad\qquad t \in \tilde{T}.$$

Let

$$R_\alpha(t) = R(t) + \alpha$$

for a real number α. Set

$$R(T) = \sum_{t \in \tilde{T}} R(t)$$

$$R_\alpha(T) = \sum_{t \in \tilde{T}} R_\alpha(t) = R(T) + \alpha\left|\tilde{T}\right|.$$

In a classification problem, $R(T)$ is the *estimated misclassification rate*, $\left|\tilde{T}\right|$ denotes the cardinality of the set $\left|\tilde{T}\right|$, $R_\alpha(t)$ is the *estimated complexity –(misclassification rate* of a classification tree), and α is a constant that can be regarded as the complexity cost per terminal node. If α is small, then there is a small penalty for having a large number of nodes. As α increases, the *minimising subtree* (the subtree $T' \leq T$ that minimises $R_\alpha(T')$*)* has fewer terminal nodes.

2.4 Discriminant Analysis

2.4.1 Introduction

McLachlan (1992) describes discriminant analysis as follows: Suppose there is a finite number, say g, of distinct populations, categories, classes or groups, denoted by $G_1,...,G_g$ (refer to G_i as groups). In discriminant analysis, the existence of the groups is known *a priori*. An entity of interest is assumed to belong to one (and only one) of the groups. Let the categorical variable z denote the group membership of the entity, where $z = i$ implies that it belongs to group G_i $(i = 1,...,g)$. Let the *p*-dimensional vector $x = (x_1,...,x_p)'$ contain the measurements on p available features of the entity. In this framework, discriminant analysis is concerned with the relationship between the group-membership label z and the feature vector x. At the decision end of the scale, the group membership of the entity is unknown and the intent is to make an outright assignment of the entity to one of the g possible groups on the basis of its associated measurements. That is, in terms of our present notation, the problem is to estimate z solely on the basis of x.

At the other extreme end of the spectrum, no assignment or allocation of the entity to one of the possible groups is intended. Rather, the problem is to draw inferences about the relationship between z and the feature variables in x.

Between these extremes lie most of the everyday situations in which discriminant analysis is applied. Typically, the problem is to make a prediction or tentative allocation for an unclassified entity.

2.4.2 Allocation rules

McLachlan (1992) describes a classified entity as an entity whose group of origin is known. A rule for the assignment of an unclassified entity to one of the groups is referred to as a discriminant or allocation rule.

Webb (1999) says that a discriminant function is a function of the pattern x that leads to a classification rule. The *p*-dimensional data vector $x = (x_1,...,x_p)'$, denotes the *p* measurements of the features of an object, which are thought to be important for

classification. In discrimination assume that there exist C groups or *classes*, denoted by $\omega_1,...,\omega_c$, with *a priori* probabilities (the probability of each class occurring) $p(\omega_1),...,p(\omega_c)$ such that $\sum_{i=1}^{c} p(\omega_i)=1$ and associated with each pattern x is a categorical variable z that denotes the class or group membership; that is , if $z=i$, then the pattern belongs to ω_i, $i\in\{1,...,C\}$.

2.4.3 Linear discriminant functions

Webb (1999) considered a family of discriminant functions that are linear combinations of the components of $x=(x_1,...,x_p)'$,

$$g(x)=w'x+w_0=\sum_{i}^{p} w_i x_i + w_0.$$

This is a *linear discriminant function*, a complete specification of which is achieved by prescribing the *weight vector* w and *threshold weight* w_0.

A linear discriminant function can arise through assumptions of normal distributions for the class densities, with equal covariance matrices. Alternatively, without making distributional assumptions, we may impose the form of the discriminant function to be linear and determine its parameters.

The most widely used classifier is that based on the normal distribution,

$$p(x\mid\omega_i)=\frac{1}{(2\Pi)^{p/2}|\Sigma_i|^{1/2}}\exp\left\{-\frac{1}{2}(x-\mu_i)'\Sigma_i^{-1}(x-\mu_i)\right\}.$$

Classification is achieved by assigning a pattern to a class for which the posterior probability, $p(\omega_i\mid x)$, is the greatest, or equivalently $\log[p(\omega_i\mid x)]$. Using Bayes' rule and the normal assumption for the conditional densities above, we have

$$\log[p(\omega_i\mid x)]=\log[p(x\mid\omega_i)+\log(p(\omega_i))-\log(p(x))]$$

$$=-\frac{1}{2}(x-\mu_i)'\Sigma_i^{-1}(x-\mu_i)-\frac{1}{2}\log(|\Sigma_i|)-\frac{p}{2}\log(2\Pi)+\log(p(\omega_i))-\log(p(x)).$$

Since $p(x)$ is independent of class, the discriminant rule is: assign x to ω_i if $g_i > g_j$, for all $j \neq i$, where

$$g_i(x) = \log\left(p(\omega_i)\right) - \frac{1}{2}\log\left(|\Sigma_i|\right) - \frac{1}{2}(x-\mu_i)' \Sigma_i^{-1}(x-\mu_i).$$

Classifying a pattern x on the basis of the values of $g_i(x),\ i=1,...,c,$ gives the *normal-based quadratic discriminant function*. When the covariance matrices are equal, i.e. $\Sigma_i = \Sigma,\ i=1,...,c,$ the normal-based quadratic discriminant function becomes the linear discriminant function, i.e. $LDF(x) = \left(x - \frac{1}{2}(\mu_i + \mu_c)\right)' \Sigma^{-1}(\mu_i - \mu_c),\ i=1,...,c-1.$

2.5 Markov Random Fields, ICM and Gibbs Sampler

2.5.1 Markov random fields

Besag (1986) talks about *Markov random fields* by associating them with satellite imagery. Each picture element, or pixel, has a particular colour. The colours may be unordered, and represent the value per pixel of some underlying variable, such as intensity. Besag (1986) states that "… there is supposed to be a true but unknown colouring of the pixels … the aim is to reconstruct the scene from two imperfect sources of information."

With each pixel there is a possible multivariate record, which provides data on the colour of the pixel. By assuming that the records for any particular scene follow a known statistical distribution and that pixels close together tend to have the same colour, Besag (1986) aims to construct a scene of unknown colouring of pixels with additional knowledge that pixels close together tend to have the same colours, by using non-degenerate Markov random field, which represents the local characteristics of the underlying scene. Besag (1986) states that such an approach enables the two assumptions to be "combined by Bayes' theorem and the true scene to be estimated according to standard criteria".

In developing his methodologies, Besag (1986) uses the following notation and makes the following assumptions. Suppose a two-dimensional region *S* is partitioned into *n* pixels, labelled in some manner by the integers i = *1, 2, …, n*. Each pixel can take one of *c* colours, labelled *1, 2, …, c*, with *c* finite. Assume there is no deterministic exclusions, so that the minimal sample space is Ω = *{1, 2, …, c}*^{n}. An arbitrary colouring of S will be denoted by x = *(*x_1*, *x_2*, …, *x_n*)*, where x_i is the corresponding colour of pixel i. x^* is used to denote the true but unknown scene and interpret this as a particular realisation of a random vector X = *(*X_1*, *X_2*, …, *X_n*)* where X_i assigns colour to pixel i. y_i denotes the observed record at i and y is the corresponding vector, interpreted as the realisation of the random vector, Y = *(*Y_1*, *Y_2*, …, *Y_n*)*. *P(.)* and *P*$_T$*(.)* denote probabilities of named events.

Besag (1986) makes two assumptions:

Assumption 1: Given any particular scene x, the random variables *Y*$_1$*, Y*$_2$*, …, Y*$_n$ are conditionally independent and each *Y*$_i$ has the same known conditional density function $f(y_i \mid \mathrm{x_i})$, dependent only on x_i. Thus, the conditional density of the observed records y, given x, is simply

$$l(y \mid \mathrm{x}) = \prod_{i=1}^{n} f(y_i \mid \mathrm{x_i}).$$

Two modifications to Assumption 1 are made:

(1) There may be overlaps between records, in that y_i may contain information not only from pixel i but also from adjacent pixels. The conditioning set in f must then be expanded to include the x_j`s at these pixels.

(2) The assumption of conditional independence is not always valid: for example, the reflectance from adjacent pixels may be noticeably more alike than those from pixels further apart.

Assumption 2: the true colouring x^* is a realisation of a locally dependent Markov random field with specified distribution $\{p(x)\}$.

$\{p(x)\}$ is a probability distribution which assigns colourings to *S*. Denote by x_A a colouring of the subset *A* of *S* and, in particular, by $x_{S|i}$ a colouring of all pixels other

than pixel i; $x_S = x$ and $x_{\{i\}} = x_i$. Consider the conditional probability $P(x_i \mid x_{S\setminus i})$ of colour x_i occurring at pixel i, given the colouring $x_{S|i}$ elsewhere. Viewed through its conditional distribution at each pixel, $\{p(x)\}$ is termed a *Markov random field*.

Focusing on fields whose conditional distributions are *locally dependent*, that is dependent only on the colours of pixels in the immediate vicinity of pixel i. Thus, suppose that for every x,

$$P(x_i \mid x_{S\setminus i}) \equiv p_i(x_i \mid x_{\partial i}),$$

where p_i is specific to the pixel i and ∂_i is a subset of $S\setminus i$. The members of the set ∂_i are termed the *neighbours* of pixel i. In practice, the problem is approached from the other end, by first naming the neighbours ∂_i of each pixel i and then selecting $\{p(x)\}$ from among the corresponding class of probability distributions. $\{p(x)\}$ is to be viewed merely as our prior distribution for the true scene x^*.

Besag (1986) considers some connected probabilistic methods of estimating the true scene x^*. The estimate $\hat{x}$ is chosen to have maximum probability, given the vector of records *y*. Thus, by Bayes' thereom, $\hat{x}$ maximises

$$P(x \mid y) \propto l(y \mid x)p(x)$$

with respect to x. In a Bayesian framework, $\hat{x}$ is the maximum *a posteriori* estimate of x^*, being the mode of its posterior distribution. Besag (1989) explains this, in the context of Bayesian Image Analysis, as combining the prior density and the likelihood by Bayes' theorem to form the posterior density $P(x \mid y)$ of x given y, as shown above. A major strength of the Bayesian approach is that an interval estimate (Bayesian confidence interval) can be attached to each pixel.

Besag (1986) says that an important requirement is to maximise the expected proportion of correctly classified pixels, that is, to estimate x_i^*, for each i, by $\hat{x}_i$ which maximises

$$P(x_i \mid y) \propto \sum_{x_{s|i}} l(y \mid x) p(x),$$

the marginal (posterior) probability of x_i at i, given the records y. $P(x_i \mid y)$ depends on all the records for (almost) any $\{p(x)\}$.

2.5.2 Iterated Conditional Modes (ICM)

According to Besag (1986) if we want to update the colour $\hat{x}_i$ at pixel i, ($\hat{x}$ denotes a provisional estimate of the true scene x^*), using all available information, the colour with maximum conditional probability is chosen, given the record y and the current reconstruction $\hat{x}_{s|i}$ elsewhere; that is, the new $\hat{x}_i$ maximises $P\left(x_i \mid y, \hat{x}_{s|i}\right)$ with respect to x_i. It follows from Bayes' theorem that

$$P\left(x_i \mid y, \hat{x}_{s|i}\right) \propto f(y_i \mid x_i) p_i\left(x_i \mid \hat{x}_{\partial i}\right),$$

so that implementation is trivial for *any* locally dependent $\{p(x)\}$. Note that, because of the assumption of local dependency of the colours we need only condition on $\hat{x}_{\partial i}$, the colours of the neighbouring pixels. When applied to each pixel in turn, the procedure defines a single cycle of an iterative algorithm for estimating x^*. The algorithm is applied for a fixed number of cycles or until convergence, to produce the final estimate of x^*. Note that

$$P(x \mid y) = P\left(x_i \mid y, x_{s|i}\right) P\left(x_{s|i} \mid y\right),$$

so that $P\left(\hat{x} \mid y\right)$ never decreases at any stage and eventual convergence is assured. In practice, convergence to what must therefore be a local maximum of $P(x \mid y)$, is extremely rapid, with few if any changes occurring after about the sixth cycle. Note that its dependence only on the local characteristics of $\{p(x)\}$ ensures the rapid convergence. This method is labelled *ICM*, representing "*iterated conditional modes*".

2.5.3 Gibbs sampler

Besag (1989) says that any $P(x \mid y)$ is a Gibbs distribution, a fact that motivates use of the term '*Gibbs sampler*'. The procedure is to construct a discrete-time Markov chain, with state space the space of all valid images x and limit distribution $\{P(x \mid y)\}$. The Markov chain is then simulated and produces a sequence of (stochastically dependent) images sampled from $\{P(x \mid y)\}$. Each site is visited in turn and the current value there is replaced by one sampled randomly from the associated conditional distribution, given the current states of all other image attributes.

Each pixel is considered in turn and, when at pixel i, a new x_i is generated from the univariate conditional distribution $\left\{P\left(x_i \mid x_{\partial i}, y\right)\right\}$. Viewed at the end of each cycle, this produces a time-homogeneous Markov chain whose limit distribution must be consistent with the individual conditional distributions and hence with $\{P(x \mid y)\}$.

2.6 The Geographer's Viewpoint on Urban and Rural Classifications

The Report of the United Kingdom's Office for National Statistics, a guide entitled *Urban and Rural Area Definitions: A User Guide, Census 2001*, henceforth referred to as the *UKO Guide*, shows that similarly to South Africa, the UK began defining urban and rural within the local Government structure itself, i.e. county boroughs, municipal boroughs and urban districts. In South Africa a similar structure existed (that is before the process of redetermining the municipal structures by the Municipal Demarcation Board) for Local Governments, i.e. transitional local councils (TLC) denoting the urban part of the local authority and transitional rural councils (TRC) denoting the rural part. It

was not until the local Government reforms in the UK in the early 1970s that different approaches to defining urban and rural areas became necessary.

From the UKO Guide it is evident that there are a number of different urban/ rural definitions in use, for different needs, mainly as a result of different policies.

Methods for defining an urban or rural area that were deployed over the years in the UK are the following:

- Groupings of about four Enumeration Districts (EDs), (called Enumeration Areas, i.e. EAs in South Africa) within the urban land.
- Making use of the population weighted centroids where an ED was defined as 'urban' if its centroid was either wholly within the area of urban land or within a 150 metre buffer of the boundary.
- The Scottish 1991 Census made use of geographically contiguous groups of postcodes and densities of addresses to designate localities. The use of addresses to create population estimates has advantages in the sense that the exercise can be repeated outside census years. In fact, the favoured single criterion definition of 'urban' has been based on land use, whether measured directly as land parcels or by proxy as (residential and commercial) address densities.

Another approach suggested in the UKO Guide is to classify places based on their social and economic characteristics. The approach requires that data be collected for a consistent place geography and the use of sophisticated statistical techniques. Stats SA has developed an area based place name geographical frame for South Africa. The frame was developed by aggregating EAs into places. Although the EA-types are attached to each EA, the aggregation of EAs into places did not take EA-types into consideration and thus gives no clear indication of urban and rural.

The problems of defining *rural* areas are more intractable than those of defining urban areas, leading one observer to suggest that what constitutes rurality is largely a matter of convenience (Newby, 1986, in the UKO Guide). The problem with this approach of defining areas like small settlements on the fringes of large towns and cities to remote villages and hamlets to large farming areas as rural, is the economic and social changes that have taken place in rural areas that resemble an urban style of life and work.

However, according to the UKO Guide, “rural areas have distinctive character; these attributes include tracts of open countryside, low population densities, a scattering of small to medium-sized settlements, less developed transport infrastructure and lack of access to services and amenities, especially of the type provided in larger urban centres.” For practical purposes these characteristics have been used to describe “rurality” even in South Africa.

The UKO Guide talks about the rural land as the “remainder” or “all land which is not defined as urban” that is land which is not built on and which is mostly “open” or “countryside”. Serious limitations using this approach are cited. “It fails to recognise the existence of settlements with populations smaller than the arbitrary minimum set for ‘urban’ areas, it fails to recognise the functional relationship between urban areas and smaller settlements within the surrounding countryside and it ignores those social/economic characteristics that may be deemed to pertain to the term ‘rural’. ” Given these problems associated with the “urban land residual” approach, there have been three main types of approaches to defining rural areas in a more realistic manner:

- To assign some urban areas to be “rural” in nature
- To classify local authority areas and/or wards on the basis of characteristics which are deemed to identify them as “rural”
- To identify smaller settlements on the basis of land use characteristics other than those used in the urban areas definition

The UKO Guide defines the following elements for operationalising the terms urban and rural:

Sense	**Descriptors**	**Measure**
Land	Land parcel characteristics	i. Extensive land parcels ii. Land cover iii. Land use
Population	Settlement characteristics	Resident population
Economy	Sub-regional characteristics	Economic role/integration

According to the UKO Guide, *settlement size* is the leading candidate to be a stand-alone criterion for demarcating urban from rural areas.

Clarke (1972) states that urban populations differ strongly from rural populations in distribution, density, ways of life, structure and growth. Distinction between urban and rural is a “thorny problem for the population geographer”. Urban population is considered in terms of town living, that is to say the concentration of dwellings in a recognisable street pattern, where people live in some social and economic interdependence, enjoying common administrative, cultural and social amenities. But such a definition is too vague for statistical analysis.

Clarke (1972) argues that there are certain inherent difficulties in the urban-rural classification of population.

- Firstly, it is no easy task to draw a line between what is urban and what is rural. There exists a wide range of settlement patterns between the two, especially in advanced countries. There towns are increasingly tentacular and large communities exist in the urban-rural fringe, where urban and rural cultures merge.
- Secondly, towns vary enormously in character and function.
- Thirdly, population data are normally available only for administrative units, whose boundaries may not coincide at all with the limits between town and country.
- Fourthly, there are wide national variations in urban-rural classification, which inhibit international comparisons.

Goodall (1972) gives an economic definition of urban, comprising complex markets, where the spatial extent can be defined. He mentions that it has been customary to define urban in terms of physical characteristics, reflecting the spatial agglomeration of population and activities. Common to such definitions are

- A physical element, which emphasizes the high-density settlement of the continuous built-up area and its separation from other urban centres by a much greater area of thinly settled land
- An occupational element, which recognises the concentration of employment in secondary and tertiary industries

The economic definition of urban comprises complex markets such as labour, land, housing, capital, goods and services, where the spatial extents can be defined. The spatial extents of each market are not necessarily coincident, but they overlap and interlock is such a way as to form an urban economy.

Reif (1973) summarises the basic entities of the urban system in terms of its

- *Objects*: population, goods, vehicles
- *Activities*: residential, working, retail trade, education, production of goods and services, recreation
- *Land*: land in different uses
- *Infrastructure*: Buildings: houses, schools, shops, factories, offices; Transport facilities: roads, railway lines, airports, ports, etc.

The *urban population system* can be broken down into activities such as

- Residential activity
- Industrial activity
- Retail trade (shopping) activity
- Recreational activity, etc.

Each unit of population (person or family) can be additionally classified according to its age, sex, income level, car ownership, etc. The *urban economic system* is built around the entities 'goods and services'.

In the diagram below, Reif (1973) shows that the urban system can be considered structured by several subsystems.

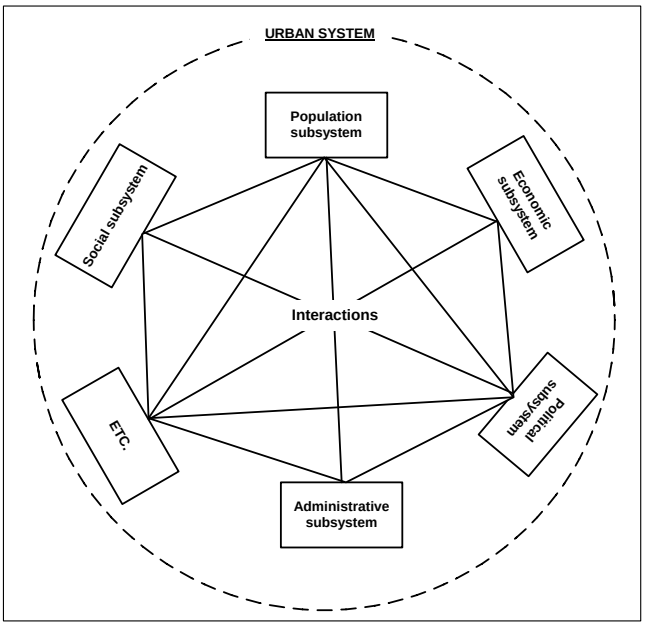


Figure 2.6.1: The urban system can be considered structured by several subsystems (Adapted from Reif 1973)

White (1987) describes *neighbourhoods* and urban society, and states that where people live is also partly determined by the location of jobs and industry, by the technology of transportation and communication, and by the availability (and selection preference for) local public services.

In general, geographers are moving away from the concept of urban and rural. This is due to the difficulty in practically separating the two, due to movement on the ground and the evidence of rural areas within urban areas. Rather, the concept of *regional geography* is being pursued again. According to Hoekveld (1990) “regional geography is about places, which means areas; it is not about objects, which have spatial attributes.” Regional geography refers to classes of areas with common attributes and therefore can be compared to other areas in the same class.

Hoekveld (1990) discusses the new regional realities, which are different from the traditional conceptual frameworks, “relationships between site, national resource bases, and society are mediated by an international economy, a nation state, world-cities, and national city or settlement systems, in addition to wide institutional and communication networks and financing organisations such as banks, pension funds, etc. On the basis of these new regional realities, regional geographers might try to hew new building blocks and assemble a new general conceptual framework to replace the redundant ones.”

2.7 Chapter Summary and Conclusion

In this chapter a literature review is conducted of the statistical techniques to be used in the classifications and definitions for urban and rural, i.e. non-spatial techniques, namely logistic regression, discriminant analysis, classification trees, and spatial techniques, namely Markov random fields, i.e. iterated conditional modes and the Gibbs sampler. The non-spatial statistical techniques will be applied and analysed in Chapter 3. Thereafter, in Chapter 4, the spatial statistical techniques which take advantage of common attributes due to spatial adjacencies, will be applied, hopefully to improve the classifications obtained from the non-spatial techniques.

The chapter also contains a discussion of the geographer’s perspective with respect to urban and rural. From the literature it is evident that the classification and definition of

urban and rural is certainly not straightforward in fact the literature gives an excellent overview of the variety of approaches that are available and can be explored and even combined. The literature does not provide a single classification or definition that can be adapted as the standard, which makes the direct application from the literature difficult. Further, the literature gives little or no indication of variables that can be attributed to urban or rural that could be used in the statistical analysis. United Nations (2006) states that due to "national differences in the characteristics that distinguish urban from rural areas, the distinction between the urban and the rural population is not yet amenable to a single definition …". The diagram by Reif (1973) (Figure 2.6.1) shows that the urban system can be made up by several subsystems namely political, economic, administrative, social and population. This suggests that the classification of urban and rural can take several aspects into consideration, some of which might be difficult to consistently monitor across time. This study only made use of available information from the 2001 Population Census of South Africa to classify areas as urban and rural.

Geographers are moving away from classifying areas into urban and rural, rather towards the concept of regional geography. Despite this, the study is relevant since the concept of urban and rural plays an important role in shaping our society, as it provides fundamental information needed for government allocations and service provision. In the recent 2005 budget speech by the Finance Minister, Mr. Manuel said "*this social intent also embodies our commitment to build a more just, more equal society, in which steady progress is made in reducing the gulfs that divide rich and poor, black and white, men and women,* ***rural and urban***".

In the next two chapters, the above mentioned statistical techniques are applied and analysed with data from census 2001, to classify areas as urban and rural.

CHAPTER 3 - *Non-Spatial Data Application and Results*

3.1 Introduction

In this chapter selected non-spatial statistical techniques are applied to selected 2001 population census data, to obtain estimates of the urban and rural population for each province and the country as a whole, by classifying areas (enumeration areas) as urban or rural. This chapter gives a detailed description of the non-spatial statistical techniques applied, namely linear logistic regression, classification trees and discriminant analysis.

In this chapter the non-spatial statistical application methodology is explained. It makes use of areas in the country that are known to be urban and rural. Due to the importance of using such areas (with known urban and rural status) in the study, the requirements and compilation of these areas are explained. The selection of 2001 population census data and the rationale for choosing these are also discussed. The results from the data applications are presented.

3.2 Methodology

3.2.1 Rationale for utilising areas of known urban and rural status in the study

An important aspect of the methodology is the use of areas in the country where the classification of urban and rural is known with certainty. For example, large cities such as Johannesburg, Cape Town and other clusters of built-up areas in the country, are known to be urban, whilst farms or areas falling under the jurisdiction of traditional authorities, are generally known to be rural and even as *deep-rural* in South Africa. The rationale behind this was to firstly identify essential patterns or predominant characteristics from areas that are known to be urban and rural, and thereafter apply (or score) areas that are not known (or ambiguous) with similar characteristics, in order to classify them as either urban or rural.

3.2.2 Description of the two sample data sets of known urban and rural status

Two different sample data sets were generated. The application of the statistical techniques and the analyses were performed utilising both sample data sets. In order to systematically identify areas where the classifications of urban and rural are known, the EA-types as defined for the 2001 population census of South Africa, were used.

EA-types are classifications of the country based on both settlement patterns and legal proclamations. There are ten categories of EA-types across the country, i.e. vacant, tribal settlement, farm, small-holding, urban settlement, informal settlement, recreational area, industrial area, institution and hostel. Each of the 80 000 odd enumeration areas was assigned with a unique EA-type for the 2001 population census. (See Appendix A.)

The first sample data set comprises all areas in the country, where the EA-type is *urban settlement*, labelled as known urban areas, and all areas in the country where the EA-type is purely *farm,* labelled as known rural areas.

The second sample data set included the above two types of areas, but in addition all areas within the country falling under the jurisdiction of traditional authorities, known as *tribal* areas, were also included, and labelled as known rural areas.

For both sample data sets, note that no subsampling was done within the selected EA-types, that is, all areas within the selected EA-types were utilised.

The main reason for utilising two sample data sets was that in the first data set a common geographical definition of rural, indicative from the research conducted in Chapter 2, i.e. *farm,* was strictly applied. *Tribal* areas (and other unknown areas) were later scored with the characteristics obtained from the sample. Utilising this sample data set to score the unknown areas, especially the *tribal* areas in the country, gives us the opportunity to determine their classification statistically. The second sample reflects South Africa more realistically, where *tribal* areas are considered as rural, mainly due to the lack of services as a result of their previous exclusion from serviced areas.

The results obtained from the two sample data sets are very different and gives rise to an interesting analysis.

For ease of writing, the first sample data set will be referred to as *urban-farm* or *sample 1* and the second as *urban-farm-tribal* or *sample 2*.

To clarify the definitions of urban and rural used in the following sections and forthcoming chapters, the definitions are repeated below:

- *urban-farm* or *sample 1* comprises the urban settlement (as urban) and farm (as rural) EA-types.
- *urban-farm-tribal* or *sample 2,* similar to urban-farm or sample 1, in addition consists of the tribal (as rural) EA-type.
- In addition to the above two definitions, some tables in the following sections will make use of the urban-rural population figures as published for the censuses (i.e. 2001 and 1996).
    - For census 2001, urban-rural figures are aggregations of geography-types (different from EA-types). During the EA demarcation phase of census 2001 each EA was assigned a unique geography-type. There are four geography-types for the country, i.e. urban-formal, urban-informal, tribal and farm. The urban-rural definition used for the census classified urban-formal and urban-informal as urban and tribal and farm as rural. (See Appendix A for a more detailed classification of urban-rural for census 2001.)
    - For census 1996, urban-rural figures were aggregations of EA-types (as defined for census 1996, different to those used in census 2001), comprising three categories, namely urban, semi-urban and rural. In 1996, rural and semi-urban comprised rural and was known as non-urban. (See Appendix A for a more detailed classification of urban-rural for census 1996.)

3.2.3 Selecting Census 2001 variables

The census endeavoured to enumerate every person present in South Africa on census night, 9-10 October 2001. The census data covers both *household* and *person* information, i.e. information about the household and each person present in the household on census night, as well as about services available to the household.

The study made use of selected household and person census information, with a *person* weighting for person as well as for the household data, i.e. the number of persons related to that household's information, e.g. the number of persons with access to piped water in the household. Variables were selected on the basis that they have some relevance to the subject matter, i.e. urban and rural. Since the literature review did not explicitly reveal variables that classify urban and rural, in this study we are essentially searching for variables that could classify or indicate urban and rural. When in doubt or uncertain about a variable it was added to the process, thus over 100 census variables were selected and applied to all provinces, and to South Africa as a whole by EA. The use of certain census variables is limiting, as they are relatively unstable and as such might be difficult to monitor across time, thus their inclusion in the analysis might be a weakness in the study. These include variables such as *employment status*, *level of education* and *work status*. Changes in these variables could render a rural EA urban (and vice versa). Nevertheless the study is limited to exploring the relevance of census variables for classifying urban and rural and forms the framework for the analysis.

The following categories of *person* data were selected:

- Language
- Employment status
- Work status
- Total births
- Level of education

The following categories of *household* data were selected:

- Household size (the number of persons in a household)
- Type of housing unit (the type of dwelling, e.g. house or brick structure, traditional dwelling, etc.)
- Rooms (number of rooms that the household utilises)
- Access to water (type of access to water the household has, e.g. piped water)
- Toilet facilities (main type of toilet facilities, e.g. flush toilet)
- Energy source for cooking (type of energy/fuel the household mainly uses for cooking, e.g. electricity)
- Gender of head of household

- Population group of head of household
- Occupation of head of household
- Annual household income

3.2.4 Process Followed

3.2.4.1 Study conducted for each province

Due to the different socio-economic characteristics and varying settlement patterns of each province in South Africa, the study was conducted separately for each province as well as for South Africa as a whole. Two sample data sets, described above, were drawn for each province as well as for the country as a whole (details given in Table 3.2.1) and each statistical technique was performed for each province and for South Africa, separately.

3.2.4.2 Partitioning the data set of known areas into training and validation data sets

Since the methodology required that part of the sample data (that is urban and rural areas that are known) be used to estimate the model and part be used to test the fitted model, each sample data set for each province and for South Africa as a whole was partitioned, using random sampling, into two independent data sets, i.e. the *training* and the *validation* data sets. Each data set contained more or less 50% of the sample data sets. The training data set was used to estimate the model and the validation data set was used to test the fitted model by analysing the confusion matrix and assessing the misclassification rate. According to Fernandez (2003) the training data provides the predictive model with a chance to identify essential patterns that are specific to the entire database. After training, the fitted model must be validated with data independent of the training set to provide a way to measure the ability of the model to distinguish between urban and rural areas. Unknown areas were thereafter scored with the predictive model to classify them as either urban or rural. Section 3.3.4 shows the confusion matrix for each statistical technique applied.

SAS Enterprise Miner was used to partition the data sets as well as to perform the analyses. The same data sets, i.e. training and validation, were used to apply linear logistic regression, classification trees and discriminant analysis.

3.2.4.3 Applying linear logistic regression

Stepwise linear logistic regression was applied to the training data set to select variables to include in the model and to obtain the estimates. The validation data set was used to test the fitted model. Table 3.3.4 (a) shows the confusion matrix. The model obtained from the training data set was applied to the unknown areas in order to classify the unknowns as urban or rural. The results were weighted, as described in section 3.2.5.1.

3.2.4.4 Applying classification trees

Classification trees were applied to the training data set and the validation data set was used for testing. Table 3.3.4 (b) shows the confusion matrix. Final nodes were weighted as described in section 3.2.5.2. The model was applied to the unknown areas.

3.2.4.5 Applying discriminant analysis

Significant variables were selected using stepwise discrimination. These variables were used to obtain the linear discriminant functions for urban and rural. The validation data set was used to test the model. Table 3.3.4 (c) shows the confusion matrix. The results were weighted as described in section 3.2.5.3 and applied to the data set of unknown areas.

3.2.5 Weighting the data with prior information

Adjustments based on the 2001 population census classifications of EAs into urban and rural areas were applied. Table 3.2.1 shows the sample sizes (i.e. units in terms of EAs, not persons) for both samples and the total population, broken down by urban and rural. The methodology applied for adjusting the predictions for linear logistic regression, classification trees and discriminant analysis is briefly explained below.

3.2.5.1 Weighting the data with prior information for logistic regression

Adjusting the predictions from a linear logistic model, to correct for sampling that is non-representative of the population:

$$y = \hat{\beta}' x + \ln\left(\frac{Q}{1-Q}\right) - \ln\left(\frac{P}{1-P}\right)$$

where Q is the proportion of the **population** in Group 1 (urban), P is the proportion of the **sample** in Group 1 (urban), x is the significant census variable and $\hat{\beta}$ is the derived estimate.

Thereafter the classification rule,

if $y \geq 0$ then classify the EA in Group 1 (urban), if $y < 0$ then classify the EA as rural, was applied.

3.2.5.2 Weighting the data with prior information for classification trees

All final nodes in the tree were converted to either urban or rural by correcting them with the population proportion. Urban totals for all final nodes in the tree were multiplied by the factor Q/P where Q is the urban proportion of the **population** and P is the urban proportion of the **sample**. Similarly, the rural totals for all final nodes were multiplied by the factor $(1-Q)/(1-P)$ where $1-Q$ is the rural proportion of the **population** and $1-P$ is the rural proportion of the **sample**.

3.2.5.3 Weighting the data with prior information for linear discriminant analysis

The following classification rule was used:

If $LDF_1(x) - LDF_2(x) \geq \log\left(\frac{Q}{1-Q}\right)$ then classify the EA in Group 1 (urban),

if $LDF_1(x) - LDF_2(x) < \log\left(\frac{Q}{1-Q}\right)$ then classify the EA in Group 2 (rural),

where Q is the prior probability of Group 1 (urban) and $1-Q$ is the prior for Group 2 (rural) in the population.

Table 3.2.1 Sample and population sizes used for each province and for South Africa as a whole (Units are EAs.)

		Sample 1		Sample 2		Population*	
		(Urban-Farm)	%	(Urban-Farm-Tribal)	%	(2001 Census)	%
W. Cape	Rural	707	12	707	12	810	11
	Urban	5265	88	5265	88	6291	89
	Total	5972	100	5972	100	7101	100
E. Cape	Rural	582	16	10284	78	14208	77
	Urban	2968	84	2968	22	4162	23
	Total	3550	100	13252	100	18370	100
N. Cape	Rural	374	28	395	30	406	27
	Urban	941	72	941	70	1103	73
	Total	1315	100	1336	100	1509	100
F. State	Rural	828	22	1415	32	1486	29
	Urban	2991	78	2991	68	3697	71
	Total	3819	100	4406	100	5183	100
KZN	Rural	800	17	6445	62	6834	54
	Urban	3957	83	3957	38	5919	46
	Total	4757	100	10402	100	12753	100
N. West	Rural	614	27	3797	69	4318	67
	Urban	1680	73	1680	31	2159	33
	Total	2294	100	5477	100	6477	100
Gauteng	Rural	257	3	257	3	356	3
	Urban	9424	97	9424	97	12846	97
	Total	9681	100	9681	100	13202	100
MP	Rural	724	29	3096	64	3336	58
	Urban	1749	71	1749	36	2392	42
	Total	2473	100	4845	100	5728	100
Limpopo	Rural	451	37	8753	92	9481	91
	Urban	761	63	761	8	984	9
	Total	1212	100	9514	100	10465	100
S. Africa	Rural	5337	15	35149	54	41235	51
(Sum-Parts)	Urban	29736	85	29736	46	39553	49
	Total	35073	100	64885	100	80788	100
S.Africa	Rural	5337	15	35149	54	41235	51
(as a whole)	Urban	29736	85	29736	46	39552	49
	Total	35073	100	64885	100	80787	100

* The population sizes (units in terms of EAs) used here make use of geography-types as defined during Census 2001. (See section 3.2.2 and Appendix A for definitions.)

Table 3.2.1 shows the number of EAs in each sample as well as the total number of EAs for Census 2001. The difference between Sample 1 and Sample 2 is the inclusion of the tribal communities in Sample 2. This difference is evident for provinces such as the Eastern Cape, the Free State, KwaZulu-Natal, North West, Mpumalanga and Limpopo, whilst provinces such as the Western Cape and Gauteng have similar sample sizes since they do not have tribal areas.

3.3 Results

The results obtained from linear logistic regression, classification trees and discriminant analysis are presented below. Thereafter overall results are discussed in terms of the aggregated population for the classifications of urban and rural as derived by means of each statistical technique. The best classifications were selected for the map analyses.

3.3.1 Results from linear logistic regression

The estimated logistic regression model for estimating the log (odds of urban) for each province and South Africa as a whole, for both samples, is given in detail in Appendix B. Regression parameter estimates were selected using a stepwise procedure with 5% inclusion probability. Tables 3.3.1 (a) and (b) show a summary of some significant variables occurring amongst the provinces and South Africa. In the case where the variable increases the odds of urban, 1 denotes it and in the case where the variable decreases the odds of urban, 0 denotes it. The confusion matrix is given in section 3.3.4.

Generally, examining the results from linear logistic regression, for sample 1, important variables such as *population density*, *unemployed persons, flush toilets connected to sewer system, number of children ever born i.e. 0-5, and white headed households,* increase the odds of urban, whilst *persons with no schooling*, *households using wood as the main source of energy for cooking*, *head of household occupation is skilled agricultural and fishery workers,* increase the odds of rural.

Generally, for sample 2 important variables such as *population density*, *unemployed persons*, *flush toilet connected to sewer system*, *number of children ever born i.e. 0-5,* and *persons who have completed primary schooling*, increase the odds of urban, whilst *persons with no schooling*, *persons living in traditional/hut structures, households using wood as the main source of energy for cooking*, *head of household occupation is*

skilled agricultural and fishery workers, persons whose employment status is homemaker or housewife, larger household sizes i.e. 10 persons and more, *households with no annual income, Black African headed households* and *households with chemical toilets or pit latrines*, increase the odds of rural.

Comparing sample 1 and sample 2, common variables are *population density*, *unemployed persons*, *households with flush toilets connected to sewer system*, *smaller number of children ever born i.e. 0-5*, that increase the odds of urban, whilst *persons with no schooling, households that use wood as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers,* increase the odds of rural.

Comparing sample 1 and sample 2 for variables that are not common between both, sample 1 contains a variable such as *White headed households,* which increases the odds of urban, whilst sample 2 contains a variable such as *persons with complete primary schooling*, which increases the odds of urban. In addition, sample 2 contains variables such *as persons whose employment status is homemaker/ housewife, larger household size i.e. 10+ persons, households with no annual income, households using chemical toilets or pit latrines (with or without) ventilation*, *persons living in traditional/hut structures* and *Black African head of household,* which all increase the odds of rural.

Therefore we can assume that since urban settlements and farms are common EA-types in both samples, that variables such as *population density*, *unemployed persons*, *households with flush toilets connected to sewer system*, *smaller number of children ever born i.e. 0-5, White headed households and persons with complete primary schooling,* separate urban settlements from rural, whilst *persons with no schooling, households that use wood as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers* separate farm (rural) settlements. An even further assumption can be made that tribal settlements, which are only contained in sample 2, can be separated from urban and farm (rural) settlements by variables such as *persons whose employment status is homemaker/housewife, larger household sizes i.e. 10+ persons, households with no annual income, households using chemical toilets or pit latrines (with or without ventilation)*, *persons living in traditional/hut structures* and *Black African head of household.*

Table 3.3.1 (a) Summary of significant variables obtained for linear logistic regression for the Western Cape, Eastern Cape, Northern Cape, Free State and KwaZulu-Natal

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Person											
X_1	Population density	1	1		1	1	1	1	1	1	1
Employment Status	*(Employment status of each person)*										
X_{13}	Employed	0	0								
X_{14}	Unemployed										1
X_{16}	Home-maker or housewife										0
Total Births	*(Total children ever born)*										
X_{27}	0-5 children						1			1	
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling	0	0			0				0	
X_{32}	Complete primary								1		1
Household											
Household Size	*(Total number of persons in a household)*										
X_{37}	6-10 persons				0						
X_{38}	More than 10 persons								0		
Housing Unit	*(Type of living quarters)*										
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials								0		
X_{44}	Informal dwelling/ shack, in backyard	1	1		1						0
Access to Water	*(Type of access to water)*										
X_{62}	Water vendor					1					
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)	1	1	1	1						1
X_{65}	Chemical toilet				0						
X_{67}	Pit latrine without ventilation				0						
Energy source	*(Type of energy/fuel mainly used for cooking)*										
X_{73}	Wood			0				0		0	

	W. Cape		E. Cape		N. Cape		F. State		KZN	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Gender of Head of Household										
X_{78} Female			1							0
Population Group of Head of Household										
X_{82} White	1	1							1	
Occupation of Head of Household										
X_{88} Skilled agricultural and fishery workers						0				
Annual Household Income										
X_{93} No income						0				
X_{94} R 1 - R 4 800	1	1								

"1" denotes increasing the odds of urban; "0" denotes decreasing the odds of urban

Table 3.3.1 (b) Summary of significant variables obtained for linear logistic regression for North West, Gauteng, Mpumalanga, Limpopo and South Africa as a whole

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	Person										
X_1	Population density		1	1	1	1	1	1	1	1	1
Employment Status	*(Employment status of each person)*										
X_{13}	Employed					1		1			
X_{14}	Unemployed									1	1
X_{16}	Home-maker or housewife						0				
X_{17}	Pensioner or retired person									1	1
Work Status	*(Main activity or work status of person)*										
X_{24}	Self-employed									1	
Total Births	*(Total children ever born)*										
X_{27}	0-5 children	1				1	1				1
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling									0	
	Household										
Household Size	*(Total number of persons in a household)*										
X_{37}	6-10 persons									0	
X_{38}	More than 10 persons						0				0
Housing Unit	*(Type of living quarters)*										
X_{39}	House or brick structure on a separate stand or yard									0	
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials									0	
X_{44}	Informal dwelling/ shack, in backyard						1				
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter								1		1
X_{47}	Caravan or tent			1	1						
Access to Water	*(Type of access to water)*										
X_{53}	Piped water (tap) inside dwelling									1	1

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{54}	Piped water (tap) inside yard									1	1
X_{57}	Borehole					0					
X_{60}	Dam/ pool/ stagnant water					0					
X_{62}	Water vendor								1		0
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)		1	1	1				1		1
X_{64}	Flush toilet (with septic tank)								1		1
X_{66}	Pit latrine with ventilation (VIP)		0								
X_{67}	Pit latrine without ventilation										0
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{70}	Electricity		1								
X_{72}	Paraffin						0				
X_{73}	Wood	0		0	0	0	0	0	0		0
X_{74}	Coal								0		
Population Group of Head of Household											
X_{79}	Black African								0		
Occupation of Head of Household											
X_{83}	Legislators, senior officials and managers			1	1						
X_{88}	Skilled agricultural and fishery workers			0	0						
X_{91}	Elementary occupations	0									

"1" denotes increasing the odds of urban; "0" denotes decreasing the odds of urban

3.3.2 Results from classification trees

Tree diagrams, showing the main variables and how they split, for each province and South Africa, for both samples, are presented in Appendix C. Tables 3.3.2 (a) and (b) analyse the significant variables occurring for each province and South Africa for each sample. The confusion matrix is given in section 3.3.4.

For sample 1 common variables amongst provinces that appear in the tree are *population density*, *households with flush toilets connected to sewer system*,

households that use wood as the main source of energy for cooking, *skilled agricultural or fishery or elementary workers*, *persons with some primary schooling*.

For sample 2 common variables amongst provinces that appear in the tree are *population density*, *households with flush toilets connected to sewer system*, *households that use wood as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers*, *persons with no schooling*, *persons whose main language at home is Xitsonga*, *households using flush toilets with septic tanks, chemical toilets, pit latrines (with or without ventilation) or bucket latrines*.

Comparing sample 1 and sample 2, common variables between them are *population density*, *households with flush toilets connected to sewer system*, *households that use wood as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers*.

In addition, comparing sample 1 and sample 2 for variables that are not common between them, sample 1 contains variables such as *persons with some primary schooling.* Sample 2 contains variables such as *persons with no schooling*, *persons whose main language at home is Xitsonga*, *households using flush toilets with septic tanks, chemical toilets, pit latrines (with or without ventilation) or bucket latrines*.

Therefore we can assume, since urban settlements and farms are common EA-types in both samples, that *population density*, *households with flush toilets connected to sewer system, households that use wood as the main source of energy for cooking, skilled agricultural or fishery or elementary workers*, and *persons with some primary schooling,* separate the urban and farm settlements. An even further assumption can be made that tribal settlements, which are only contained in sample 2 can be separated by variables such as *persons with no schooling*, *persons whose main language at home is Xitsonga*, *households using flush toilets with septic tanks, chemical toilets, pit latrines (with or without ventilation) or bucket latrines.*

Table 3.3.2 (a) Summary of significant variables occurring in classification trees for the Western Cape, Eastern Cape, Northern Cape, Free State and KwaZulu-Natal

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	Person										
X_1	Population density	√	√	√	√	√	√	√	√	√	√
Language	*(Language most often spoken at home)*										
X_9	Setswana						√				
Employment Status	*(Employment status of each person)*										
X_{14}	Unemployed	√	√								
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling		√								
X_{31}	Some primary	√		√							
X_{34}	Grade 12/ Std 10		√								
	Household										
Household Size	*(Total number of persons in a household)*										
X_{36}	1-5 persons										√
Rooms	*(Number of rooms that the household utilises)*										
X_{49}	1-3 rooms								√		
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)			√	√						√
X_{64}	Flush toilet (with septic tank)				√						
X_{65}	Chemical toilet								√		
X_{67}	Pit latrine without ventilation								√		
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{73}	Wood				√	√		√		√	√
Gender of Head of Household											
X_{77}	Male								√		
Population Group of Head of Household											
X_{82}	White										√

	W. Cape		E. Cape		N. Cape		F. State		KZN	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Occupation of Head of Household										
X_{88} Skilled agricultural and fishery workers	√	√							√	
X_{91} Elementary occupations	√	√								

Table 3.3.2 (b) Summary of significant variables occurring in classification trees for North West, Gauteng, Mpumalanga, Limpopo and South Africa

	N. West		Gauteng		MP		Limpopo		S. Africa	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Person										
X_1 Population Density	√	√	√	√	√	√	√	√	√	√
Language (Language most often spoken at home)										
X_2 Afrikaans						√				
X_{12} Xitsonga								√		√
Level of Education (Highest level of education the person completed)										
X_{30} No schooling										√
Household										
Housing Unit (Type of living quarters)										
X_{45} Informal dwelling/ shack, not in backyard, informal/ squatter						√				
Access to Water (Type of access to water)										
X_{56} Piped water on community stand: > 200 metres			√	√						
Toilet facilities (Main type of toilet facilities)										
X_{63} Flush toilet (connected to sewerage system)		√				√		√		√
X_{64} Flush toilet (with septic tank)								√		
X_{68} Bucket latrine		√								
Energy source for cooking (Type of energy/ fuel mainly used for cooking)										
X_{73} Wood						√				√
Occupation of Head of Household										
X_{88} Skilled agricultural and fishery workers			√	√			√			

	N. West		Gauteng		MP		Limpopo		S. Africa	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{91} Elementary occupations					√					

3.3.3 Results from discriminant analysis

Stepwise discriminant analysis was used to select the most significant variables (at the 5% level of significance). Appendix D contains the detailed results, i.e. coefficients of the linear discriminant functions for urban and rural, for each province and for South Africa as a whole. Tables 3.3.3 (a) and (b) show the difference between the coefficients of the urban and rural linear discriminate functions. In the case where the difference is positive, it is denoted by 1, that is the variable increases the odds of urban. In the case where the difference is negative, it is denoted by 0, that is the variable increases the odds of rural. The confusion matrix is given in section 3.3.4.

Generally, examining the results from discriminant analysis, for sample 1, important variables such as *population density*, *unemployed persons*, *number of children ever born i.e. 0-5, persons living in informal dwellings in informal/squatter area*, *households with flush toilets connected to sewer system*, *households using bucket latrines and female headed households,* increase the odds of urban, whilst *households accessing water from rainwater tanks or from rivers/streams, households that use wood or paraffin as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers*, increase the odds of rural.

Generally, for sample 2 important variables such as *population density*, *unemployed persons*, *persons living in informal dwellings in informal/squatter area*, *households with flush toilets connected to sewer system and households using bucket latrines,* increase the odds of urban, whilst *households that use wood or paraffin as the main source of energy for cooking*, *skilled agricultural or fishery or elementary workers*, *persons with no schooling or some primary schooling*, and *Black African head of households,* increase the odds of rural.

Comparing sample 1 and sample 2 common variables are *population density*, *unemployed persons*, *persons living in informal dwellings in informal/squatter area*, *households with flush toilets connected to sewer system*, and *households using bucket latrines*, increase the odds of urban, whilst *households that use wood or paraffin as the*

main source of energy for cooking and *skilled agricultural or fishery or elementary workers*, increase the odds of rural.

In addition, comparing sample 1 and sample 2 for variables that are not common to both, sample 1 contains the variable *female head of households*, which increases the odds of urban. Sample 1 contains the variable *households with main source of water from rainwater tanks or rivers/streams*, which increases the odds of rural, whilst sample 2 contains variables such as *persons with no schooling or some primary schooling*, and *Black African head of household*, which increase the odds of rural.

Therefore we can assume, since urban settlements and farms are common EA-types in both samples, that *population density*, *unemployed persons*, *smaller number of children ever born i.e. 0-5, persons living in informal dwellings in informal/squatter area*, *households with flush toilets connected to sewer system, households using bucket latrines* and *female headed households,* separate urban settlements from rural, whilst *households that use wood or paraffin as the main source of energy for cooking* and *skilled agricultural or fishery or elementary workers*, separate the farm (rural) settlements. An even further assumption can be made that tribal settlements, which are only contained in sample 2, can be separated from urban and farm (rural) settlements by variables such as *persons with no schooling or some primary schooling*, *households accessing water from rainwater tanks or rivers/streams*, and *Black African head of household.*

Table 3.3.3 (a) Summary of significant variables obtained for linear discriminant analysis for the Western Cape, Eastern Cape, Northern Cape, Free State and KwaZulu-Natal

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	Person										
X_1	Population density				1	1	1	1	1		1
Language	*(Language most often spoken at home)*										
X_2	Afrikaans						1				
X_3	English						1				
X_9	Setswana								1		
Employment Status	*(Employment status of each person)*										
X_{13}	Employed	0	0								
X_{14}	Unemployed	1	1			1					1
X_{15}	Scholar or student							1			
Work Status	*(Main activity or work status of person)*										
X_{22}	Paid employee									0	
Total Births	*(Total children ever born)*										
X_{27}	0-5 children					1	1			1	
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling								0	0	0
X_{31}	Some primary	0	0								0
X_{33}	Some secondary							1			
	Household										
Household Size	*(Total number of persons in a household)*										
X_{36}	1-5 persons							1			
Housing Unit	*(Type of living quarters)*										
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials									0	
X_{41}	Flat in a block of flats										0
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter	1	1		1	1			1		1
X_{47}	Caravan or tent						0				
Access to Water	*(Type of access to water)*										
X_{53}	Piped water (tap) inside dwelling				1						
X_{54}	Piped water (tap) inside yard				1						
X_{57}	Borehole									0	
X_{59}	Rainwater tank			0		0					
X_{60}	Dam/ pool/ stagnant water			0							

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{61}	River/ stream						0			0	
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)	1	1	1	1						1
X_{64}	Flush toilet (with septic tank)	1	1								1
X_{65}	Chemical toilet								0		
X_{66}	Pit latrine with ventilation (VIP)								0		
X_{67}	Pit latrine without ventilation								0		
X_{68}	Bucket latrine			1	1	0			0		
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{70}	Electricity									1	1
X_{72}	Paraffin							1			
X_{73}	Wood			0	0	0	0	0	0	0	
X_{75}	Animal dung							0	0		
Gender of Head of Household											
X_{77}	Male			1							
X_{78}	Female	1	1	1							
Population Group of Head of Household											
X_{79}	Black African						1				
Occupation of Head of Household											
X_{88}	Skilled agricultural and fishery workers	0	0	0	0	0	0	0		0	0
X_{89}	Craft and related trades workers	1	1								
X_{90}	Plant and machine operators and assemblers				0			0			
X_{91}	Elementary occupations	0	0	0		0	0	0		0	
Annual Household Income											
X_{94}	R 1 - R 4 800			1							

"1" denotes increasing the odds of urban; "0" denotes decreasing the odds of urban

Table 3.3.3 (b) Summary of significant variables obtained for linear discriminant analysis for North West, Gauteng, Mpumalanga, Limpopo and South Africa

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Person											
X_1	Population density	1	0			1	1		1		
Language	*(Language most often spoken at home)*										
X_2	Afrikaans							1	1		
X_3	English								1		
X_4	IsiNdebele			1	1				1		
X_6	IsiZulu						1				
X_{12}	Xitsonga								0		
Employment Status	*(Employment status of each person)*										
X_{14}	Unemployed							1			
X_{21}	Could not find work							1			
Work Status	*(Main activity or work status of person)*										
X_{22}	Paid employee						0				
X_{24}	Self-employed			1	1						
Total Births	*(Total children ever born)*										
X_{27}	0-5 children					1					
Household											
Household Size	*(Total number of persons in a household)*										
X_{37}	6-10 persons							1			
Housing Unit	*(Type of living quarters)*										
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials					0				1	
X_{44}	Informal dwelling/ shack, in backyard		1								1
X_{45}	Informal dwelling/		1	1	1		1			1	1

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	shack, not in backyard, informal/ squatter										
Rooms	*(Number of rooms that the household utilises)*										
X_{50}	4-6 rooms		1								
Access to Water	*(Type of access to water)*										
X_{57}	Borehole			0	0	0					
X_{61}	River/ stream					0				0	
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)	1	1	1	1		1		1	0	1
X_{64}	Flush toilet (with septic tank)		1	0	0			0			1
X_{66}	Pit latrine with ventilation (VIP)	1									
X_{67}	Pit latrine without ventilation		0								0
X_{68}	Bucket latrine	1	1				1	0		1	1
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{70}	Electricity	0									
X_{72}	Paraffin						0		1	0	0
X_{73}	Wood			0	0	0	0	0			
X_{75}	Animal dung	0									0
Gender of Head of Household											
X_{78}	Female							1		1	
Population Group of Head of Household											
X_{79}	Black African		0				0		0		

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Occupation of Head of Household											
X_{86}	Clerks								1		
X_{88}	Skilled agricultural and fishery workers			0	0	0	0	0	0	0	0
X_{89}	Craft and related trades workers	0									
X_{90}	Plant and machine operators and assemblers	0				0				0	
X_{91}	Elementary occupations	0	0	0	0	0				0	0
X_{92}	Occupations unspecified or not elsewhere classified	0									
Annual Household Income											
X_{93}	No income			1	1						
X_{99}	R 76 801 - R 153 600					1		1			

"1" denotes increasing the odds of urban; "0" denotes decreasing the odds of urban

3.3.4 Confusion matrices

Table 3.3.4 (a) is the confusion matrix for linear logistic regression for both samples, for the validation data sets only, for each province and for South Africa as a whole. Noticeable misclassifications, i.e. over 10%, where rural EAs (farms) have been wrongly classified as urban (urban settlements), for sample 1 occur for Gauteng, Eastern Cape, North West and Mpumalanga, whilst for sample 2, these only occur for Gauteng. Misclassifications over 10%, where urban EAs (urban settlements) have been wrongly classified as rural (farm or tribal settlements) for sample 2 occur for Limpopo and Mpumalanga.

Table 3.3.4 (a) Confusion matrix for linear logistic regression

	Sample 1					Sample 2				
	1		0		Total	1		0		Total
Western Cape										
1	2631	99%	21	1%	2652	2627	99%	22	1%	2649
0	21	6%	313	94%	334	23	7%	314	93%	337
Total	2652		334		2986	2650		336		2986
Eastern Cape										
1	1445	98%	27	2%	1472	1274	95%	70	5%	1344
0	50	17%	253	83%	303	44	1%	5238	99%	5282
Total	1495		280		1775	1318		5308		6626
Northern Cape										
1	464	97%	12	3%	476	465	96%	18	4%	483
0	11	6%	170	94%	181	11	6%	174	94%	185
Total	475		182		657	476		192		668
Free State										
1	1482	99%	9	1%	1491	1508	98%	29	2%	1537
0	18	4%	400	96%	418	30	5%	636	95%	666
Total	1500		409		1909	1538		665		2203
KwaZulu-Natal										
1	1971	99%	15	1%	1986	1849	95%	93	5%	1942
0	31	8%	361	92%	392	55	2%	3204	98%	3259
Total	2002		376		2378	1904		3297		5201
North West										
1	808	98%	20	2%	828	812	94%	50	6%	862
0	42	13%	277	87%	319	42	2%	1834	98%	1876
Total	850		297		1147	854		1884		2738
Gauteng										
1	4708	100%	15	0%	4723	4708	100%	15	0%	4723
0	25	21%	92	79%	117	25	21%	92	79%	117
Total	4733		107		4840	4733		107		4840
Mpumalanga										
1	867	97%	28	3%	895	741	88%	99	12%	840
0	37	11%	304	89%	341	71	4%	1511	96%	1582
Total	904		332		1236	812		1610		2422
Limpopo										
1	373	95%	19	5%	392	284	76%	88	24%	372
0	2	1%	212	99%	214	68	2%	4317	98%	4385
Total	375		231		606	352		4405		4757
RSA										
1	14836	99%	108	1%	14944	14318	96%	623	4%	14941
0	225	9%	2367	91%	2592	397	2%	17104	98%	17501
Total	15061		2475		17536	14715		17727		32442

"1" = urban and "0" = rural

Table 3.3.4 (b) is the confusion matrix for classification trees for both samples, for the validation data sets only, for each province and for South Africa as a whole. Noticeable misclassifications, i.e. over 10%, where rural EAs (farms) have been wrongly classified as urban (urban settlements), for sample 1 occur for Gauteng, RSA and Western Cape, whilst for sample 2, they occur only for Gauteng. Misclassifications over 10%, where urban EAs (urban settlements) have been wrongly classified as rural (farm or tribal settlements), for sample 2 occur for Limpopo and Mpumalanga.

Table 3.3.4 (b) Confusion matrix for classification trees

	Sample 1					Sample 2				
	1		0		Total	1		0		Total
Western Cape										
1	2642	100%	10	0%	2652	2632	99%	17	1%	2649
0	37	11%	297	89%	334	24	7%	313	93%	337
Total	2679		307		2986	2656		330		2986
Eastern Cape										
1	1447	98%	25	2%	1472	1253	93%	91	7%	1344
0	12	4%	291	96%	303	46	1%	5236	99%	5282
Total	1459		316		1775	1299		5327		6626
Northern Cape										
1	468	98%	8	2%	476	450	93%	33	7%	483
0	16	9%	165	91%	181	3	2%	182	98%	185
Total	484		173		657	453		215		668
Free State										
1	1484	100%	7	0%	1491	1488	97%	49	3%	1537
0	16	4%	402	96%	418	32	5%	634	95%	666
Total	1500		409		1909	1520		683		2203
KwaZulu-Natal										
1	1973	99%	13	1%	1986	1832	94%	110	6%	1942
0	41	10%	351	90%	392	60	2%	3199	98%	3259
Total	2014		364		2378	1892		3309		5201
North West										
1	814	98%	14	2%	828	814	94%	48	6%	862
0	9	3%	310	97%	319	26	1%	1850	99%	1876
Total	823		324		1147	840		1898		2738
Gauteng										
1	4712	100%	11	0%	4723	4718	100%	5	0%	4723
0	35	30%	82	70%	117	42	36%	75	64%	117
Total	4747		93		4840	4760		80		4840
Mpumalanga										
1	848	95%	47	5%	895	680	81%	160	19%	840
0	8	2%	333	98%	341	17	1%	1565	99%	1582
Total	856		380		1236	697		1725		2422
Limpopo										
1	371	95%	21	5%	392	293	79%	79	21%	372
0	1	0%	213	100%	214	66	2%	4319	98%	4385
Total	372		234		606	359		4398		4757
RSA										
1	14862	99%	82	1%	14944	13976	94%	965	6%	14941
0	313	12%	2279	88%	2592	425	2%	17076	98%	17501
Total	15175		2361		17536	14401		18041		32442

"1" = urban and "0" = rural

Table 3.3.4 (c) is the confusion matrix for discriminant analysis for both samples, for the validation data sets only, for each province. Noticeable misclassifications, i.e. over 10%, where rural EAs (farms) have been wrongly classified as urban (urban settlements), for sample 1 occur for Gauteng, RSA, KwaZulu-Natal and Mpumalanga, whilst for sample 2, they occur only for Gauteng. Misclassifications over 10%, where urban EAs (urban settlements) have been wrongly classified as rural (farm or tribal settlements), for sample 2 occur for Limpopo and Mpumalanga.

Table 3.3.4 (c) Confusion matrix for discriminant analysis

	Sample 1					Sample 2				
	1		0		Total	1		0		Total
Western Cape										
1	2615	99%	37	1%	2652	2612	99%	37	1%	2649
0	34	10%	300	90%	334	35	10%	302	90%	337
Total	2649		337		2986	2647		339		2986
Eastern Cape										
1	1442	98%	30	2%	1472	1243	92%	101	8%	1344
0	26	9%	277	91%	303	46	1%	5236	99%	5282
Total	1468		307		1775	1289		5337		6626
Northern Cape										
1	463	97%	13	3%	476	469	97%	14	3%	483
0	19	10%	162	90%	181	16	9%	169	91%	185
Total	482		175		657	485		183		668
Free State										
1	1486	100%	5	0%	1491	1476	96%	61	4%	1537
0	29	7%	389	93%	418	40	6%	626	94%	666
Total	1515		394		1909	1516		687		2203
KwaZulu-Natal										
1	1972	99%	14	1%	1986	1812	93%	130	7%	1942
0	45	11%	347	89%	392	62	2%	3197	98%	3259
Total	2017		361		2378	1874		3327		5201
North West										
1	811	98%	17	2%	828	814	94%	48	6%	862
0	22	7%	297	93%	319	32	2%	1844	98%	1876
Total	833		314		1147	846		1892		2738
Gauteng										
1	4715	100%	8	0%	4723	4715	100%	8	0%	4723
0	31	26%	86	74%	117	32	27%	85	73%	117
Total	4746		94		4840	4747		93		4840
Mpumalanga										
1	871	97%	24	3%	895	721	86%	119	14%	840
0	36	11%	305	89%	341	66	4%	1516	96%	1582
Total	907		329		1236	787		1635		2422
Limpopo										
1	369	94%	23	6%	392	309	83%	63	17%	372
0	14	7%	200	93%	214	173	4%	4212	96%	4385
Total	383		223		606	482		4275		4757
RSA										
1	14843	99%	101	1%	14944	14032	94%	909	6%	14941
0	352	14%	2240	86%	2592	537	3%	16964	97%	17501
Total	15195		2341		17536	14569		17873		32442

"1" = urban and "0" = rural

3.3.5 Overall results in terms of aggregated population totals

Tables 3.3.5 (a) and 3.3.5 (b) show the overall results in terms of aggregated urban and rural population per province and for South Africa as a whole, based on the classifications as derived by means of the three statistical techniques discussed in the previous sections, for sample 1 *urban-farm* and sample 2 *urban-farm-tribal*, respectively. Two results were calculated for South Africa 1) by adding the urban and rural population as obtained for each province (sum-parts), and 2) by applying the statistical techniques for South Africa as a whole. For comparison purposes the census 2001 and 1996 figures for urban and rural for each province and for South Africa, as published in the discussion document, *Investigations into appropriate definitions of urban and rural areas for South Africa*, report no. 03-02-20 (2001), are included in the table.

Table 3.3.5 (a) Population classified by urban and rural, per province and for South Africa, as obtained for the three non-spatial statistical techniques, for sample 1, i.e. urban-farm

		Linear Logistic Regression	%	Classi-fication Trees	%	Discrim-inant Analysis	%		Census 2001	%	Census 1996	%
W. Cape	**Rural**	447266	10	438204	10	461325	10		435626	10	418918	11
	Urban	4077053	90	4086115	90	4062994	90		4088709	90	3537956	89
	Total	4524319	100	4524319	100	4524319	100		4524335	100	3956874	100
E. Cape	**Rural**	226942	4	414973	6	2142188	33		3936529	61	3897080	62
	Urban	6209759	96	6021728	94	4294513	67		2500234	39	2405446	38
	Total	6436701	100	6436701	100	6436701	100		6436763	100	6302526	100
N. Cape	**Rural**	147035	18	147134	18	150115	18		142267	17	208694	25
	Urban	675681	82	675582	82	672601	82		680460	83	631627	75
	Total	822716	100	822716	100	822716	100		822727	100	840321	100
F. State	**Rural**	401221	15	396563	15	1006248	37		654660	24	822353	31
	Urban	2305544	85	2310202	85	1700517	63		2052115	76	1811151	69
	Total	2706765	100	2706765	100	2706765	100		2706775	100	2633504	100
KZN	**Rural**	4307050	46	2950704	31	3864930	41		5091375	54	4700589	56
	Urban	5118976	54	6475322	69	5561096	59		4334642	46	3716432	44
	Total	9426026	100	9426026	100	9426026	100		9426017	100	8417021	100
N. West	**Rural**	1203270	33	391706	11	1338751	36		2135581	58	1896267	57
	Urban	2466093	67	3277657	89	2330612	64		1533768	42	1458558	43
	Total	3669363	100	3669363	100	3669363	100		3669349	100	3354825	100
Gauteng	**Rural**	321637	4	220221	2	270820	3		246380	3	221932	3
	Urban	8515498	96	8616914	98	8566315	97		8590798	97	7126491	97
	Total	8837135	100	8837135	100	8837135	100		8837178	100	7348423	100
MP	**Rural**	923972	30	559882	18	932602	30		1834556	59	1690666	60
	Urban	2199038	70	2563128	82	2190408	70		1288434	41	1110046	40
	Total	3123010	100	3123010	100	3123010	100		3122990	100	2800712	100
Limpopo	**Rural**	1104205	21	379662	7	1427330	27		4573183	87	4364169	88
	Urban	4169433	79	4893976	93	3846308	73		700459	13	565199	12
	Total	5273638	100	5273638	100	5273638	100		5273642	100	4929368	100
S. Africa	**Rural**	9082598	20	5899049	13	11594309	26		19050159	43	18220668	45
(Sum-Parts)	**Urban**	35737075	80	38920624	87	33225364	74		25769619	58	22362906	55
	Total	44819673	100	44819673	100	44819673	100		44819778	100	40583574	100
S.Africa	**Rural**	15165764	34	4534509	10	12625836	28					
(All)	**Urban**	29653909	66	40285164	90	32193837	72					
	Total	44819673	100	44819673	100	44819673	100					

It is evident from Table 3.3.5 (a), for some provinces and even for South Africa as a whole that there are large differences between the results obtained from the statistical techniques and the published figures for urban and rural from census 2001 and census 1996. The results obtained from the statistical techniques, especially for provinces such as the Eastern Cape, Limpopo, Mpumalanga, North West and even for South Africa, show an astoundingly greater number of urban dwellers than there are rural dwellers, compared to the two census figures, where these provinces show mainly rural dwellers. Urban and rural populations for the provinces of the Western Cape, Northern Cape and Gauteng remain similar to those of the two censuses. These provinces do not have tribal settlements. Therefore it can be deduced that the differences in population figures for provinces such as the Eastern Cape, Limpopo, Mpumalanga and North West and even for South Africa as a whole, are the result of the classification of many tribal settlements as urban, that is, generally all three statistical techniques have classified the majority of the tribal EAs as urban. (See section 3.3.6 for map analysis.)

Table 3.3.5 (b) Population classified by urban and rural, per province and for South Africa, as obtained for the three non-spatial statistical techniques, for sample 2, i.e. urban-farm-tribal

		Linear logistic regression	%	Classi-fication trees	%	Discrim-inant analysis	%		Census 2001	%	Census 1996	%
W. Cape	Rural	448204	10	437331	10	461325	10		435626	10	418918	11
	Urban	4076115	90	4086988	90	4062994	90		4088709	90	3537956	89
		4524319	100	4524319	100	4524319	100		4524335	100	3956874	100
E. Cape	Rural	4039533	63	4055575	63	4118876	64		3936529	61	3897080	62
	Urban	2397168	37	2381126	37	2317825	36		2500234	39	2405446	38
		6436701	100	6436701	100	6436701	100		6436763	100	6302526	100
N. Cape	Rural	159996	19	154942	19	156871	19		142267	17	208694	25
	Urban	662720	81	667774	81	665845	81		680460	83	631627	75
		822716	100	822716	100	822716	100		822727	100	840321	100
F. State	Rural	673831	25	681059	25	675801	25		654660	24	822353	31
	Urban	2032934	75	2025706	75	2030964	75		2052115	76	1811151	69
		2706765	100	2706765	100	2706765	100		2706775	100	2633504	100
KZN	Rural	5419969	58	5473047	58	5619984	60		5091375	54	4700589	56
	Urban	4006057	42	3952979	42	3806042	40		4334642	46	3716432	44
		9426026	100	9426026	100	9426026	100		9426017	100	8417021	100
N. West	Rural	2290511	62	2309291	63	2299995	63		2135581	58	1896267	57
	Urban	1378852	38	1360072	37	1369368	37		1533768	42	1458558	43
		3669363	100	3669363	100	3669363	100		3669349	100	3354825	100
Gauteng	Rural	321637	4	213793	2	270820	3		246380	3	221932	3
	Urban	8515498	96	8623342	98	8566315	97		8590798	97	7126491	97
		8837135	100	8837135	100	8837135	100		8837178	100	7348423	100
MP	Rural	1887983	60	1923295	62	1918009	61		1834556	59	1690666	60
	Urban	1235027	40	1199715	38	1205001	39		1288434	41	1110046	40
		3123010	100	3123010	100	3123010	100		3122990	100	2800712	100
Limpopo	Rural	4724887	90	4766208	90	4694302	89		4573183	87	4364169	88
	Urban	548751	10	507430	10	579336	11		700459	13	565199	12
		5273638	100	5273638	100	5273638	100		5273642	100	4929368	100
S. Africa	Rural	19966551	45	20014541	45	20215983	45		19050159	43	18220668	45
(Sum-Parts)	Urban	24853122	55	24805132	55	24603690	55		25769619	58	22362906	55
		44819673	100	44819673	100	44819673	100		44819778	100	40583574	100
S.Africa	Rural	19816920	44	20200678	45	20678423	46					
(All)	Urban	25002753	56	24618995	55	24141250	54					
		44819673	100	44819673	100	44819673	100					

Results from table 3.3.5 (b) are very different from those presented in table 3.3.5 (a) but follow a similar trend as the results for the 2001 and 1996 censuses. This is due to the sampling methodology that predefines the classification of tribal settlements as rural, similar to the censuses.

3.3.6 Map analysis

What follows is a map analysis for the Eastern Cape, Free State, KwaZulu-Natal, North West, Mpumalanga, Limpopo and for South Africa based on the statistical technique that results in the best classifications (lowest misclassification rates) for samples 1 and 2. (The Western Cape, Northern Cape and Gauteng are not presented below, since these provinces have similar map analyses for both the samples and the census.) For comparison purposes census 2001 classifications are mapped for each province (see Appendix E).

Urban areas are shown in blue on the maps and rural areas in green.

3.3.6.1 Maps for the Eastern Cape

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *classification trees*. According to classification trees only 6% of the population in the Eastern Cape is classified as rural and 94% as urban, when compared to Census 2001, 61% is classified as rural and 39% as urban, and similarly for Census 1996, 62% as rural and 38% as urban. Map 3.3.6.1 (a) shows that previous township areas such as Ibhayi and Motherwell, Port Elizabeth and East London city and tribal areas such as Makaula, Quakeni, Mhlanga, Imizizi, and others are some of the highest population urban areas in the Eastern Cape. Map 3.3.6.1 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

3.3.6.2 Maps for the Free State

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *linear logistic regression*. According to linear logistic regression 15% of the population in the Free State is classified as rural and 85% as urban, when compared to Census 2001, 24% is classified as rural and 76% as urban, and similarly for Census 1996, 31% as rural and 69% as urban. Map 3.3.6.2 (a) shows that previous township areas such as Mangaung, Botshabelo and Thabong, Bloemfontein city and tribal areas such as Namahadi, Kutlwanong, Monontsha, Bolata, and others are some of the highest population urban areas in the Free State. Map 3.3.6.2 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

3.3.6.3 Maps for KwaZulu-Natal

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *linear logistic regression*. According to linear logistic regression 46% of the population in KwaZulu-Natal is classified as rural and 56% as urban, when compared to Census 2001, 54% is classified as rural and 46% as urban, and similarly for Census 1996, 56% as rural and 44% as urban. Map 3.3.6.3 (a) shows that cities such as Durban, Pietermaritzburg and Pinetown, towns such as Chatsworth, Phoenix, Madadeni and Stanger, previous township areas such as Umlazi, Kwa-Mashu, Inanda, Ntuzuma and Edendale, tribal areas such as Hlubi and Dube, and others are some of the highest populated urban areas in KwaZulu-Natal. Map 3.3.6.3 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

3.3.6.4 Maps for North West

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *classification trees*. According to classification trees, 11% of the population in North West is classified as rural and 89% as urban, when compared to Census 2001, 58% is classified as rural and 42% as urban, and similarly for Census 1996, 57% as rural and 43% as urban. Map 3.3.6.4 (a) shows that parts of towns such as Mabopane, Ga-Rankuwa, Rustenburg, Klerksdorp, Temba, Mmabatho and Potchefstroom, previous township areas such as Jouberton, Kanana, Ikageng, Khuma and Lethlabile, tribal areas such as Bafukeng, Bathlaping Ba Ga Phuduhutswana, Bakgatla Ba Ga Kgafela, Tirisano, Amandebele A Lebelo, Bakgatla Ba Mmakau, Batlharo Ba Lotlhwareand Dube and others are some of the highest population urban areas in North West. Map 3.3.6.4 (b) shows sample 2 where the technique that results in the best classification is *classification trees*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

3.3.6.5 Maps for Mpumalanga

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *classification trees*. According to classification trees, 18% of the population in Mpumalanga is classified as rural and 82% as urban, when compared to Census 2001, 59% is classified as rural and 41% as urban, and similarly for Census 1996, 60% as rural and 40% as urban. Map 3.3.6.5 (a) shows that towns such as Witbank, Middelburg, Matsulu and Kanyamazane, previous township areas such as Embalenhle, KwaGuqa, Mhluzi, Sakhile and Ekangala, tribal areas such as Moretele, Mkobola, Matsamo, Moutse, Msogwaba, KwaMhlanga, Siboshwa and others are some of the highest population urban areas in Mpumalanga. Map 3.3.6.5 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural. The Kruger Park is shown as rural when classification trees is applied to sample 1, and when linear logistic regression is applied to sample 2 although some camps are shown as rural, the larger EAs (in terms of area) are shown as urban, although generally speaking, the effects of the different techniques does not effect the results as much as the sample constitution, in this case, due to the differences in

census variables applied for both techniques, it can lead to anomalous results, in retrospect parks and recreation EAs should not be included in the analysis.

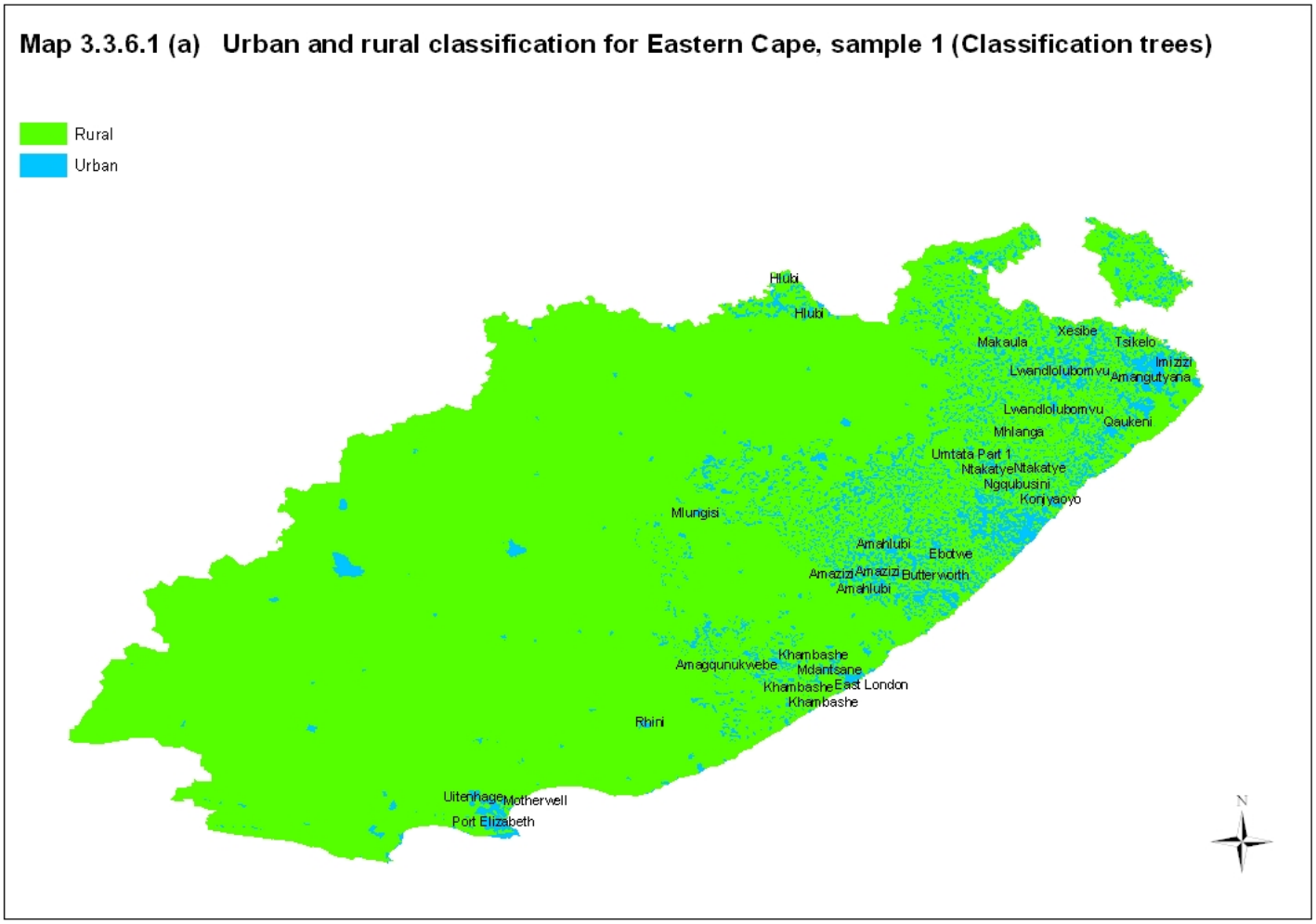
3.3.6.6 Maps for Limpopo

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *linear logistic regression*. According to linear logistic regression, 21% of the population in Limpopo is classified as rural and 79% as urban, when compared to Census 2001, 87% is classified as rural and 13% as urban, and similarly for Census 1996, 88% as rural and 12% as urban. Map 3.3.6.6 (a) shows that parts of the city of Pietersburg, towns such as Mahwelereng, Giyani, Thohoyandou and Lebowakgomo, previous township areas such as Seshego, Belabela, Phagameng, Nancefield and Regorogile, tribal areas such as Tshivhase, Modjadji, Moletji, Bankuna, Sekhukhuneland, Bakenberg, Zebediela and others are some of the highest population urban areas in Limpopo. Map 3.3.6.6 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

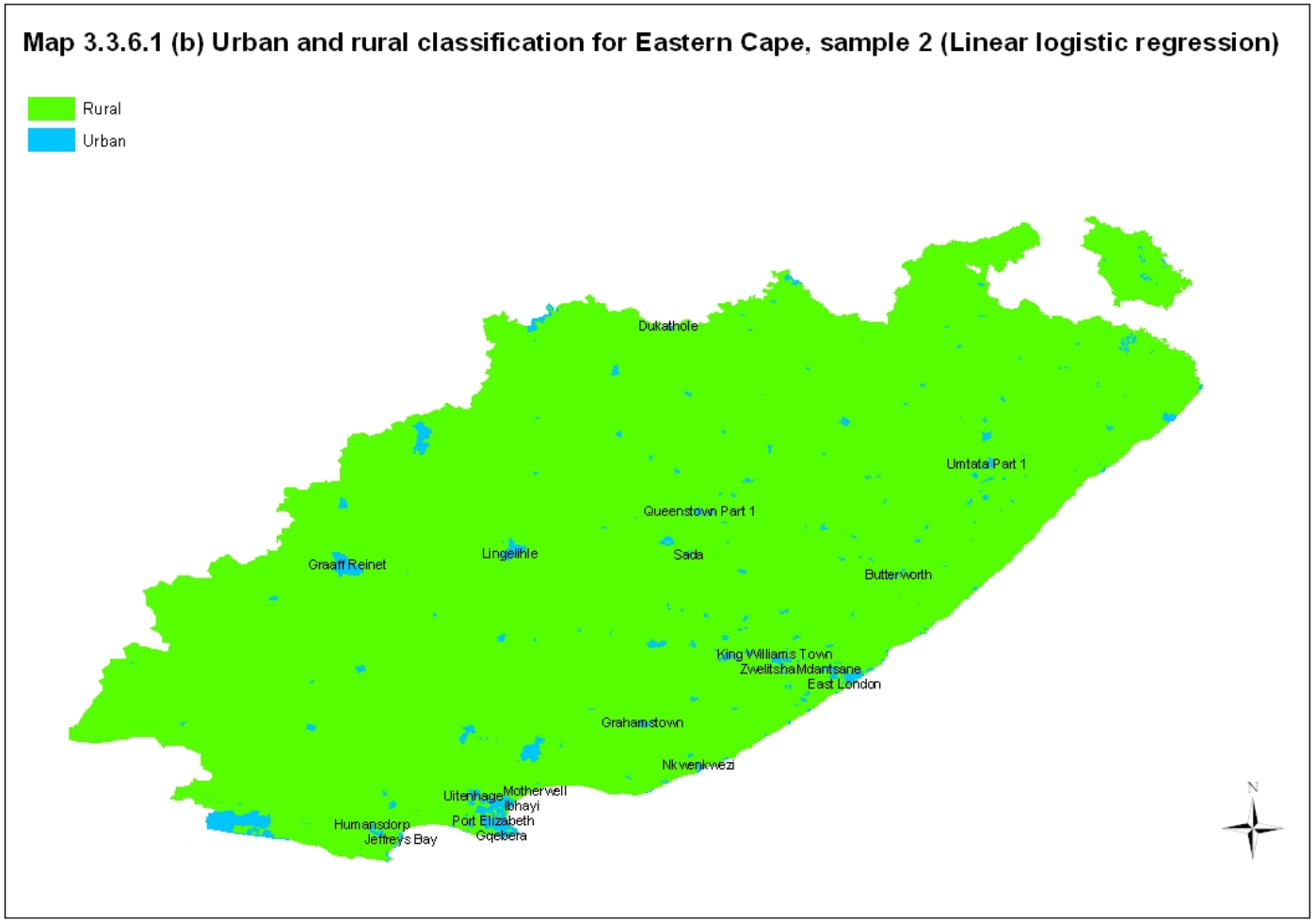
3.3.6.7 Maps for South Africa as a whole

For sample 1, the non-spatial statistical technique resulting in the best classification is that of *linear logistic regression*. According to linear logistic regression, 34% of the population in the RSA is classified as rural and 66% as urban, when compared to Census 2001, 43% is classified as rural and 58% as urban, and similarly for Census 1996, 45% as rural and 55% as urban. Map 3.3.6.7 (a) shows that cities such as Johannesburg, Cape Town, Durban, Pretoria, Port Elizabeth, Pietermaritzburg, Roodepoort, towns such as Chatsworth, Mdantsane, Phoenix and Mabopane, previous township areas such as Soweto, Mitchell's Plain, Umlazi, Tembisa, Katlehong and Khayelitsha, tribal areas such as Bafokeng, Tshivhase, Moletji, Mkobola, Hlubi, Namahadi, Msogwaba and others are some of the highest population urban areas in the RSA. Map 3.3.6.7 (b) shows sample 2 where the technique that results in the best classification is *linear logistic regression*. Comparing both maps shows that for sample 1 the statistical technique has classified most tribal areas as urban. The sampling methodology used for sample 2 predefines tribal areas as rural.

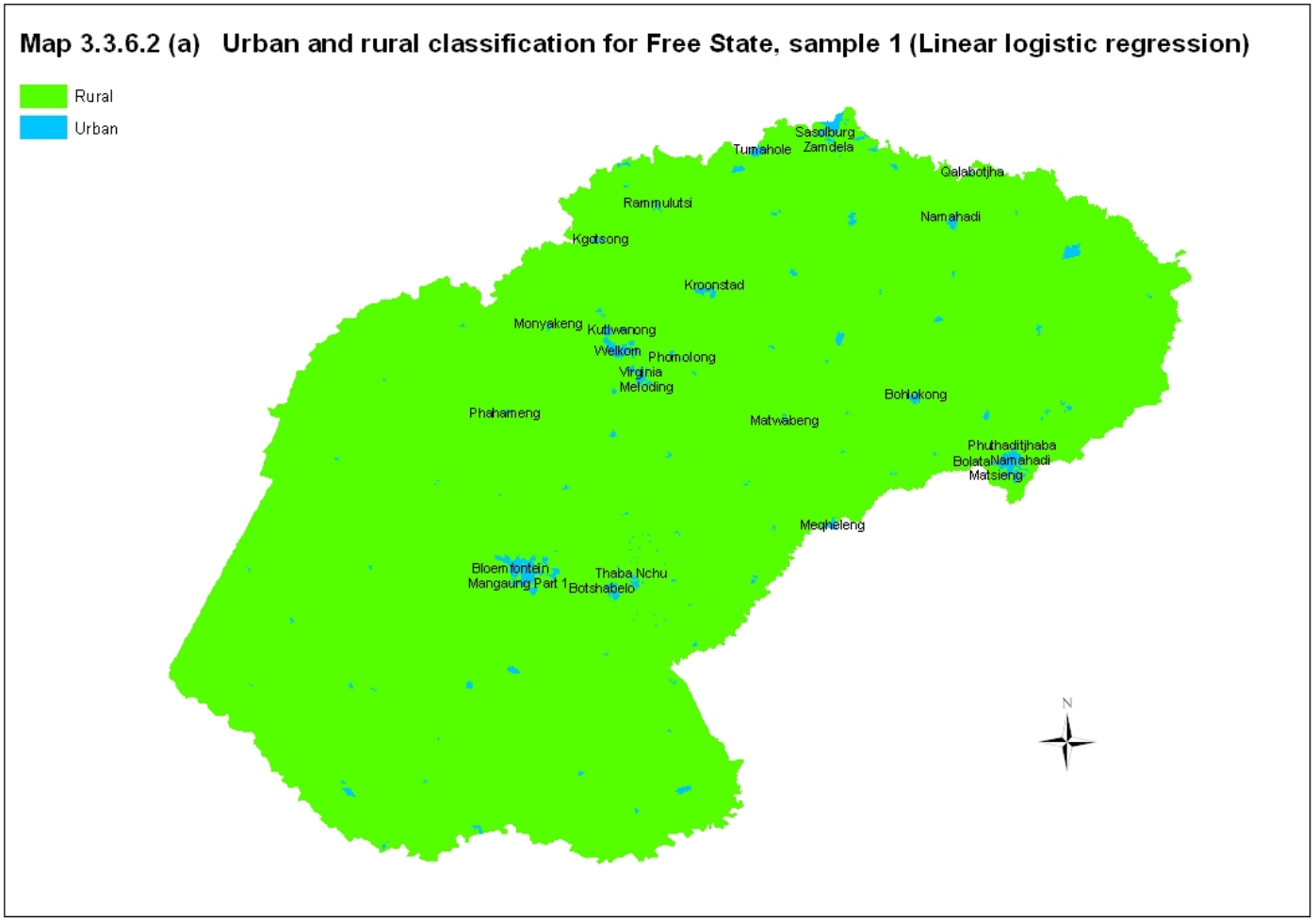
Map 3.3.6.1 (a) Urban and rural classification for Eastern Cape, sample 1 (Classification trees)



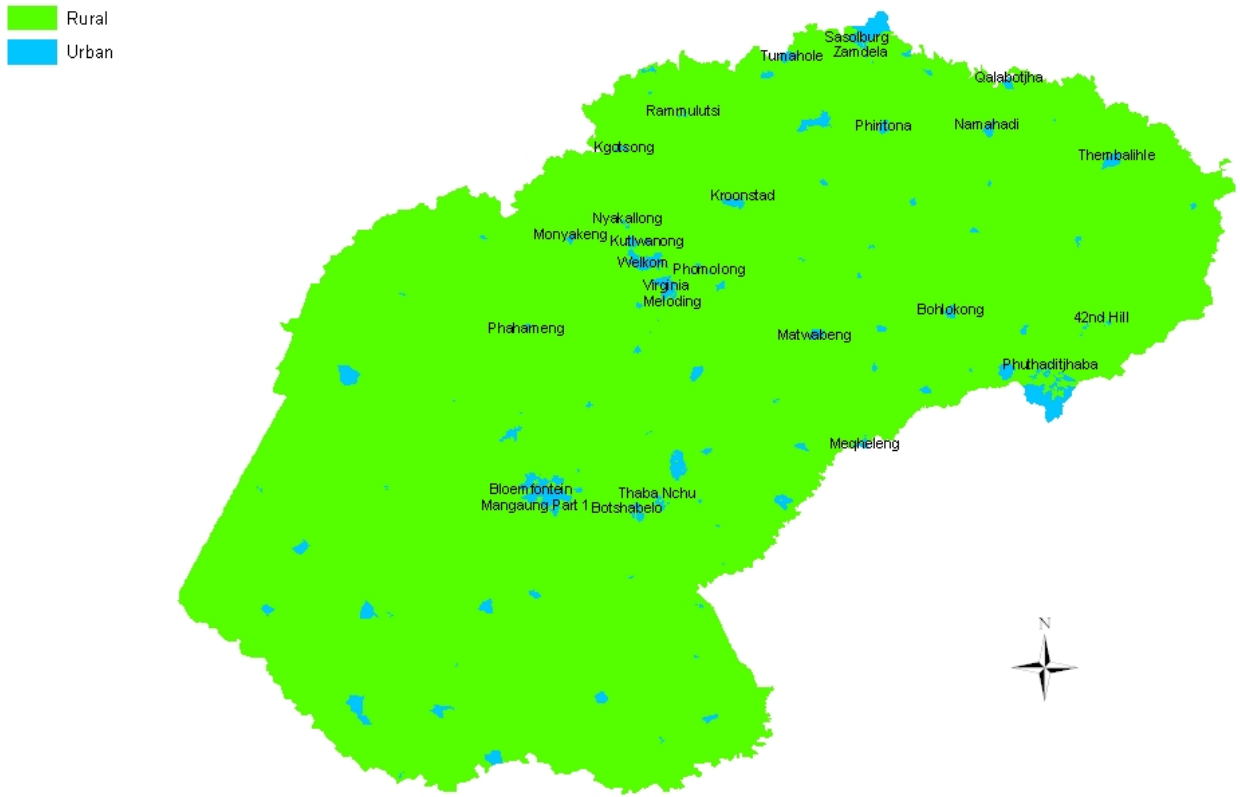
Map 3.3.6.1 (b) Urban and rural classification for Eastern Cape, sample 2 (Linear logistic regression)



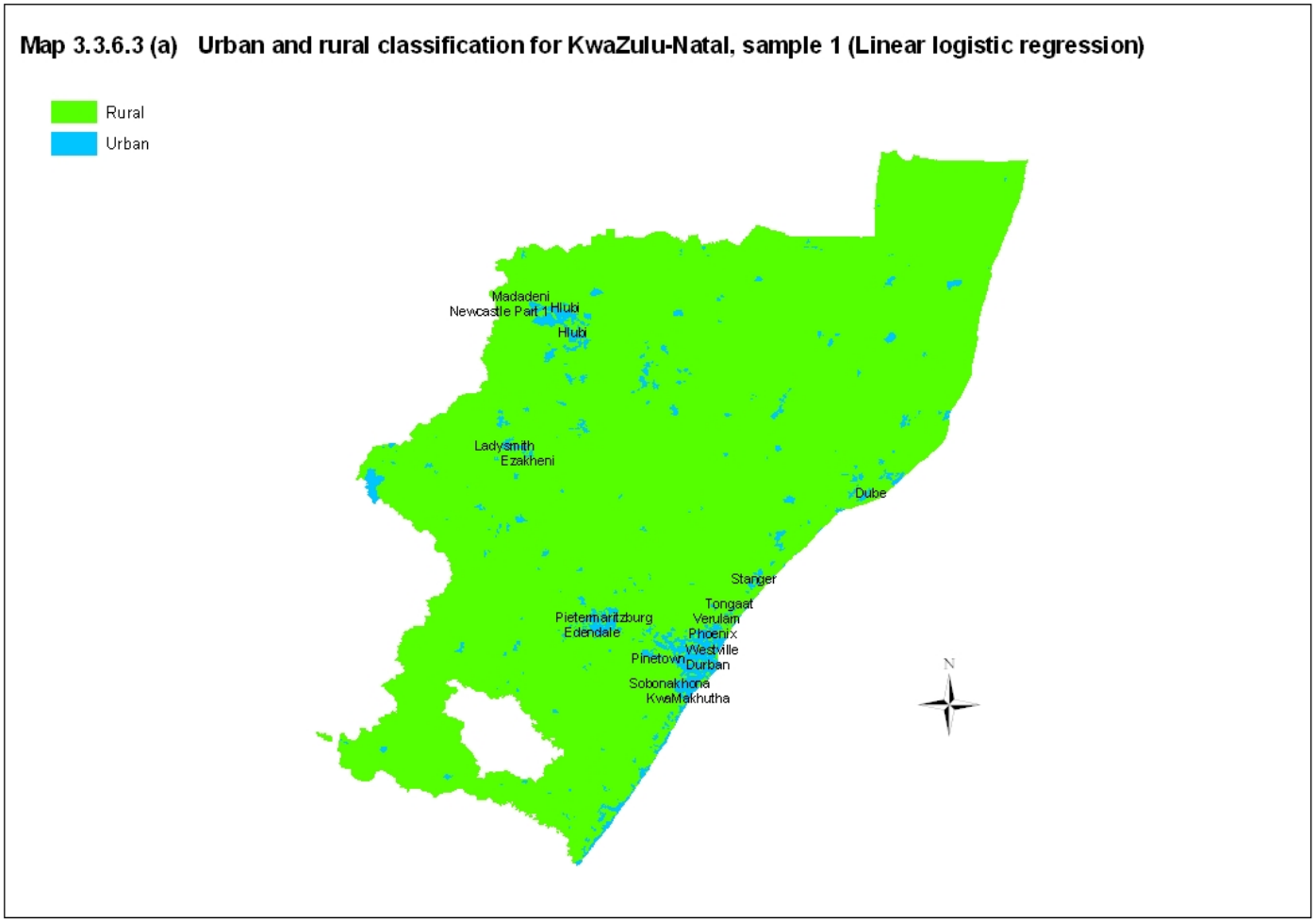
Map 3.3.6.2 (a) Urban and rural classification for Free State, sample 1 (Linear logistic regression)



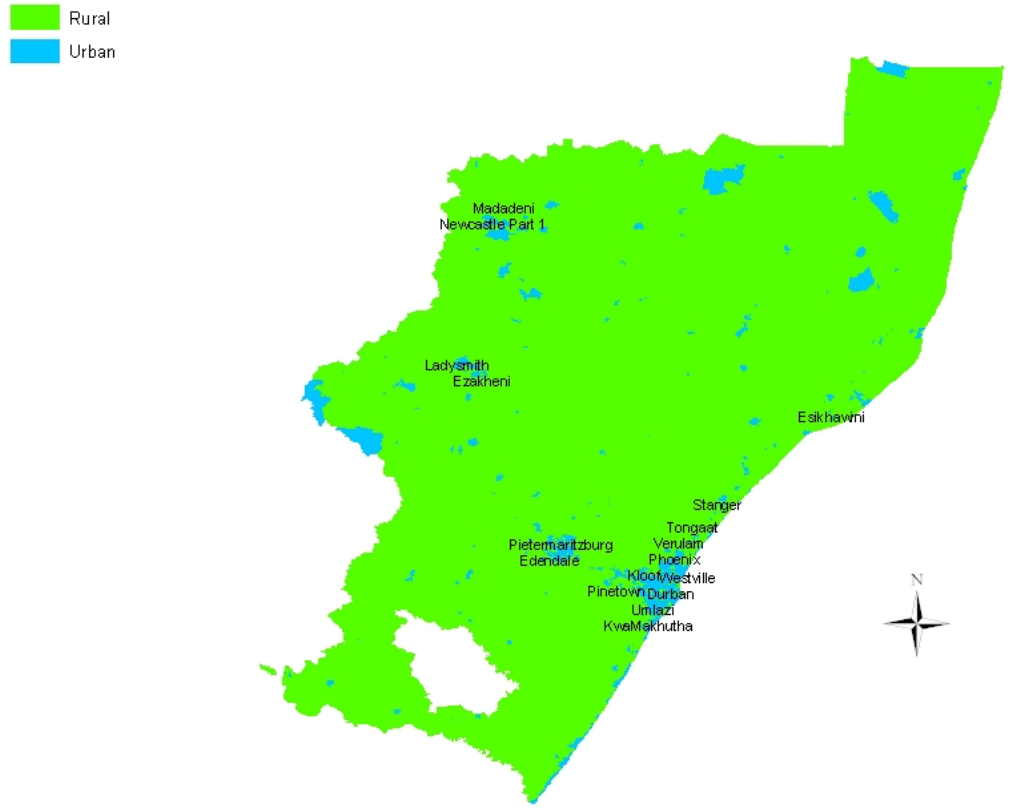
Map 3.3.6.2 (b) Urban and rural classification for Free State, sample 2 (Linear logistic regression)



Map 3.3.6.3 (a) Urban and rural classification for KwaZulu-Natal, sample 1 (Linear logistic regression)

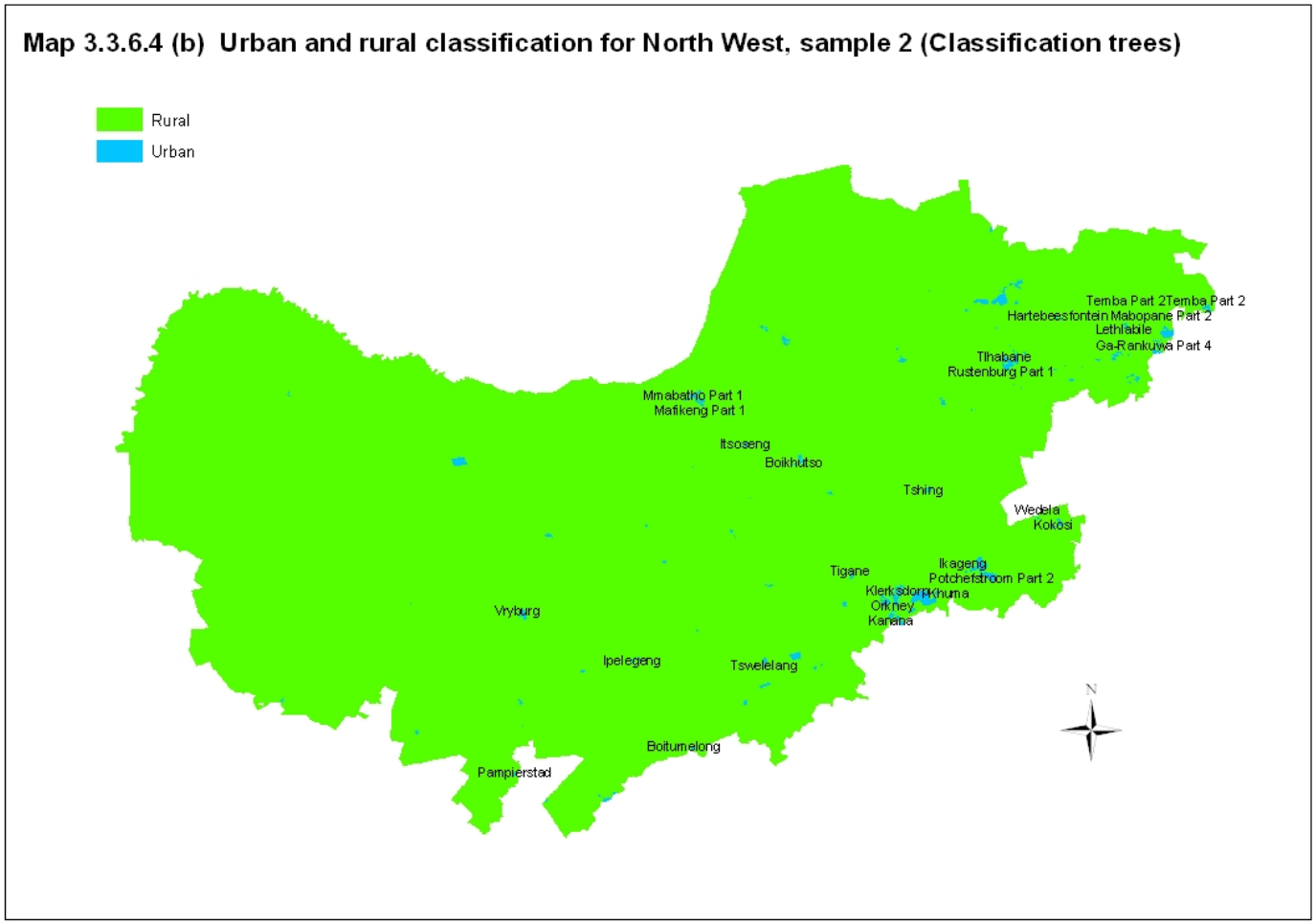


Map 3.3.6.3 (b) Urban and rural classification for KwaZulu-Natal, sample 2 (Linear logistic regression)

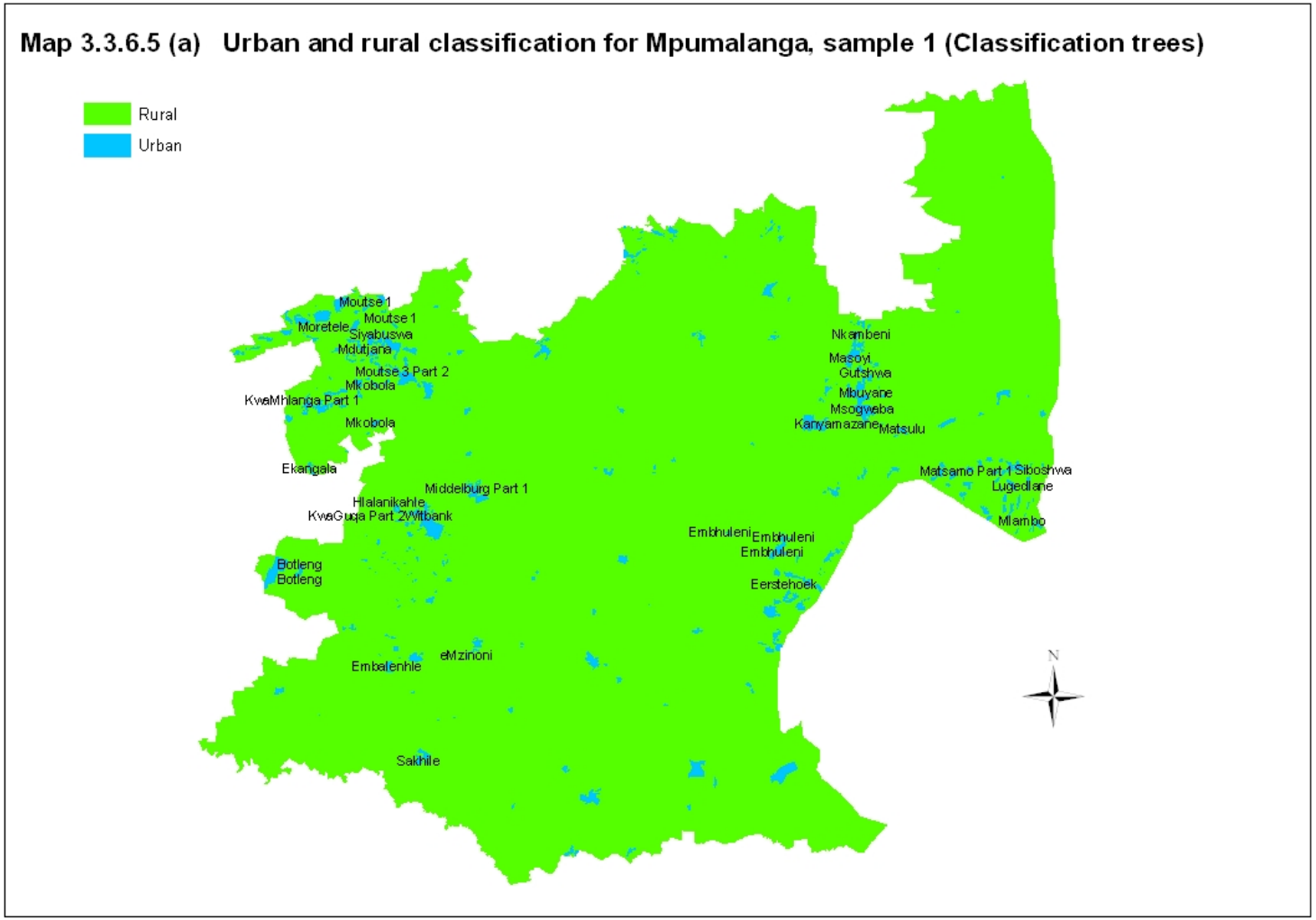


Map 3.3.6.4 (a) Urban and rural classification for North West, sample 1 (Classification trees)

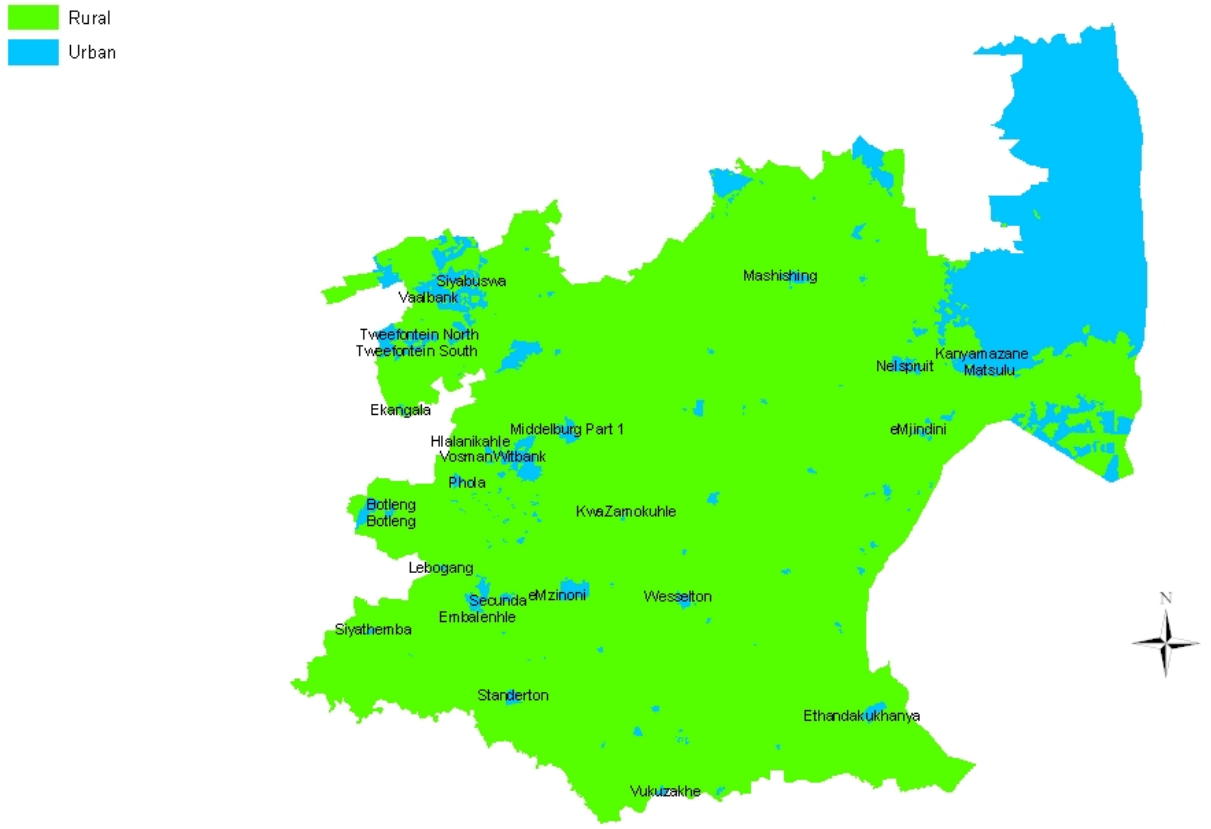
Map 3.3.6.4 (b) Urban and rural classification for North West, sample 2 (Classification trees)



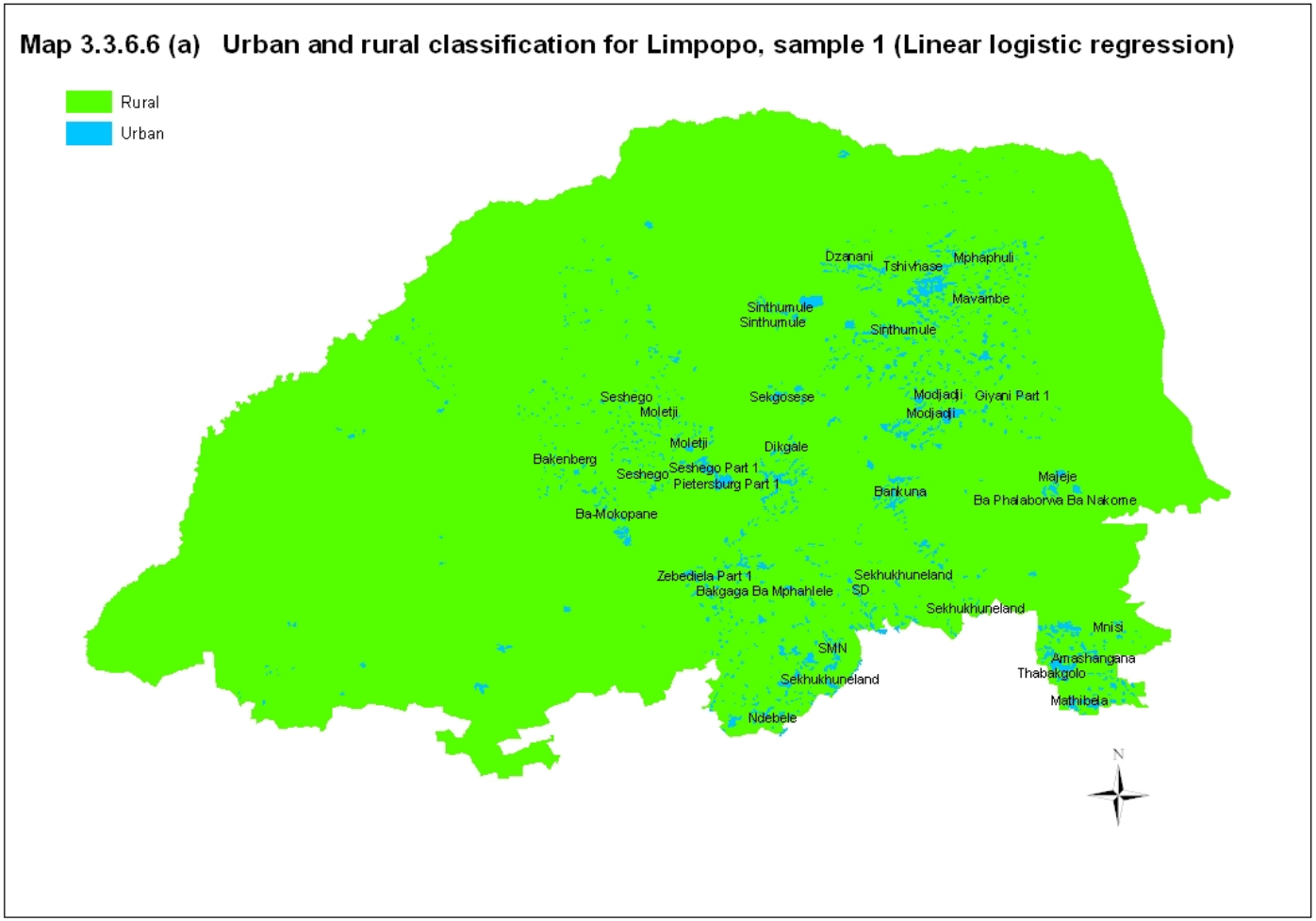
Map 3.3.6.5 (a) Urban and rural classification for Mpumalanga, sample 1 (Classification trees)



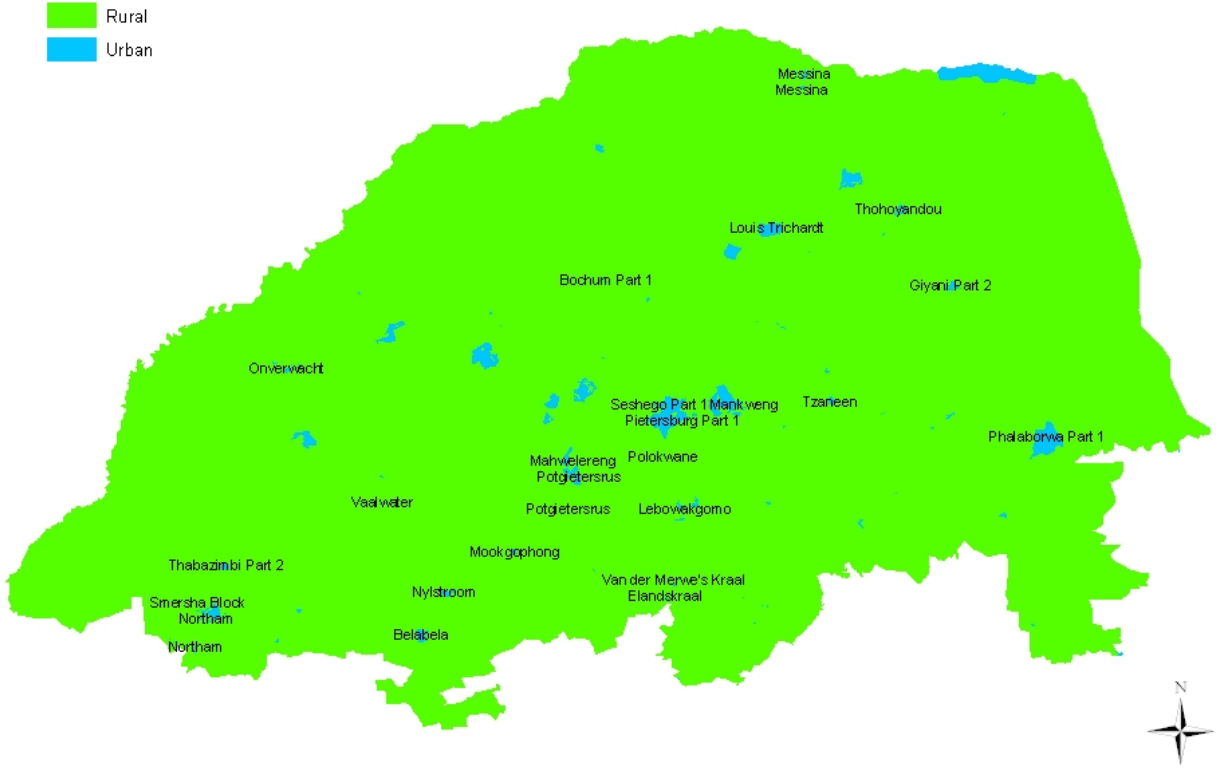
Map 3.3.6.5 (b) Urban and rural classification for Mpumalanga, sample 2 (Linear logistic regression)



Map 3.3.6.6 (a) Urban and rural classification for Limpopo, sample 1 (Linear logistic regression)

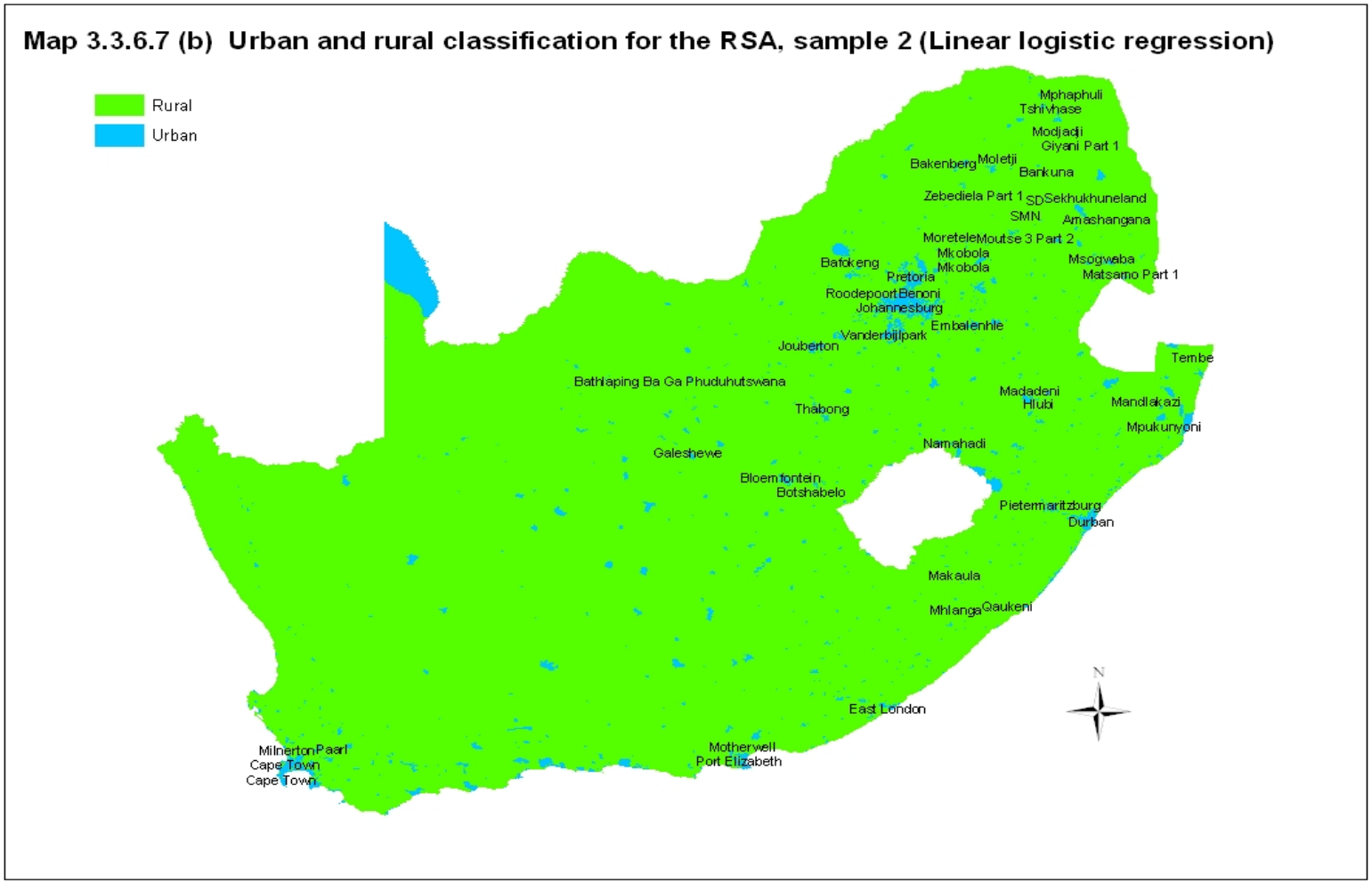


Map 3.3.6.6 (b) Urban and rural classification for Limpopo, sample 2 (Linear logistic regression)



Map 3.3.6.7 (a) Urban and rural classification for the RSA, sample 1 (Linear logistic regression)

Map 3.3.6.7 (b) Urban and rural classification for the RSA, sample 2 (Linear logistic regression)



3.4 Chapter summary and conclusion

In this chapter detailed discussions of the applications, methodologies and results were presented for the non-spatial statistical techniques, namely linear logistic regression, classification trees and discriminant analysis.

Generally, the results (i.e. significant variables, misclassification rates and population aggregates) obtained for all three statistical techniques for both samples, are more or less similar within each sample, but differ between the two samples.

From the three statistical techniques, classification trees provide combinations of significant variables for assigning areas into urban and rural, whilst linear logistic regression and discriminant analysis give more information, that is, both are able to separate significant variables more clearly for urban and rural. Thus combining the results obtained from linear logistic regression and discriminant analysis for sample 1 shows that variables such as *population density*, *unemployed persons*, *number of children ever born i.e. 0-5*, *persons living in informal dwellings in informal/ squatter areas*, *households with flush toilets connected to sewer*, *households using bucket latrines* and *female or White headed households,* separate the urban from the rural settlements, whilst variables such as *persons with no schooling*, *households accessing water from rainwater tanks or rivers/streams, households using wood or paraffin as the main source of energy for cooking*, and *head of household occupation is skilled agriculture and fishery workers or elementary occupations*, separate rural, i.e. farm settlements. For sample 2 variables such as *population density*, *unemployed persons*, *number of children ever born i.e. 0-5*, *persons living in informal dwellings in informal/squatter areas*, *households with flush toilets connected to sewer*, *households using bucket latrines* and *persons who have completed primary schooling*, separate the urban settlements, whilst variables such as *persons with no or some primary schooling*, *households using wood or paraffin as the main source of energy for cooking*, *head of household occupation is skilled agriculture and fishery workers or elementary occupations*, *persons living in traditional/hut structures*, *African headed households*, *households with chemical toilets or pit latrines*, *larger household sizes i.e. 10 or more*, *households with no annual income* and *persons whose employment status is homemaker or housewife*, separate rural i.e. farm and tribal settlements. Combining all the significant variables obtained from both samples for urban settlement, can be

assumed to separate urban settlements from rural, and common significant variables obtained between both samples for rural, can separate rural, i.e. farm settlements, whilst variables that are not common for rural between the two samples, can be assumed to separate out rural, i.e. tribal settlements. Such variables are *persons living in traditional/hut structures*, *African headed households*, *households with chemical toilets or pit latrines*, *larger household sizes i.e. 10 or more*, *households with no annual income* and *persons whose employment status is homemaker or housewife*.

Results from the confusion matrices, section 3.3.4, show that there are provinces for both samples that have large misclassifications (above 10%), however, looking at these more critically, their actual figures are relatively small when compared to the total number of EAs in the samples.

Generally, the population figures obtained, based on the classifications produced by the models for sample 1, are very different from the population totals for both censuses (and sometimes differ markedly amongst themselves), whilst in contrast, those produced by the models based on sample 2 generally agree amongst themselves and with the population figures obtained from the censuses. This is due to the sampling methodology for sample 2 that predefines the classification of tribal settlements as rural, which is the same classification for both censuses, whilst for sample 1, large parts of tribal areas are classified as urban.

The next chapter contains the analysis using spatial statistical techniques.

CHAPTER 4 - *Spatial Data Application and Results*

4.1 Introduction

The previous chapter discussed in detail the classification of areas into urban and rural using non-spatial statistical techniques, i.e. linear logistic regression, classification trees and discriminant analysis. In this chapter, spatial statistical techniques, namely 1) straight-majority-rule, and 2) Iterated Conditional Modes (ICM) based on the principles of Markov Random Fields, are applied to the classification of urban and rural.

The motivation for making use of spatial statistical techniques is mainly because the classification of areas into urban and rural is a spatial matter; this was included to explore the impact of similarities amongst adjacent areas in the urban and rural classification.

In this chapter the spatial statistical application is explained. The results from the spatial data applications are summarised and presented.

4.2 Methodology

4.2.1 Straight-majority-rule

Straight-majority-rule is an iterative procedure for determining the urban or rural status of a particular enumeration area (say ***X***) based on the urban or rural status of its neighbouring enumeration areas. As the name implies, the urban or rural classification for ***X*** is based on the status of the majority of its neighbouring or surrounding enumeration areas. For the process, a neighbourhood (say ***Z***) was defined as all enumeration areas touching (topologically connected to) that particular enumeration area (i.e. ***X***). Each enumeration area was initially (iteration 0) assigned an urban or rural status based on the results with the lowest misclassification rates obtained from the non-spatial statistical techniques discussed in Chapter 3. Subsequent iterations made use of the results of previous iterations to determine the urban/rural status of each ***X***, until stability was reached, i.e. no further changes to ***X*** based on ***Z***, occurred. The enumeration areas that changed for each iteration were recorded and the population totals were aggregated. In order to compare the results with those obtained in the non-spatial statistical techniques, the areas of known urban or rural status, as

defined in Chapter 3, remained unchanged, and were used in the procedure to determine the status of unknown areas.

Finally a misclassification rate for each province and for South Africa as a whole was calculated, based on the results of the final iteration. Areas of known urban and rural status were iterated once to redetermine their urban and rural status based on the results of the final iteration. A misclassification rate was calculated by taking the known areas that changed urban or rural status, divided by the total number of known areas. The correctly and incorrectly classified EAs are shown in Table 4.3.1.11. This method to calculate the misclassification rate was used since the areas of known urban and rural status were excluded from each iteration.

Straight-majority-rule was applied for each province and for South Africa. The results are presented in Section 4.3.1.

4.2.2 Markov Random Fields

Based on the principles of Markov Random Fields and Bayesian analysis, ICM was used. The method made use of a *likelihood* and a *prior* probability to produce a *posterior* probability. For the likelihood, the density function obtained from the non-spatial statistical technique, i.e. discriminant analysis, was used. That is, using a Multivariate Normal model,

$$f(y_i \mid x_i) = \frac{1}{(2\Pi)^{p/2}|\Sigma|} e^{-1/2\left(y_i - \mu(x_i)\right)\sum^{-1}\left(y_i - \mu(x_i)\right)'} \propto e^{-1/2\left(y_i - \mu(x_i)\right)\sum^{-1}\left(y_i - \mu(x_i)\right)'}$$

where $y_i = (y_{1i},...,y_{pi})$ are the significant census variables from the discriminant analysis for each enumeration area, $\mu(x_i)$ is the mean vector of the class x_i (i.e. $x_i = urban$ or $rural$) and $\sum$ is the common covariance matrix of the $y's$.

For the prior probability, the Markov Random Field model as stated in Besag (1986) was adapted for our application,

$$p_i(k \mid \cdot) = \frac{e^{\beta u_i(k)}}{\sum_{l=1}^{c} e^{\beta u_i(l)}}.$$

This assigns conditional probability to the class k at pixel i, given the classes in the neighbouring pixels, where $u_i(l)$ denotes the number of neighbours of i having colour l, and β is a fixed parameter. According to Besag (1986) $\beta = 1.5$ works well and was used in the calculations.

Thus the conditional prior probability in the case of urban is

$$P[Urban \mid neighbouring\_classes] \propto \frac{e^{1.5*number\_of\_urban\_EAs\_in\_neighbourhood}}{e^{1.5*number\_of\_urban\_EAs\_in\_neighbourhood} + e^{1.5*number\_of\_rural\_EAs\_in\_neighbourhood}}$$

and for rural is

$$P[Rural \mid neighbouring\_classes] \propto \frac{e^{1.5*number\_of\_rural\_EAs\_in\_neighbourhood}}{e^{1.5*number\_of\_urban\_EAs\_in\_neighbourhood} + e^{1.5*number\_of\_rural\_EAs\_in\_neighbourhood}}$$

.

The *likelihood* and *prior* probabilities were multiplied by each other to give a *posterior* probability. EAs were assigned an urban or rural classification based on the larger of the two probabilities, i.e. if the urban probability was larger than the rural probability then the EA was classified as urban, similarly if the rural probability was larger, the EA was classified as rural.

The process was iterated until no further changes to ***X*** based on ***Z***, occurred. The enumeration areas that changed for each iteration were recorded and population totals were aggregated. In order to compare results with those obtained in the non-spatial statistical techniques, the areas of known urban or rural status, as defined in Chapter 3, remained unchanged, and were used in the simulation to determine the status of unknown areas.

Finally a misclassification rate for each province and for South Africa as a whole was estimated in a similar manner as for straight-majority-rule.

ICM was run for each province and for South Africa. The results are presented in Section 4.3.2.

4.3 Results

4.3.1 Results for Straight-majority-rule

Based on the methodology described in Chapter 2, straight-majority-rule was applied for each province and for South Africa as a whole. The tables in this section are shown in two parts. Tables 4.3.1.1-10 (Part 1) show the number of EAs that changed from the original classification for each province and for South Africa. Iteration 0 gives the number of EAs classified as rural and urban for the original (un-iterated) classification. The number of EAs that changed for each iteration is expressed as a percentage of the number of rural and urban EAs of the original classification (iteration 0). Table 4.3.1.1-10 (Part 2) shows the aggregated population for the original classification (iteration 0) and for other iterations as a result of the changes in EA classification. *Please note that the population figures are slightly different from those given in Chapter 3; this is a result of the random rounding used by Statistics South Africa in SuperCross*[4]*.* Table 4.3.1.11 shows the estimated number (and percent) of correctly and incorrectly classified EAs for straight-majority-rule, for each province and for South Africa.

In general, most provinces show that many EAs, i.e. unknown status EAs, have changed urban/rural status, mainly in the first iteration. Although some provinces such as the Western Cape, Northern Cape, Free State and Gauteng show large changes in the EA classification, these changes have little or no impact on the population aggregations. This is mainly due to changes of low population rural EAs to urban. The Eastern Cape on the other hand shows the opposite; there smaller changes in EA classification, have a larger impact on the population aggregates. Similar results are evident for KwaZulu-Natal and Limpopo. Although there are changes in the EA classification, these changes have little or no impact on the population aggregates for sample 2.

[4] SuperCross is the software used by Statistics South Africa to disseminate census data. To prevent disclosure of information that is less than 5, random rounding is used.

Table 4.3.1.1 (Part 1) Western Cape - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations				
		0	1	2	3	4
Western Cape (Sample 1 - Urban-Farm)						
No. of EAs that changed:						
Rural to Urban		150	97	2	0	0
Urban to Rural		979	94	5	1	0
TOTAL		1129	191	7	1	0
% EAs that changed:						
Rural to Urban	%		65	1	0	0
Urban to Rural	%		10	1	0	0
TOTAL	%		17	1	0	0
Western Cape (Sample 2 - Urban-Farm-Tribal)						
No. of EAs that changed:						
Rural to Urban		83	49	2	0	0
Urban to Rural		1046	113	5	1	0
TOTAL		1129	162	7	1	0
% EAs that changed:						
Rural to Urban	%		59	2	0	0
Urban to Rural	%		11	0	0	0
TOTAL	%		14	1	0	0

Table 4.3.1.1 (Part 2) Western Cape - Comparison of the population changes for Straight-majority-rule

		Iterations				
		0	1	2	3	4
Western Cape (Sample 1 - Urban-Farm)						
Rural		447271	463016	463135	463603	463603
Urban		4077044	4061299	4061180	4060712	4060712
TOTAL		4524315	4524315	4524315	4524315	4524315
Rural	%	10	10	10	10	10
Urban	%	90	90	90	90	90
TOTAL	%	100	100	100	100	100
Western Cape (Sample 2 - Urban-Farm-Tribal)						
Rural		437329	462473	463135	463603	463603
Urban		4086986	4061842	4061180	4060712	4060712
TOTAL		4524315	4524315	4524315	4524315	4524315
Rural	%	10	10	10	10	10
Urban	%	90	90	90	90	90
TOTAL	%	100	100	100	100	100

Table 4.3.1.2 (Part 1) Eastern Cape - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations													
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Eastern Cape (Sample 1 - Urban-Farm)															
No. of EAs that changed:															
Rural to Urban		4986	1030	303	54	14	11	4	0	0	0	0	0	0	0
Urban to Rural		9834	5544	676	270	170	80	67	34	19	16	20	5	4	0
TOTAL		14820	6574	979	324	184	91	71	34	19	16	20	5	4	0
% EAs that changed:															
Rural to Urban	%		21	6	1	0	0	0	0	0	0	0	0	0	0
Urban to Rural	%		56	7	3	2	1	1	0	0	0	0	0	0	0
TOTAL	%		44	7	2	1	1	0	0	0	0	0	0	0	0
Eastern Cape (Sample 2 - Urban-Farm-Tribal)															
No. of EAs that changed:															
Rural to Urban		4229	170	22	4	2	2	0							
Urban to Rural		889	158	7	0	0	0	0							
TOTAL		5118	328	29	4	2	2	0							
% EAs that changed:															
Rural to Urban	%		4	1	0	0	0	0							
Urban to Rural	%		18	1	0	0	0	0							
TOTAL	%		6	1	0	0	0	0							

Table 4.3.1.2 (Part 2) Eastern Cape - Comparison of the population changes for Straight-majority-rule

		Iterations													
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Eastern Cape (Sample 1 - Urban-Farm)															
Rural		415002	2497810	2603600	2673286	2722777	2743139	2761762	2771487	2778071	2782259	2787555	2789863	2790579	2790579
Urban		6021694	3938885	3833095	3763410	3713919	3693557	3674934	3665209	3658625	3654437	3649140	3646833	3646117	3646117
TOTAL		6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696
Rural	%	6	39	40	42	42	43	43	43	43	43	43	43	43	43
Urban	%	94	61	60	58	58	57	57	57	57	57	57	57	57	57
TOTAL	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Eastern Cape (Sample 2 - Urban-Farm-Tribal)															
Rural		4039569	4055956	4049901	4049188	4049185	4048393	4048393							
Urban		2397126	2380740	2386795	2387507	2387510	2388302	2388302							
TOTAL		6436696	6436696	6436696	6436696	6436696	6436696	6436696							
Rural	%	63	63	63	63	63	63	63							
Urban	%	37	37	37	37	37	37	37							
TOTAL	%	100	100	100	100	100	100	100							

Table 4.3.1.3 (Part 1) Northern Cape - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations			
		0	1	2	3
Northern Cape (Sample 1 - Urban-Farm)					
No. of EAs that changed:					
Rural to Urban		40	23	2	0
Urban to Rural		154	53	2	0
TOTAL		194	76	4	0
% EAs that changed:					
Rural to Urban	%		58	5	0
Urban to Rural	%		34	1	0
TOTAL	%		39	2	0
Northern Cape (Sample 2 - Urban-Farm-Tribal)					
No. of EAs that changed:					
Rural to Urban		77	43	4	0
Urban to Rural		96	24	0	0
TOTAL		173	67	4	0
% EAs that changed:					
Rural to Urban	%		56	5	0
Urban to Rural	%		25	0	0
TOTAL	%		39	2	0

Table 4.3.1.3 (Part 2) Northern Cape - Comparison of the population changes for Straight-majority-rule

		Iterations			
		0	1	2	3
Northern Cape (Sample 1 - Urban-Farm)					
Rural		147038	158365	156435	156435
Urban		675681	664354	666284	666284
TOTAL		822719	822719	822719	822719
Rural	%	18	19	19	19
Urban	%	82	81	81	81
TOTAL	%	100	100	100	100
Northern Cape (Sample 2 - Urban-Farm-Tribal)					
Rural		159997	162528	160107	160107
Urban		662722	660191	662612	662612
TOTAL		822719	822719	822719	822719
Rural	%	19	20	19	19
Urban	%	81	80	81	81
TOTAL	%	100	100	100	100

Table 4.3.1.4 (Part 1) Free State - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations				
		0	1	2	3	4
Free State (Sample 1 - Urban-Farm)						
No. of EAs that changed:						
Rural to Urban		206	154	22	1	0
Urban to Rural		1158	106	13	0	0
TOTAL		1364	260	35	1	0
% EAs that changed:						
Rural to Urban	%		75	11	0	0
Urban to Rural	%		9	1	0	0
TOTAL	%		19	3	0	0
Free State (Sample 2 - Urban-Farm-Tribal)						
No. of EAs that changed:						
Rural to Urban		135	81	10	1	0
Urban to Rural		642	70	8	2	0
TOTAL		777	151	18	3	0
% EAs that changed:						
Rural to Urban	%		60	7	1	0
Urban to Rural	%		11	1	0	0
TOTAL	%		19	2	0	0

Table 4.3.1.4 (Part 2) Free State - Comparison of the population changes that changed for Straight-majority-rule

		Iterations				
		0	1	2	3	4
Rural		401239	431336	431001	430802	430802
Urban		2305526	2275429	2275764	2275963	2275963
TOTAL		2706765	2706765	2706765	2706765	2706765
Rural	%	15	16	16	16	16
Urban	%	85	84	84	84	84
TOTAL	%	100	100	100	100	100
Rural		673832	674583	677720	679023	679023
Urban		2032932	2032182	2029045	2027742	2027742
TOTAL		2706765	2706765	2706765	2706765	2706765
Rural	%	25	25	25	25	25
Urban	%	75	75	75	75	75
TOTAL	%	100	100	100	100	100

Table 4.3.1.5 (Part 1) KwaZulu-Natal - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations												
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
KwaZulu-Natal (Sample 1 - Urban-Farm)														
No. of EAs that changed:														
Rural to Urban		5263	351	51	7	2	0	0	0	0	0	0	0	0
Urban to Rural		2732	434	84	36	8	6	3	3	3	4	2	6	0
TOTAL		7995	785	135	43	10	6	3	3	3	4	2	6	0
% EAs that changed:														
Rural to Urban	%		7	1	0	0	0	0	0	0	0	0	0	0
Urban to Rural	%		16	3	1	0	0	0	0	0	0	0	0	0
TOTAL	%		10	2	1	0	0	0	0	0	0	0	0	0
KwaZulu-Natal (Sample 2 - Urban-Farm-Tribal)														
No. of EAs that changed:														
Rural to Urban		938	325	32	13	1	0	0	0	0	0			
Urban to Rural		1412	167	18	8	9	6	5	4	1	0			
TOTAL		2350	492	50	21	10	6	5	4	1	0			
% EAs that changed:														
Rural to Urban	%		35	3	1	0	0	0	0	0	0			
Urban to Rural	%		12	1	1	1	0	0	0	0	0			
TOTAL	%		21	2	1	0	0	0	0	0	0			

Table 4.3.1.5 (Part 2) KwaZulu-Natal - Comparison of the population changes for Straight-majority-rule

		Iterations												
		0	1	2	3	4	5	6	7	8	9	10	11	12
KwaZulu-Natal (Sample 1 - Urban-Farm)														
Rural		4307043	4570182	4602660	4629297	4635344	4639790	4641194	4642844	4644672	4647187	4648260	4651991	4651991
Urban		5118948	4855809	4823331	4796694	4790647	4786201	4784797	4783147	4781319	4778804	4777731	4774000	4774000
TOTAL		9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991
Rural	%	46	48	49	49	49	49	49	49	49	49	49	49	49
Urban	%	54	52	51	51	51	51	51	51	51	51	51	51	51
TOTAL	%	100	100	100	100	100	100	100	100	100	100	100	100	100
KwaZulu-Natal (Sample 2 - Urban-Farm-Tribal)														
Rural		5419941	5400010	5396923	5393442	5398616	5403147	5406929	5409219	5409897	5409897			
Urban		4006050	4025981	4029068	4032549	4027375	4022844	4019062	4016772	4016094	4016094			
TOTAL		9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991	9425991			
Rural	%	57	57	57	57	57	57	57	57	57	57			
Urban	%	43	43	43	43	43	43	43	43	43	43			
TOTAL	%	100	100	100	100	100	100	100	100	100	100			

Table 4.3.1.6 (Part 1) North West - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations						
		0	**1**	**2**	**3**	**4**	**5**	**6**
North West (Sample 1 - Urban-Farm)								
No. of EAs that changed:								
Rural to Urban		632	273	164	17	6	0	0
Urban to Rural		3551	635	57	12	2	1	0
TOTAL		4183	908	221	29	8	1	0
% EAs that changed:								
Rural to Urban	%		43	26	3	1	0	0
Urban to Rural	%		18	2	0	0	0	0
TOTAL	%		22	5	1	0	0	0
North West (Sample 2 - Urban-Farm-Tribal)								
No. of EAs that changed:								
Rural to Urban		756	105	27	3	2	0	
Urban to Rural		244	78	15	3	3	0	
TOTAL		1000	183	42	6	5	0	
% EAs that changed:								
Rural to Urban	%		14	4	0	0	0	
Urban to Rural	%		32	6	1	1	0	
TOTAL	%		18	4	1	1	0	

Table 4.3.1.6 (Part 2) North West - Comparison of the population changes for Straight-majority-rule

		Iterations						
		0	1	2	3	4	5	6
North West (Sample 1 - Urban-Farm)								
Rural		391725	673916	640804	641912	642675	643880	643880
Urban		3277611	2995420	3028532	3027424	3026662	3025456	3025456
TOTAL		3669336	3669336	3669336	3669336	3669336	3669336	3669336
Rural	%	11	18	17	17	18	18	18
Urban	%	89	82	83	83	82	82	82
TOTAL	%	100	100	100	100	100	100	100
North West (Sample 2 - Urban-Farm-Tribal)								
Rural		2309290	2308127	2299833	2299972	2301475	2301475	
Urban		1360046	1361209	1369503	1369364	1367861	1367861	
TOTAL		3669336	3669336	3669336	3669336	3669336	3669336	
Rural	%	63	63	63	63	63	63	
Urban	%	37	37	37	37	37	37	
TOTAL	%	100	100	100	100	100	100	

Table 4.3.1.7 (Part 1) Gauteng - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations				
		0	**1**	**2**	**3**	**4**
Gauteng (Sample 1 - Urban-Farm)						
No. of EAs that changed:						
Rural to Urban		320	162	16	1	0
Urban to Rural		3201	90	8	0	0
TOTAL		3521	252	24	1	0
% EAs that changed:						
Rural to Urban	%		51	5	0	0
Urban to Rural	%		3	0	0	0
TOTAL	%		7	1	0	0
Gauteng (Sample 2 - Urban-Farm-Tribal)						
No. of EAs that changed:						
Rural to Urban		320	158	21	1	0
Urban to Rural		3201	91	8	0	0
TOTAL		3521	249	29	1	0
% EAs that changed:						
Rural to Urban	%		49	7	0	0
Urban to Rural	%		3	0	0	0
TOTAL	%		7	1	0	0

Table 4.3.1.7 (Part 2) Gauteng - Comparison of the population changes for Straight-majority-rule

		Iterations				
		0	1	2	3	4
Gauteng (Sample 1 - Urban-Farm)						
Rural		321624	328264	326083	325725	325725
Urban		8515456	8508816	8510997	8511355	8511355
TOTAL		8837080	8837080	8837080	8837080	8837080
Rural	%	4	4	4	4	4
Urban	%	96	96	96	96	96
TOTAL	%	100	100	100	100	100
Gauteng (Sample 2 - Urban-Farm-Tribal)						
Rural		321624	332204	326083	325725	325725
Urban		8515456	8504877	8510997	8511355	8511355
TOTAL		8837080	8837080	8837080	8837080	8837080
Rural	%	4	4	4	4	4
Urban	%	96	96	96	96	96
TOTAL	%	100	100	100	100	100

Table 4.3.1.8 (Part 1) Mpumalanga - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mpumalanga (Sample 1 - Urban-Farm)										
No. of EAs that changed:										
Rural to Urban		451	266	86	13	4	0	0	0	0
Urban to Rural		2804	279	41	16	11	2	2	1	0
TOTAL		3255	545	127	29	15	2	2	1	0
% EAs that changed:										
Rural to Urban	%		59	19	3	1	0	0	0	0
Urban to Rural	%		10	1	1	0	0	0	0	0
TOTAL	%		17	4	1	0	0	0	0	0
Mpumalanga (Sample 2 - Urban-Farm-Tribal)										
No. of EAs that changed:										
Rural to Urban		270	70	13	3	0				
Urban to Rural		613	204	14	4	0				
TOTAL		883	274	27	7	0				
% EAs that changed:										
Rural to Urban	%		26	5	1	0				
Urban to Rural	%		33	2	1	0				
TOTAL	%		31	3	1	0				

Table 4.3.1.8 (Part 2) Mpumalanga - Comparison of the population changes for Straight-majority-rule

		Iterations								
		0	1	2	3	4	5	6	7	8
Mpumalanga (Sample 1 - Urban-Farm)										
Rural		559846	690720	676808	679365	681743	683080	684366	685595	685595
Urban		2563107	2432233	2446145	2443588	2441210	2439873	2438587	2437358	2437358
TOTAL		3122953	3122953	3122953	3122953	3122953	3122953	3122953	3122953	3122953
Rural	%	18	22	22	22	22	22	22	22	22
Urban	%	82	78	78	78	78	78	78	78	78
TOTAL	%	100	100	100	100	100	100	100	100	100
Mpumalanga (Sample 2 - Urban-Farm-Tribal)										
Rural		1887935	1902785	1900620	1900371	1900371				
Urban		1235018	1220168	1222333	1222582	1222582				
TOTAL		3122953	3122953	3122953	3122953	3122953				
Rural	%	60	61	61	61	61				
Urban	%	40	39	39	39	39				
TOTAL	%	100	100	100	100	100				

Table 4.3.1.9 (Part 1) Limpopo - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Limpopo (Sample 1 - Urban-Farm)												
No. of EAs that changed:												
Rural to Urban		2512	555	242	34	13	4	0	0	0	0	0
Urban to Rural		6741	1866	261	95	50	16	3	9	2	1	0
TOTAL		9253	2421	503	129	63	20	3	9	2	1	0
% EAs that changed:												
Rural to Urban	%		22	10	1	1	0	0	0	0	0	0
Urban to Rural	%		28	4	1	1	0	0	0	0	0	0
TOTAL	%		26	5	1	1	0	0	0	0	0	0
Limpopo (Sample 2 - Urban-Farm-Tribal)												
No. of EAs that changed:												
Rural to Urban		804	51	7	1	0						
Urban to Rural		147	69	6	0	0						
TOTAL		951	120	13	1	0						
% EAs that changed:												
Rural to Urban	%		6	1	0	0						
Urban to Rural	%		47	4	0	0						
TOTAL	%		13	1	0	0						

Table 4.3.1.9 (Part 2) Limpopo - Comparison of the population changes for Straight-majority-rule

		Iterations										
		0	1	2	3	4	5	6	7	8	9	10
Limpopo (Sample 1 - Urban-Farm)												
Rural		1104155	2021332	2047635	2080534	2097822	2101968	2103214	2108775	2109960	2110712	2110712
Urban		4169405	3252227	3225924	3193025	3175738	3171592	3170346	3164784	3163600	3162847	3162847
TOTAL		5273559	5273559	5273559	5273559	5273559	5273559	5273559	5273559	5273559	5273559	5273559
Rural	%	21	38	39	39	40	40	40	40	40	40	40
Urban	%	79	62	61	61	60	60	60	60	60	60	60
TOTAL	%	100	100	100	100	100	100	100	100	100	100	100
Limpopo (Sample 2 - Urban-Farm-Tribal)												
Rural		4724829	4747178	4747431	4747431	4747431						
Urban		548730	526381	526129	526129	526129						
TOTAL		5273559	5273559	5273559	5273559	5273559						
Rural	%	90	90	90	90	90						
Urban	%	10	10	10	10	10						
TOTAL	%	100	100	100	100	100						

Table 4.3.1.10 (Part 1) RSA - Comparison of the number of EAs that changed for Straight-majority-rule

		Iterations												
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
RSA (Sample 1 - Urban-Farm)														
No. of EAs that changed:														
Rural to Urban		30310	2096	406	79	16	4	2	0	0	0	0	0	0
Urban to Rural		15404	3831	534	196	84	41	17	7	12	7	5	6	0
TOTAL		45714	5927	940	275	100	45	19	7	12	7	5	6	0
% EAs that changed:														
Rural to Urban	%		7	1	0	0	0	0	0	0	0	0	0	0
Urban to Rural	%		25	3	1	1	0	0	0	0	0	0	0	0
TOTAL	%		13	2	1	0	0	0	0	0	0	0	0	0
RSA (Sample 2 - Urban-Farm-Tribal)														
No. of EAs that changed:														
Rural to Urban		7857	1249	144	19	4	4	0	0	0				
Urban to Rural		8045	853	113	25	9	6	2	1	0				
TOTAL		15902	2102	257	44	13	10	2	1	0				
% EAs that changed:														
Rural to Urban	%		16	2	0	0	0	0	0	0				
Urban to Rural	%		11	1	0	0	0	0	0	0				
TOTAL	%		13	2	0	0	0	0	0	0				

Table 4.3.1.10 (Part 2) RSA - Comparison of the population changes for Straight-majority-rule

		Iterations												
		0	1	2	3	4	5	6	7	8	9	10	11	12
RSA (Sample 1 - Urban-Farm)														
Rural		15165704	16883147	17006880	17094838	17128266	17145887	17153330	17157021	17162879	17167083	17169756	17173487	17173487
Urban		29653710	27936267	27812534	27724576	27691148	27673527	27666085	27662394	27656535	27652332	27649658	27645927	27645927
TOTAL		44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414
Rural	%	34	38	38	38	38	38	38	38	38	38	38	38	38
Urban	%	66	62	62	62	62	62	62	62	62	62	62	62	62
TOTAL	%	100	100	100	100	100	100	100	100	100	100	100	100	100
RSA (Sample 2 - Urban-Farm-Tribal)														
Rural		19816833	19993842	19986709	19989986	19995653	19998151	19999568	20000033	20000033				
Urban		25002581	24825572	24832705	24829428	24823761	24821263	24819846	24819381	24819381				
TOTAL		44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414				
Rural	%	44	45	45	45	45	45	45	45	45				
Urban	%	56	55	55	55	55	55	55	55	55				
TOTAL	%	100	100	100	100	100	100	100	100	100				

Table 4.3.1.11 Correctly and incorrectly classified EAs for Straight-majority-rule

	Sample 1					Sample 2				
	1		0		Total	1		0		Total
Western Cape										
1	5047	96%	218	4%	5265	5047	96%	218	4%	5265
0	86	12%	621	88%	707	86	12%	621	88%	707
Total	5133		839		5972	5133		839		5972
Eastern Cape										
1	2826	95%	142	5%	2968	2750	93%	218	7%	2968
0	64	11%	518	89%	582	52	1%	10232	99%	10284
Total	2890		660		3550	2802		10450		13252
Northern Cape										
1	830	88%	111	12%	941	830	88%	111	12%	941
0	32	9%	342	91%	374	32	8%	363	92%	395
Total	862		453		1315	862		474		1336
Free State										
1	2938	98%	53	2%	2991	2929	98%	62	2%	2991
0	52	6%	776	94%	828	56	4%	1359	96%	1415
Total	2990		829		3819	2985		1421		4406
KwaZulu-Natal										
1	3775	95%	182	5%	3957	3685	93%	272	7%	3957
0	60	8%	740	93%	800	71	1%	6374	99%	6445
Total	3835		922		4757	3756		6646		10402
North West										
1	1608	96%	72	4%	1680	1546	92%	134	8%	1680
0	54	9%	560	91%	614	32	1%	3765	99%	3797
Total	1662		632		2294	1578		3899		5477
Gauteng										
1	9392	100%	32	0%	9424	9392	100%	32	0%	9424
0	79	31%	178	69%	257	78	30%	179	70%	257
Total	9471		210		9681	9470		211		9681
Mpumalanga										
1	1625	93%	124	7%	1749	1583	91%	166	9%	1749
0	70	10%	654	90%	724	53	2%	3043	98%	3096
Total	1695		778		2473	1636		3209		4845
Limpopo										
1	716	94%	45	6%	761	689	91%	72	9%	761
0	39	9%	412	91%	451	13	0%	8740	100%	8753
Total	755		457		1212	702		8812		9514
RSA										
1	28664	96%	1072	4%	29736	28448	96%	1288	4%	29736
0	470	9%	4867	91%	5337	476	1%	34673	99%	35149
Total	29134		5939		35073	28924		35961		64885

Represented in the maps below is a selection of a few provinces, where the changes in EA classification have a large impact on the population aggregates. The final iteration for each province is mapped. The red polygons on the map show areas that have changed.

Eastern Cape – Map 4.3.1 (a)

For the Eastern Cape for sample 1, straight-majority-rule iterates 13 times before reaching stability. In the first iteration 44% of EAs changed classifications, 21% changed from rural to urban and 56% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 6% at the initial un-iterated setting to 39% in the first iteration, whilst the urban population drops from 94% to 61%. For the other iterations smaller changes in population occur. This has mainly occurred in the tribal and vacant areas of the Eastern Cape. For sample 2, the process iterates 6 times before reaching stability. The population percentages remain unchanged.

North West – Map 4.3.1 (b)

For the North West for sample 1, straight-majority-rule iterates 6 times before reaching stability. In the first iteration 22% of EAs changed classifications, 43% changed from rural to urban and 18% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 11% at the initial un-iterated setting to 18% in the first iteration, whilst the urban population drops from 89% to 82%. For the other iterations smaller changes in population occur. These occur mainly in the tribal and vacant areas, as well as areas with informal settlements in the North West. For sample 2, the process iterates 5 times before reaching stability. The population percentages remain unchanged.

Mpumalanga – Map 4.3.1 (c)

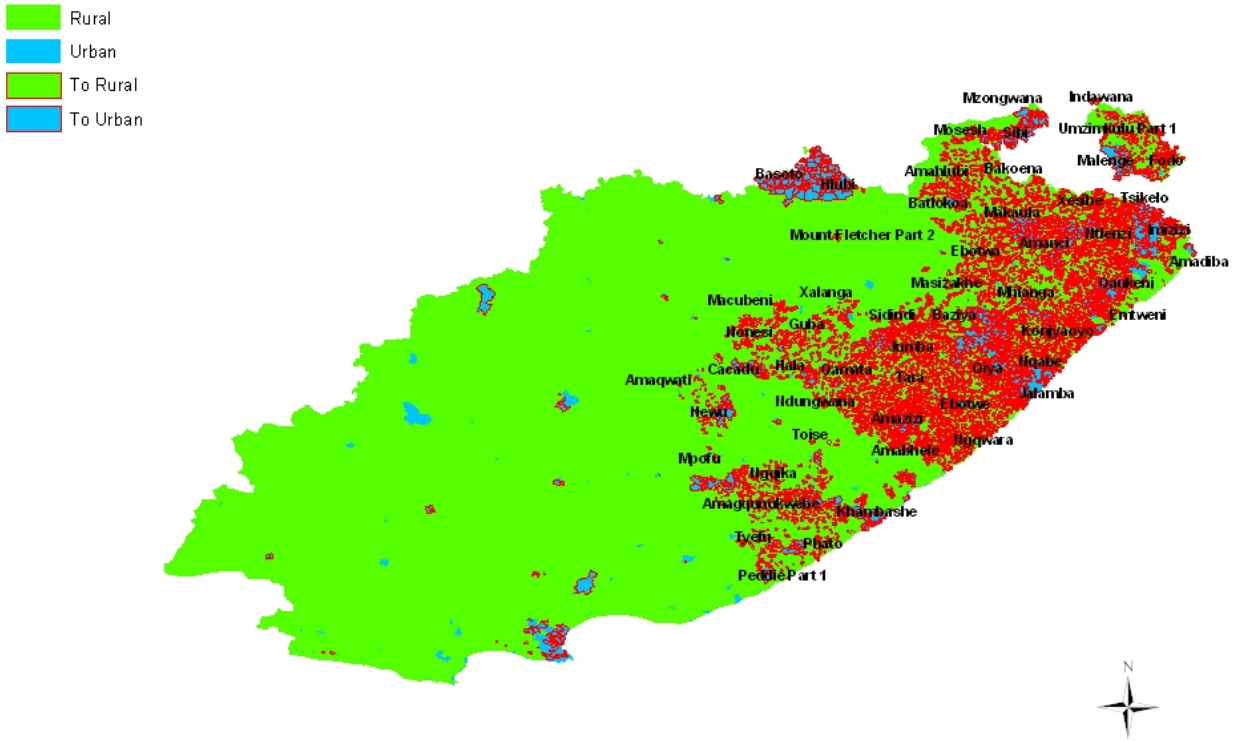
For Mpumalanga for sample 1, straight-majority-rule iterates 8 times before reaching stability. In the first iteration 17% EAs changed classifications, 59% changed from rural to urban and 10% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 18% at the initial un-iterated setting to 22% in the first iteration, whilst the urban population drops from 82% to 78%. For the other iterations smaller changes in population occur. These occur mainly in the tribal and vacant areas of Mpumalanga. For sample 2, the process iterates 4 times

before reaching stability. The population percentages change slightly in iteration 1 thereafter remain unchanged.

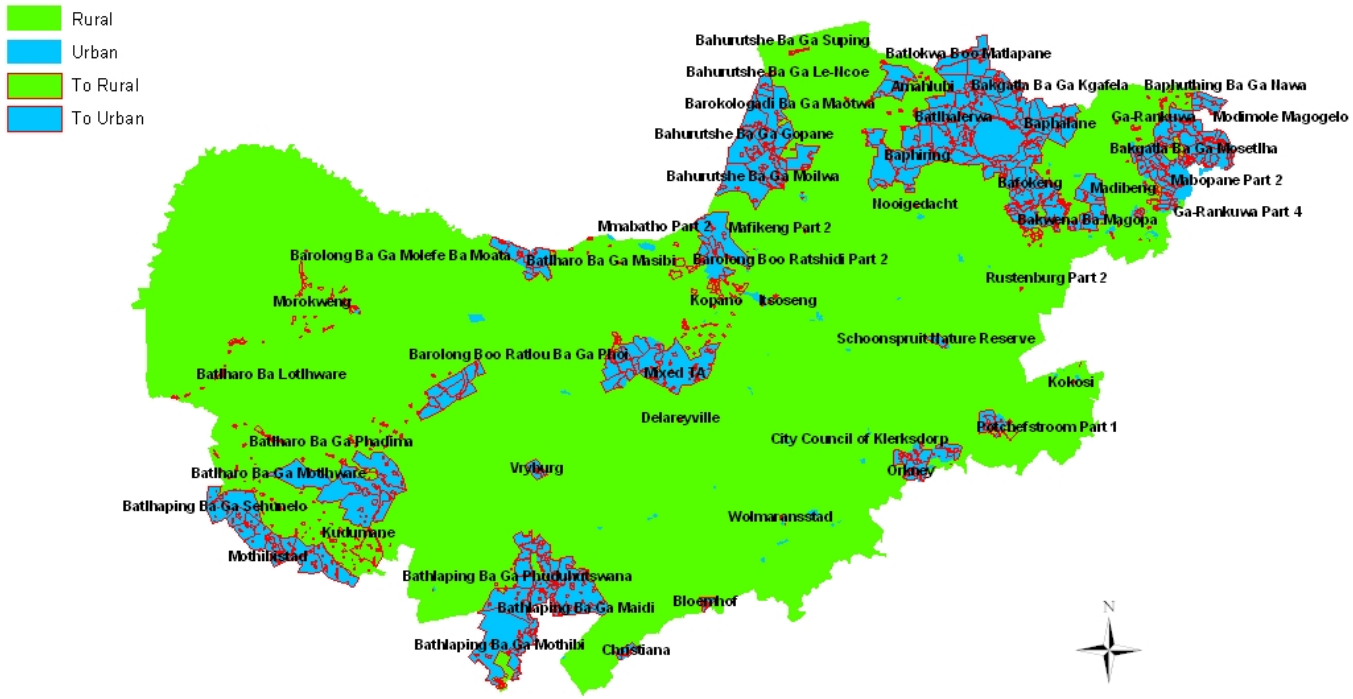
Limpopo – Map 4.3.1 (d)

For Limpopo for sample 1, straight-majority-rule iterates 10 times before reaching stability. In the first iteration 26% EAs changed classifications, 22% changed from rural to urban and 28% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 21% at the initial un-iterated setting to 38% in the first iteration, whilst the urban population drops from 79% to 62%. For the other iterations smaller changes in population occur. These occur mainly in the tribal and vacant areas of Limpopo. For sample 2, the process iterates 4 times before reaching stability. The population percentages remain unchanged.

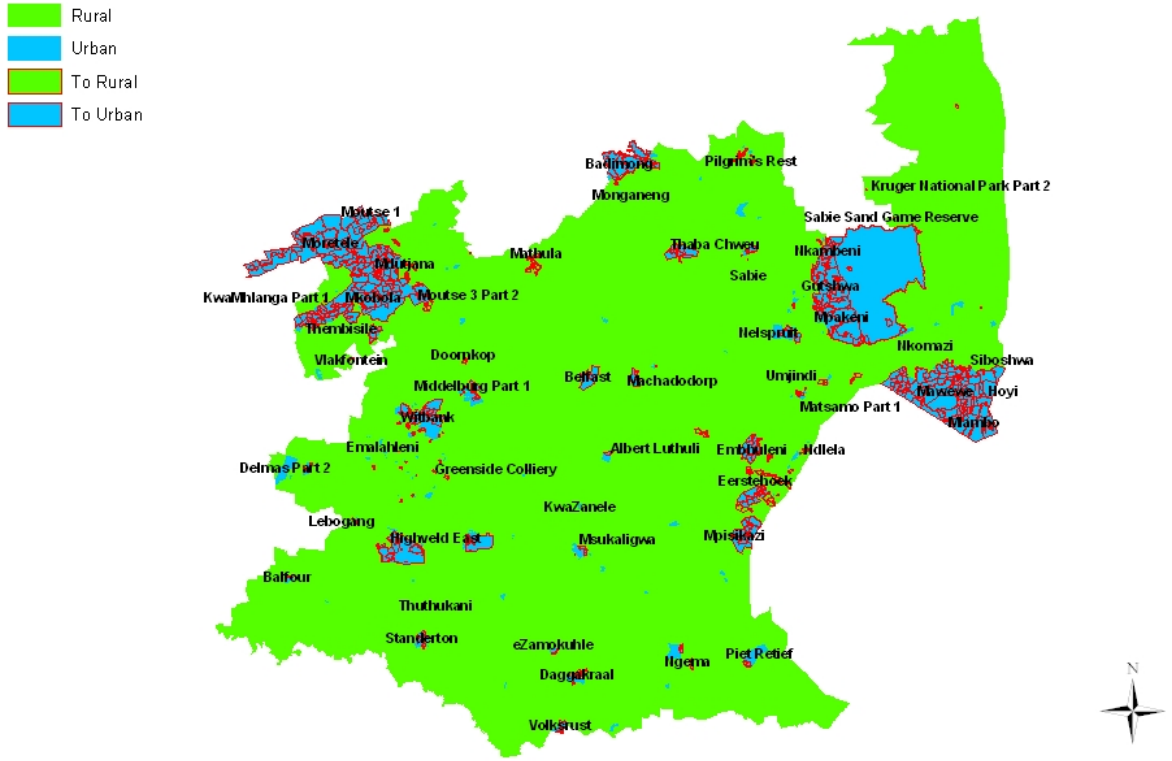
Map 4.3.1 (a) Urban and rural classification for Straight-Majority-Rule for Eastern Cape (sample 1, final iteration)



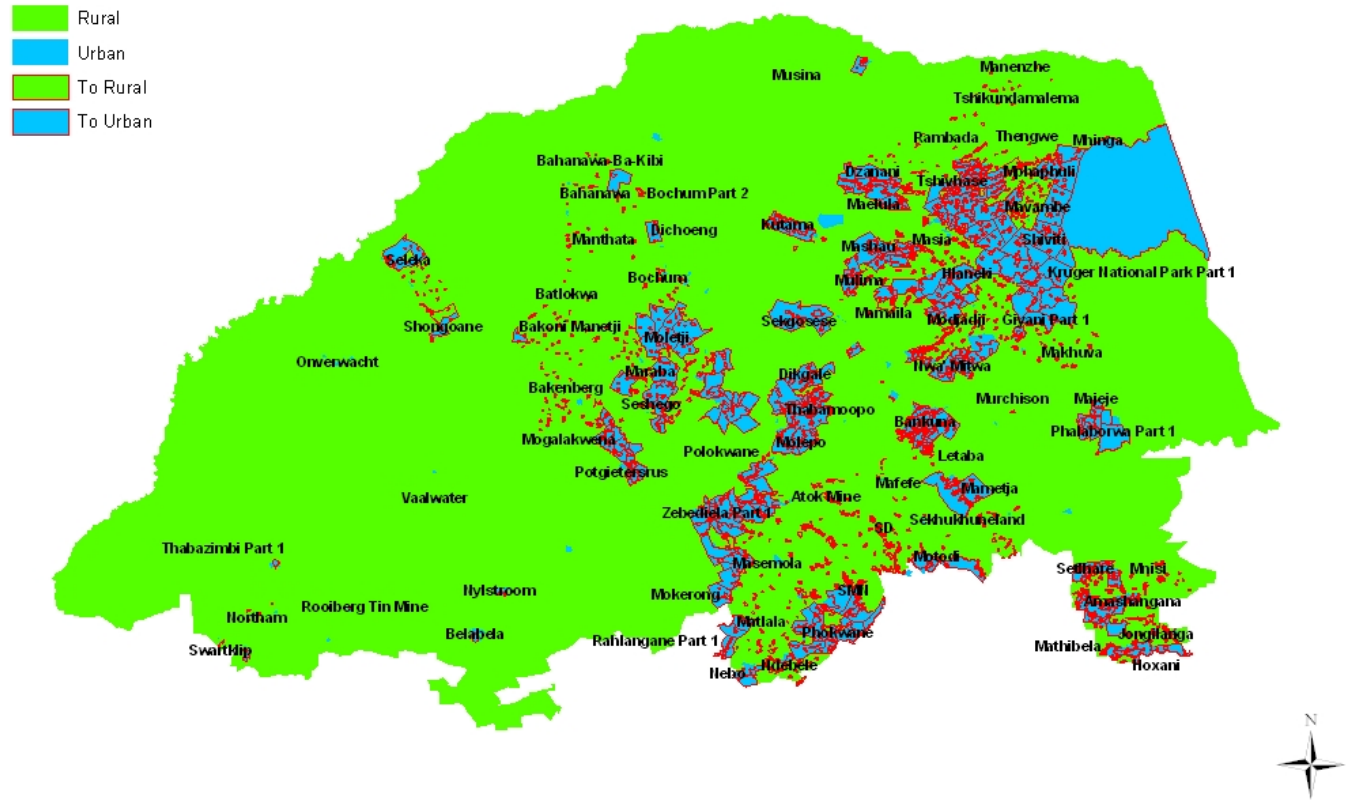
Map 4.3.1 (b) Urban and rural classification for Straight-majority-rule for North West (sample 1, final iteration)



Map 4.3.1 (c) Urban and rural classification for Straight-majority-rule for Mpumalanga (sample 1, final iteration)



Map 4.3.1 (d) Urban and rural classification for Straight-majority-rule for Limpopo (sample 1, final iteration 1)



4.3.2 Results for ICM

Based on the methodology described in Chapter 2, ICM was applied for each province and for South Africa as a whole. The tables below are similar to those presented in section 4.3.1. Tables 4.3.2.1-10 (Part 1) show the number of EAs that changed from the original classification for each province and for South Africa, in this case the original classification was the results as obtained from the non-spatial statistical method, that is discriminant analysis. Tables 4.3.2.1-10 (Part 2) show the aggregated population for the original classification (iteration 0) and for other iterations as a result of the changes in EA classification. Table 4.3.2.11 shows the number (and percentage) of correctly and incorrectly classified EAs for ICM, for each province and for South Africa.

In general, the results are very similar to those obtained for straight-majority-rule. However, comparing Tables 4.3.1.11 and 4.3.2.11 there are more correctly classified EAs for ICM for all provinces than for straight-majority-rule. In some cases, for example the Eastern Cape, KwaZulu-Natal, Limpopo and Mpumalanga, the number of iterations is less for ICM than straight-majority-rule.

Table 4.3.2.1 (Part 1) Western Cape - Comparison of the number of EAs that changed for ICM

		Iterations			
		0	**1**	**2**	**3**
Western Cape (Sample 1 - Urban-Farm)					
No. of EAs that changed:					
Rural to Urban		249	113	3	0
Urban to Rural		880	3	0	0
TOTAL		1129	116	3	0
% EAs that changed:					
Rural to Urban	%		45	1	0
Urban to Rural	%		0	0	0
TOTAL	%		10	0	0
Western Cape (Sample 2 - Urban-Farm-Tribal)					
No. of EAs that changed:					
Rural to Urban		249	114	3	0
Urban to Rural		880	2	0	0
TOTAL		1129	116	3	0
% EAs that changed:					
Rural to Urban	%		46	1	0
Urban to Rural	%		0	0	0
TOTAL	%		10	0	0

Table 4.3.2.1 (Part 2) Western Cape - Comparison of the population changes for ICM

		Iterations			
		0	1	2	3
Western Cape (Sample 1 - Urban-Farm)					
Rural		461328	444663	443501	443501
Urban		4062987	4079652	4080814	4080814
TOTAL		4524315	4524315	4524315	4524315
Rural	%	10	10	10	10
Urban	%	90	90	90	90
TOTAL	%	100	100	100	100
Western Cape (Sample 2 - Urban-Farm-Tribal)					
Rural		461328	443185	442023	442023
Urban		4062987	4081130	4082292	4082292
TOTAL		4524315	4524315	4524315	4524315
Rural	%	10	10	10	10
Urban	%	90	90	90	90
TOTAL	%	100	100	100	100

Table 4.3.2.2 (Part 1) Eastern Cape - Comparison of the number of EAs that changed for ICM

		Iterations									
		0	1	2	3	4	5	6	7	8	9
Eastern Cape (Sample 1 - Urban-Farm)											
No. of EAs that changed:											
Rural to Urban		8962	412	85	19	6	5	5	2	1	0
Urban to Rural		5858	1322	130	27	4	1	0	0	0	0
TOTAL		14820	1734	215	46	10	6	5	2	1	0
% EAs that changed:											
Rural to Urban	%		5	1	0	0	0	0	0	0	0
Urban to Rural	%		23	2	0	0	0	0	0	0	0
TOTAL	%		12	1	0	0	0	0	0	0	0
Eastern Cape (Sample 2 - Urban-Farm-Tribal)											
No. of EAs that changed:											
Rural to Urban		4379	34	1	0						
Urban to Rural		739	30	1	0						
TOTAL		5118	64	2	0						
% EAs that changed:											
Rural to Urban	%		1	0	0						
Urban to Rural	%		4	0	0						
TOTAL	%		1	0	0						

Table 4.3.2.2 (Part 2) Eastern Cape - Comparison of the population changes for ICM

		Iterations									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Eastern Cape (Sample 1 - Urban-Farm)											
Rural		2142233	2561230	2593625	2603517	2603499	2603040	2601321	2600840	2600620	2600620
Urban		4294463	3875466	3843070	3833179	3833197	3833656	3835375	3835856	3836076	3836076
TOTAL		6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696	6436696
Rural	%	33	40	40	40	40	40	40	40	40	40
Urban	%	67	60	60	60	60	60	60	60	60	60
TOTAL	%	100	100	100	100	100	100	100	100	100	100
Eastern Cape (Sample 2 - Urban-Farm-Tribal)											
Rural		4118891	4113315	4112133	4112133						
Urban		2317805	2323381	2324563	2324563						
TOTAL		6436696	6436696	6436696	6436696						
Rural	%	64	64	64	64						
Urban	%	36	36	36	36						
TOTAL	%	100	100	100	100						

Table 4.3.2.3 (Part 1) Northern Cape - Comparison of the number of EAs that changed for ICM

		Iterations			
		0	1	2	3
Northern Cape (Sample 1 - Urban-Farm)					
No. of EAs that changed:					
Rural to Urban		78	25	0	
Urban to Rural		116	1	0	
TOTAL		194	26	0	
% EAs that changed:					
Rural to Urban	%		32	0	
Urban to Rural	%		1	0	
TOTAL	%		13	0	
Northern Cape (Sample 2 - Urban-Farm-Tribal)					
No. of EAs that changed:					
Rural to Urban		71	21	3	0
Urban to Rural		102	3	0	0
TOTAL		173	24	3	0
% EAs that changed:					
Rural to Urban	%		30	4	0
Urban to Rural	%		3	0	0
TOTAL	%		14	2	0

Table 4.3.2.3 (Part 2) Northern Cape - Comparison of the population changes for ICM

		Iterations			
		0	1	2	3
Northern Cape (Sample 1 - Urban-farm)					
Rural		150122	148982	148982	
Urban		672597	673737	673737	
TOTAL		822719	822719	822719	
Rural	%	18	18	18	
Urban	%	82	82	82	
TOTAL	%	100	100	100	
Northern Cape (Sample 2 - Urban-farm-tribal)					
Rural		156876	155232	155229	155229
Urban		665843	667487	667490	667490
TOTAL		822719	822719	822719	822719
Rural	%	19	19	19	19
Urban	%	81	81	81	81
TOTAL	%	100	100	100	100

Table 4.3.2.4 (Part 1) Free State - Comparison of the number of EAs that changed for ICM

		Iterations			
		0	1	2	3
Free State (Sample 1 - Urban-Farm)					
No. of EAs that changed:					
Rural to Urban		1364	1280	23	0
Urban to Rural		0	0	0	0
		1364	1280	23	0
% EAs that changed:					
Rural to Urban	%		94	2	0
Urban to Rural	%		0	0	0
TOTAL	%		94	2	0
Free State (Sample 2 - Urban-Farm-Tribal)					
No. of EAs that changed:					
Rural to Urban		121	50	3	0
Urban to Rural		656	28	0	0
		777	78	3	0
% EAs that changed:					
Rural to Urban	%		41	2	0
Urban to Rural	%		4	0	0
TOTAL	%		10	0	0

Table 4.3.2.4 (Part 2) Free State - Comparison of the population changes for ICM

		Iterations			
		0	1	2	3
Free State (Sample 1 - Urban-Farm)					
Rural		1006256	391114	387569	387569
Urban		1700509	2315651	2319196	2319196
TOTAL		2706765	2706765	2706765	2706765
Rural	%	37	14	14	14
Urban	%	63	86	86	86
TOTAL	%	100	100	100	100
Free State (Sample 2 - Urban-Farm-Tribal)					
Rural		675802	661685	660876	660876
Urban		2030963	2045080	2045889	2045889
TOTAL		2706765	2706765	2706765	2706765
Rural	%	25	24	24	24
Urban	%	75	76	76	76
TOTAL	%	100	100	100	100

Table 4.3.2.5 (Part 1) KwaZulu-Natal - Comparison of the number of EAs that changed for ICM

		Iterations				
		0	**1**	**2**	**3**	**4**
KwaZulu-Natal (Sample 1 - Urban-Farm)						
No. of EAs that changed:						
Rural to Urban		4465	105	9	0	0
Urban to Rural		3530	264	25	3	0
TOTAL		7995	369	34	3	0
% EAs that changed:						
Rural to Urban	%		2	0	0	0
Urban to Rural	%		7	1	0	0
TOTAL	%		5	0	0	0
KwaZulu-Natal (Sample 2 - Urban-Farm-Tribal)						
No. of EAs that changed:						
Rural to Urban		1141	174	16	0	0
Urban to Rural		1209	115	6	1	0
TOTAL		2350	289	22	1	0
% EAs that changed:						
Rural to Urban	%		15	1	0	0
Urban to Rural	%		10	0	0	0
TOTAL	%		12	1	0	0

Table 4.3.2.5 (Part 2) KwaZulu-Natal - Comparison of the population changes for ICM

		Iterations				
		0	**1**	**2**	**3**	**4**
KwaZulu-Natal *(Urban-Farm)*						
Rural		3864900	3981392	3994462	3996523	3996523
Urban		5561091	5444599	5431529	5429468	5429468
TOTAL		9425991	9425991	9425991	9425991	9425991
Rural	%	41	42	42	42	42
Urban	%	59	58	58	58	58
TOTAL	%	100	100	100	100	100
KwaZulu-Natal *(Urban-Farm-Tribal)*						
Rural		5619928	5617604	5614250	5614436	5614436
Urban		3806063	3808387	3811741	3811555	3811555
TOTAL		9425991	9425991	9425991	9425991	9425991
Rural	%	60	60	60	60	60
Urban	%	40	40	40	40	40
TOTAL	%	100	100	100	100	100

Table 4.3.2.6 (Part 1) North West - Comparison of the number of EAs that changed for ICM

		Iterations					
		0	1	2	3	4	5
North West (Sample 1 - Urban-Farm)							
No. of EAs that changed:							
Rural to Urban		2261	127	22	4	1	0
Urban to Rural		1922	259	24	4	0	0
TOTAL		4183	386	46	8	1	0
% EAs that changed:							
Rural to Urban	%		6	1	0	0	0
Urban to Rural	%		13	1	0	0	0
TOTAL	%		9	1	0	0	0
North West (Sample 2 - Urban-Farm-Tribal)							
No. of EAs that changed:							
Rural to Urban		699	22	2	0		
Urban to Rural		301	12	1	0		
TOTAL		1000	34	3	0		
% EAs that changed:							
Rural to Urban	%		3	0	0		
Urban to Rural	%		4	0	0		
TOTAL	%		3	0	0		

Table 4.3.2.6 (Part 2) North West - Comparison of the population changes for ICM

		Iterations					
		0	1	2	3	4	5
North West *(Urban-Farm)*							
Rural		1338777	1422295	1425546	1427566	1427390	1427390
Urban		2330559	2247041	2243790	2241770	2241946	2241946
TOTAL		3669336	3669336	3669336	3669336	3669336	3669336
Rural	%	36	39	39	39	39	39
Urban	%	64	61	61	61	61	61
TOTAL	%	100	100	100	100	100	100
North West *(Urban-Farm-Tribal)*							
Rural		2299997	2293714	2293232	2293232		
Urban		1369339	1375622	1376104	1376104		
TOTAL		3669336	3669336	3669336	3669336		
Rural	%	63	63	62	62		
Urban	%	37	37	38	38		
TOTAL	%	100	100	100	100		

Table 4.3.2.7 (Part 1) Gauteng - Comparison of the number of EAs that changed for ICM

		Iterations			
		0	**1**	**2**	**3**
Gauteng (Sample 1 - Urban-Farm)					
No. of EAs that changed:					
Rural to Urban		242	42	0	
Urban to Rural		3279	3	0	
TOTAL		3521	45	0	
% EAs that changed:					
Rural to Urban	%		17	0	
Urban to Rural	%		0	0	
TOTAL	%		1	0	
Gauteng (Sample 2 - Urban-Farm-Tribal)					
No. of EAs that changed:					
Rural to Urban		235	70	5	0
Urban to Rural		3286	2	0	0
TOTAL		3521	72	5	0
% EAs that changed:					
Rural to Urban	%		30	2	0
Urban to Rural	%		0	0	0
TOTAL	%		2	0	0

Table 4.3.2.7 (Part 2) Gauteng - Comparison of the population changes for ICM

		Iterations			
		0	**1**	**2**	**3**
Gauteng *(Urban-Farm)*					
Rural		272071	256844	256844	
Urban		8565009	8580236	8580236	
TOTAL		8837080	8837080	8837080	
Rural	%	3	3	3	
Urban	%	97	97	97	
TOTAL	%	100	100	100	
Gauteng *(Urban-Farm-Tribal)*					
Rural		270812	253146	251838	251838
Urban		8566268	8583934	8585242	8585242
TOTAL		8837080	8837080	8837080	8837080
Rural	%	3	3	3	3
Urban	%	97	97	97	97
TOTAL	%	100	100	100	100

Table 4.3.2.8 (Part 1) Mpumalanga - Comparison of the number of EAs that changed for ICM

		Iterations					
		0	**1**	**2**	**3**	**4**	**5**
Mpumalanga (Sample 1 - Urban-Farm)							
No. of EAs that changed:							
Rural to Urban		901	143	13	4	0	
Urban to Rural		2354	144	18	4	0	
TOTAL		3255	287	31	8	0	
% EAs that changed:							
Rural to Urban	%		16	1	0	0	
Urban to Rural	%		6	1	0	0	
TOTAL	%		9	1	0	0	
Mpumalanga (Sample 2 - Urban-Farm-Tribal)							
No. of EAs that changed:							
Rural to Urban		318	57	9	5	1	0
Urban to Rural		565	128	5	2	0	0
TOTAL		883	185	14	7	1	0
% EAs that changed:							
Rural to Urban	%		18	3	2	0	0
Urban to Rural	%		23	1	0	0	0
TOTAL	%		21	2	1	0	0

Table 4.3.2.8 (Part 2) Mpumalanga - Comparison of the population changes for ICM

		Iterations					
		0	**1**	**2**	**3**	**4**	**5**
Mpumalanga *(Urban-Farm)*							
Rural		932572	925193	928789	928899	928899	
Urban		2190381	2197760	2194164	2194054	2194054	
TOTAL		3122953	3122953	3122953	3122953	3122953	
Rural	%	30	30	30	30	30	
Urban	%	70	70	70	70	70	
TOTAL	%	100	100	100	100	100	
Mpumalanga *(Urban-Farm-Tribal)*							
Rural		1917959	1905090	1903043	1901531	1900952	1900952
Urban		1204995	1217863	1219910	1221422	1222001	1222001
TOTAL		3122953	3122953	3122953	3122953	3122953	3122953
Rural	%	61	61	61	61	61	61
Urban	%	39	39	39	39	39	39
TOTAL	%	100	100	100	100	100	100

Table 4.3.2.9 (Part 1) Limpopo - Comparison of the number of EAs that changed for ICM

		Iterations							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Limpopo (Sample 1 - Urban-Farm)									
No. of EAs that changed:									
Rural to Urban		2822	389	113	19	1	1	0	0
Urban to Rural		6431	1393	199	48	25	5	2	0
TOTAL		9253	1782	312	67	26	6	2	0
% EAs that changed:									
Rural to Urban	%		14	4	1	0	0	0	0
Urban to Rural	%		22	3	1	0	0	0	0
TOTAL	%		19	3	1	0	0	0	0
Limpopo (Sample 2 - Urban-Farm-Tribal)									
No. of EAs that changed:									
Rural to Urban		710	14	1	0				
Urban to Rural		241	76	2	0				
TOTAL		951	90	3	0				
% EAs that changed:									
Rural to Urban	%		2	0	0				
Urban to Rural	%		32	1	0				
TOTAL	%		9	0	0				

Table 4.3.2.9 (Part 2) Limpopo - Comparison of the population changes for ICM

		Iterations							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Limpopo (Sample 2 - Urban-Farm)									
Rural		1427287	2021314	2056172	2066039	2076695	2079677	2081413	2081413
Urban		3846272	3252245	3217387	3207521	3196865	3193882	3192146	3192146
TOTAL		5273559	5273559	5273559	5273559	5273559	5273559	5273559	5273559
Rural	%	27	38	39	39	39	39	39	39
Urban	%	73	62	61	61	61	61	61	61
TOTAL	%	100	100	100	100	100	100	100	100
Limpopo (Sample 2 - Urban-Farm-Tribal)									
Rural		4694252	4720839	4721862	4721862				
Urban		579307	552720	551697	551697				
TOTAL		5273559	5273559	5273559	5273559				
Rural	%	89	90	90	90				
Urban	%	11	10	10	10				
TOTAL	%	100	100	100	100				

Table 4.3.2.10 (Part 1) RSA - Comparison of the number of EAs that changed for ICM

		Iterations									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RSA (Sample 1 - Urban-Farm)											
No. of EAs that changed:											
Rural to Urban		20157	1349	116	8	0	0	0	0	0	0
Urban to Rural		25557	3743	761	233	104	51	21	21	7	0
TOTAL		45714	5092	877	241	104	51	21	21	7	0
% EAs that changed:											
Rural to Urban	%		7	1	0	0	0	0	0	0	0
Urban to Rural	%		15	3	1	0	0	0	0	0	0
TOTAL	%		11	2	1	0	0	0	0	0	0
RSA (Sample 2 - Urban-Farm-Tribal)											
No. of EAs that changed:											
Rural to Urban		9096	1146	122	26	5	2	1	3	1	0
Urban to Rural		6806	385	32	9	2	0	0	0	0	0
TOTAL		15902	1531	154	35	7	2	1	3	1	0
% EAs that changed:											
Rural to Urban	%		13	1	0	0	0	0	0	0	0
Urban to Rural	%		6	0	0	0	0	0	0	0	0
TOTAL	%		10	1	0	0	0	0	0	0	0

Table 4.3.2.10 (Part 2) RSA - Comparison of the population changes for ICM

								Iterations			
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rural		12656536	12701563	12823510	12863972	12879666	12888390	12890721	12894204	12895054	12895054
Urban		32162878	32117851	31995904	31955442	31939748	31931024	31928693	31925210	31924360	31924360
TOTAL		44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414
Rural	%	28	28	29	29	29	29	29	29	29	29
Urban	%	72	72	71	71	71	71	71	71	71	71
TOTAL	%	100	100	100	100	100	100	100	100	100	100
Rural		20678304	20464948	20426137	20416000	20414364	20413695	20413401	20412440	20412124	20412124
Urban		24141111	24354466	24393277	24403414	24405050	24405719	24406013	24406974	24407290	24407290
TOTAL		44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414	44819414
Rural	%	46	46	46	46	46	46	46	46	46	46
Urban	%	54	54	54	54	54	54	54	54	54	54
TOTAL	%	100	100	100	100	100	100	100	100	100	100

Table 4.3.2.11 Correctly and incorrectly classified EAs for ICM

	Sample 1					Sample 2				
	1		0		Total	1		0		Total
Western Cape										
1	5235	99%	30	1%	5265	5237	99%	28	1%	5265
0	74	10%	633	90%	707	74	10%	633	90%	707
Total	5309		663		5972	5311		661		5972
Eastern Cape										
1	2929	99%	39	1%	2968	2776	94%	192	6%	2968
0	56	10%	526	90%	582	64	1%	10220	99%	10284
Total	2985		565		3550	2840		10412		13252
Northern Cape										
1	922	98%	19	2%	941	911	97%	30	3%	941
0	33	9%	341	91%	374	32	8%	363	92%	395
Total	955		360		1315	943		393		1336
Free State										
1	2985	100%	6	0%	2991	2968	99%	23	1%	2991
0	49	6%	779	94%	828	45	3%	1370	97%	1415
Total	3034		785		3819	3013		1393		4406
KwaZulu-Natal										
1	3934	99%	23	1%	3957	3787	96%	170	4%	3957
0	77	10%	723	90%	800	84	1%	6361	99%	6445
Total	4011		746		4757	3871		6531		10402
North West										
1	1660	99%	20	1%	1680	1587	94%	93	6%	1680
0	34	13%	580	94%	614	58	2%	3739	98%	3797
Total	1694		2092		2294	1645		3832		5477
Gauteng										
1	9411	100%	13	0%	9424	9412	100%	12	0%	9424
0	61	24%	196	76%	257	62	24%	195	76%	257
Total	9472		209		9681	9474		207		9681
Mpumalanga										
1	1716	98%	33	2%	1749	1630	93%	119	7%	1749
0	58	8%	666	92%	724	51	2%	3045	98%	3096
Total	1774		699		2473	1681		3164		4845
Limpopo										
1	748	98%	13	2%	761	689	91%	72	9%	761
0	33	7%	418	93%	451	124	1%	8629	99%	8753
Total	781		431		1212	813		8701		9514
RSA										
1	29535	99%	201	1%	29736	28708	97%	1028	3%	29736
0	571	11%	4766	89%	5337	814	2%	34335	98%	35149
Total	30106		4967		35073	29522		35363		64885

Similar to section 4.3.1, the maps below represent a selection of a few provinces, where the changes in EA classification have a large impact on the population aggregates. The final iteration for each province is mapped. The red polygons on the map show areas that have changed.

Eastern Cape – Map 4.3.2 (a)

For the Eastern Cape for sample 1, ICM iterates 9 times before reaching stability. In the first iteration 12% of EAs changed classifications, 5% changed from rural to urban and 23% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 33% at the initial un-iterated setting to 40% in the first iteration, whilst the urban population drops from 67% to 60%. For the other iterations there are smaller or no changes in population aggregates. Changes have mainly occurred in the tribal and vacant areas of the Eastern Cape. For sample 2, the process iterates 3 times before reaching stability. The population percentages remain unchanged.

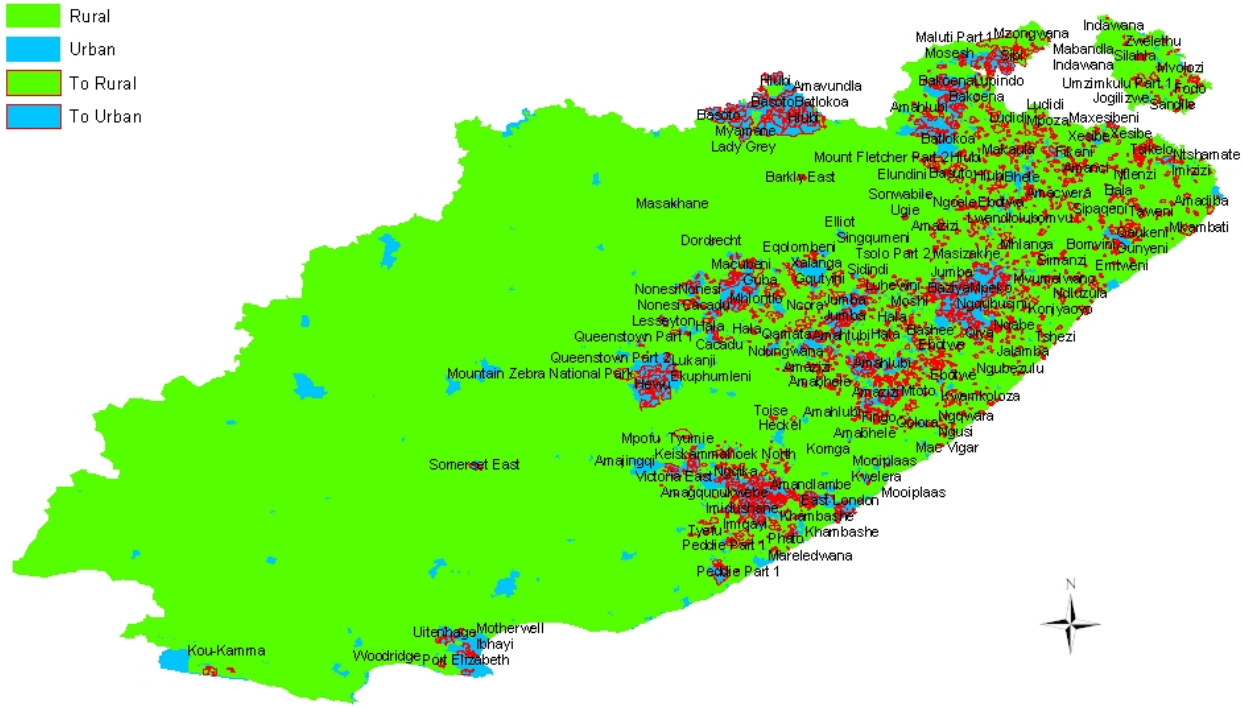
Free State – Map 4.3.2 (b)

For the Free State for sample 1, ICM iterates 3 times before reaching stability. In the first iteration 94% of EAs changed from rural to urban. The largest difference in population occurs in the first iteration where the rural population decreases from 37% at the initial un-iterated setting to 14% in the first iteration, whilst the urban population rises from 63% to 86%. For the other iterations there are smaller or no changes in population aggregates. This has mainly occurred in the tribal and vacant areas of the Free State. For sample 2, the process iterates 3 times before reaching stability. The population percentages show small changes or remain unchanged.

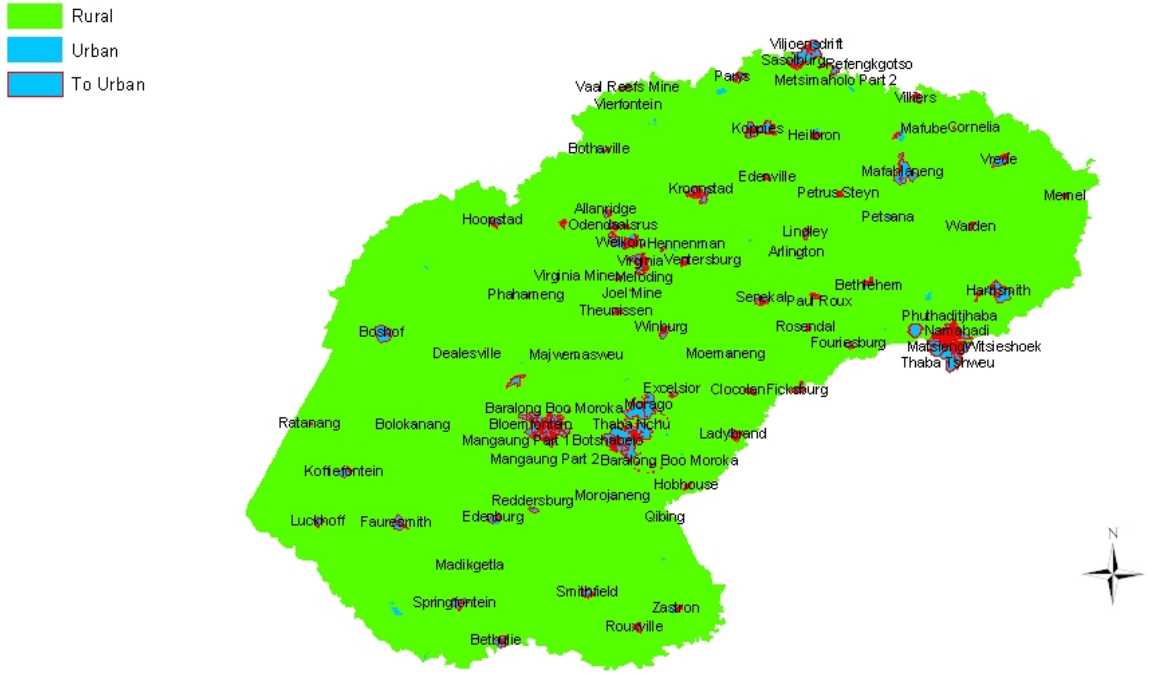
Limpopo – Map 4.3.2 (c)

For Limpopo for sample 1, ICM iterates 7 times before reaching stability. In the first iteration 9% of EAs changed classification, 2% changed from rural to urban and 32% from urban to rural. The largest difference in population occurs in the first iteration where the rural population increases from 27% at the initial un-iterated setting to 38% in the first iteration, whilst the urban population drops from 73% to 62%. For the other iterations there are smaller or no changes in population aggregates. This has mainly occurred in the tribal and vacant areas of Limpopo. For sample 2, the process iterates 3 times before reaching stability. The population percentages show small changes or remain unchanged.

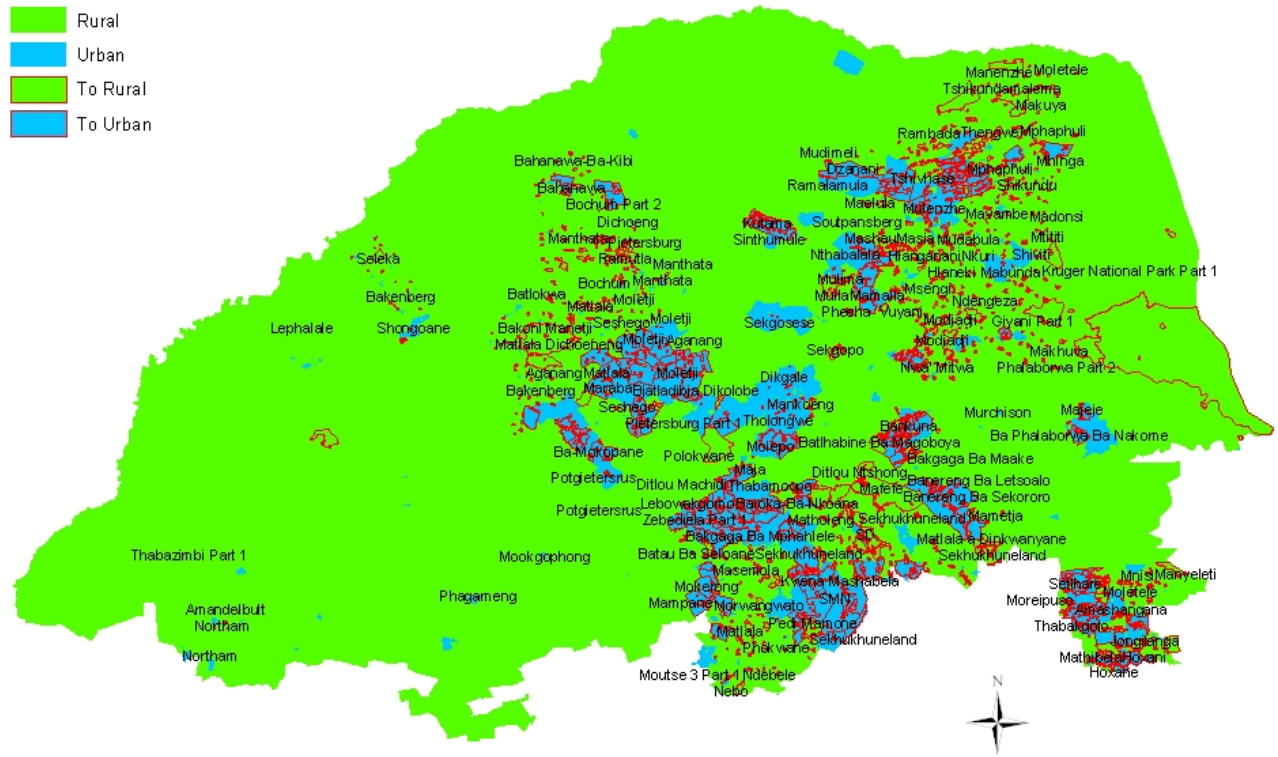
Map 4.3.2 (a) Urban and rural classification for ICM for Eastern Cape (sample 1, final iteration)



Map 4.3.2 (b) Urban and rural classification for ICM for the Free State (sample 1, final iteration)



Map 4.3.2 (c) Urban and rural classification for ICM for Limpopo (sample 1, final iteration)



4.4 Chapter summary and conclusion

In this chapter the spatial statistical techniques, i.e. *straight-majority-rule* and *ICM,* are applied to each province and South Africa for both samples. The changes in EA classifications, the correctly and incorrectly classified EAs and changes in aggregated population as a result of changes in the EA classification are tabled. Maps showing areas of change are also presented.

In general, for both methods and both samples, most provinces show that many EAs, i.e. unknown status EAs, have changed urban/rural status, mainly in the first iteration. Although some provinces show large changes in the EA classification, these changes have little or no impact on the population aggregations. This is mainly due to changes of low population rural EAs to urban. Some provinces, on the other hand, show the opposite, where smaller changes in EA classification have a larger impact on the population aggregates. Although sample 2 shows changes in the EA classifications these changes have little or no impact on the population aggregates.

Comparing the misclassified EAs for both spatial methods, shows that there are fewer misclassified EAs for ICM than for straight-majority-rule, therefore ICM has performed better. Comparing the misclassified EAs for the spatial classification, i.e. ICM, with those obtained for the non-spatial classification namely discriminant analysis, for Sample 1, shows that for six provinces, that is Western Cape, Free State, Kwazulu-Natal, Gauteng, Mpumalanga and Limpopo as well as for South Africa, there are fewer or the same number of misclassified EAs for ICM, therefore in these cases the spatial classifications have improved the results. In the cases of the Eastern Cape and North West for the rural classifications, there are more misclassified EAs for ICM, i.e. the non-spatial classifications performed better, whilst ICM performed better for the urban classifications. Northern Cape shows the opposite. For Sample 2, ICM i.e. the spatial classification, shows better results for all provinces and South Africa, implying that the application of spatial methods does improve the classifications.

Comparing the misclassified EAs for the spatial classification, i.e. straight-majority-rule, with those obtained for the non-spatial classifications (i.e. the best classifications as obtained from linear logistic regression, classification trees or discriminant analysis), for both samples, shows that for most provinces the non-spatial classifications have performed slightly better.

CHAPTER 5 -*Discussion, Recommendations and Conclusions*

5.1 Introduction

The main objective of this study was to *utilise appropriate statistical techniques to classify areas in South Africa into urban and rural*. Both non-spatial, i.e. *linear logistic regression*, *classification trees* and *discriminant analysis*, and spatial, i.e. *straight-majority-rule* and *iterated conditional modes (ICM),* statistical methodologies were investigated and applied to selected 2001 census data. These areas, as derived from each statistical method, were profiled and common characteristics amongst them were summarised for classification and definitions of urban and rural areas. Population data were aggregated to determine the overall urbanisation for the country.

Both methodologies, i.e. non-spatial and spatial, made use of areas in the country that are known with certainty to be urban and rural. The importance of utilising areas of known urban and rural status was to firstly identify essential patterns or predominant characteristics from areas that are known, and thereafter apply similar characteristics to areas that are not known or are ambiguous, in order to classify them as either urban or rural. Two different sample data sets were generated and used for all statistical analyses. Stats SA's 2001 census EA-types were used to generate the samples of knowns. The first sample data set, known as *Sample 1* or *urban-farm,* comprised the urban settlements (as urban) and farm (as rural) EA-types. The second sample data set was known as *Sample 2* or *urban-farm-tribal*. It comprised, in addition to that mentioned for sample 1, the tribal settlements (as rural).

5.2 Discussion

5.2.1 Discussion on the non-spatial statistical methods, i.e. linear logistic regression, classification trees and discriminant analysis

Stepwise linear logistic regression, classification trees and stepwise discrimination were applied to both samples' training data sets of knowns, and their validation data sets of knowns were used to test the models, from which the numbers of correctly and incorrectly classified EAs were estimated and analysed. Results were weighted with data as obtained from the 2001 census to produce population figures. Results were presented for both samples, for each province and for South Africa as a whole.

All three non-spatial statistical methods gave insight into those census variables or combinations thereof that best describe the subject under research, i.e. urban and rural. Of these three methods, linear logistic regression and discriminant analysis clearly identified significant variables for urban (increasing the odds of urban) and for rural (decreasing the odds of urban), whilst classification trees provide sets of quantitative rules for assigning areas to the two classes. In this regard linear logistic regression and discriminant analysis are preferred. The results of all three methods showed similarities within the samples. Differences were, however, noted between the samples. This was evident in the significant variables, aggregated population figures and to some extent in the misclassification rates obtained (see chapter 3). Thus one can deduce that the various statistical methods did not impact as much on the final results as the constitution of the two samples.

The results obtained for the two samples are very different. Sample 1 contained a smaller number of known EAs and more unknown status EAs than sample 2 (see Table 3.2.1). The only difference between the two samples was the inclusion of tribal settlements as known rural in sample 2. This implies that tribal settlements for sample 1 were scored from the characteristics of sample 1 (urban and farm settlements). Analysing the results further shows that many tribal settlements have been classified as urban. (See Chapter 3 Section 3.3.6 Map analysis. For example, for South Africa, approximately 40% of the tribal population, which was rural in the 2001 census classification, was classified as urban when linear logistic regression was applied.) Generally all three statistical methods applied to sample 1 have classified the majority of the tribal EAs as urban.

The results obtained for sample 2, classify fewer unknown status EAs, and the results are very similar to those obtained for both censuses, since both censuses and sample 2 predefine tribal settlements as rural. This implies to some extent that the classifications of unknown status EAs for sample 2, as scored from the statistical methods, are similar to the classifications assigned by the censuses (which were termed in the beginning of the study as being *subjective*). Since the classification of tribal settlements can swing the results drastically (which is evident from the study results), more attention should be given to correctly classifying important EA-types such as urban and tribal settlements, more especially the tribal settlements.

5.2.2 Discussion on the spatial statistical methods, i.e. straight-majority-rule and iterated conditional modes

Since the classification of areas into urban and rural is a spatial matter, it was important to explore the impact of similarities amongst adjacent areas on the classifications. Two statistical methods were investigated and applied, i.e. straight-majority-rule and iterated conditional modes (ICM). Straight-majority-rule is an iterated procedure that makes use of the majority urban/rural status of neighbouring EAs to determine the urban or rural status of an unknown status EA. Whilst ICM is similar, the method is fully Bayesian. The density function from the non-spatial statistical technique, i.e. discriminant analysis, was used for the likelihood function. For the prior probability the Markov Random Field model, as stated in Besag (1986), was adapted for this application. All known status EAs were kept fixed during the iterations. Their status was, however, used to calculate the class of unknown status EAs. In order to get a sense of the number of correctly and incorrectly classified EAs, the EAs of known urban/rural status were iterated once after the final iteration to recalculate their new (iterated) status. Comparisons were made with their original known status and misclassification rates were inferred. Results were presented for both samples, for each province and for South Africa as a whole.

The results obtained for both spatial methods were similar. For both methods most changes in classifications occurred in the first iteration. For sample 1, although some provinces show large changes in EA classification, these changes have almost no impact on the aggregated population totals. This is mainly the result of low population rural EAs changing status. On the other hand, in some provinces the opposite is true; smaller changes in classifications result in a large impact on the population aggregates. EAs that changed classifications mainly occurred for tribal settlements and vacant areas. Sample 2, for both methods, shows that although there are substantial changes in classifications, these changes have in most cases no impact on the population aggregates; in fact the population totals for each iteration remained stable.

It is, however, noticeable that the numbers of correctly classified EAs are improved when ICM is applied. This is mainly the result of utilising more information through the Bayesian approach. ICM also resulted in fewer iterations.

5.2.3 Discussion on both non-spatial and spatial statistical methodologies

Classifications of areas into urban or rural were accomplished with both methodologies. In addition, the non-spatial statistical methods provided more information on the census variables that describe or characterise (or even define) urban and rural. The spatial statistical methods further refine (or smooth) the classifications by utilising similarities of adjacent classifications. As is evident from the results obtained in Chapter 4, comparing the misclassified EAs for both spatial methods with those of the non-spatial methodologies for both samples, shows fewer misclassified EAs for ICM than for straight-majority-rule. Of the two spatial methods, ICM has therefore performed best. Thus the conclusion can be made that applying spatial methodologies that are fully Bayesian does improve the classifications.

5.2.4 Discussion on both sample 1 and sample 2

Basing all applications and analyses on the two training samples, afforded us the opportunity to compare outcomes. These comparisons have enabled us to conclude that the various statistical methods do not impact on the study as much as the constitution of the two training samples. The results for the two sets of analysis therefore differ mainly as a result of the sample selection.

The only difference between sample 1 and sample 2 is the inclusion of the tribal areas in sample 2, classified as known rural. For sample 1, the classification of tribal areas is not predefined, as in the case of sample 2; but is based on the characteristics of urban settlements and farms. When sample 1 is used, a large proportion of tribal areas are classified statistically as urban areas, a typical example is the case of the Eastern Cape province which shows drastic changes from mainly rural to largely urban, when changing from sample 2 to sample 1. This implies that these tribal areas are not in the same profile as farms where typically agricultural activities are the main source of income and livelihood. Some tribal areas tend to resemble townships since they are more formal in layout, dwellings are constructed from brick and corrugated iron, with basic services (such as electricity and water) and limited infrastructure (such as roads, but untarrred), and they are high in density. However, since tribal areas fall within the jurisdiction of tribal authorities and under traditional leadership, in the RSA these areas are classed as rural and it might be incorrect to class them as urban. The trend by the younger generation from traditional areas to move to more urban or built up areas to find employment, also affects urbanisation in the traditional areas i.e. rural-urban

migration. Since in most cases urban areas are developed for “commercial or administrative purposes” (Smit 1979) and currently tribal areas have little or no commercial development (in fact they still remain largely unintegrated with the urban hierarchy) implies that such areas are still predominantly rural. Smit (1979) also noted the long distances of such areas from cities or towns. United Nations (2006) mentions that urban areas are usually “a higher standard of living than are found in rural areas”.

The impact of South Africa’s apartheid past was captured by SPP (1983) “ … even if the relocation were suddenly to come to an end, it would not alter the position of millions of people already relocated, nor undermine, substantially the major restructuring of South Africa into a ‘white’ core and ten ethnic Bantustans on the periphery that is already far advanced.” According to Murray (1987) such tribal areas maybe considered ‘urban’ due to the “sheer density of population concentrated there … ‘urban’ in respect of their population densities but ‘rural’ in respect of the absence of proper urban infrastructure or services”. This is certainly observable from the results of the study. When sample 1 was applied large proportions of tribal areas were classified as urban, ‘urban’ mainly as a result of large population densities and ‘rural’ due to its poor infrastructure and services, described by SPP (1983) as “… a place to stay with no economic base …”, in areas that were previously reserved to relocate several hundred thousand people during the apartheid era. South Africa’s previous apartheid ‘”reserve” areas still suffers from lack of development that can classify them as urban in the normal sense of the word.

Utilising the two samples, it is evident from the results that the classification of tribal settlements can swing the results drastically, it can be argued that due to this, there is opportunity to include a third classification category for tribal areas, in addition to urban and farm settlements.

Taking the above statements of Smit and SPP into consideration, it can be accepted that sample 2, with tribal areas predefined as rural, more realistically depicts the situation in this country, and thus provides more realistic classifications and definitions for urban and rural.

For sample 1, although tribal areas show the most significant change in classification from rural to urban, smaller changes are noted for EA types such as institutions, hostels and smallholdings. These changes are mainly attributed to high densities.

5.2.5 Discussion on the application and analysis per province and for South Africa as a whole

At the beginning of the study it was decided to apply the statistical techniques and analyse the results per province and for South Africa as a whole. The motivation for this was that South Africa's provinces have varying characteristics and it was hoped that the study could highlight these.

Here again the constitution of the samples dominated the results, that is the statistical methods in most cases showed very similar results for any particular province, the differences being mainly between the samples.

Observing the results from Chapters 3 and 4 shows that, in general, within each of the samples the classifications for the RSA as a whole performs more or less similarly compared to the separate provincial classifications, with the exception of Gauteng, where the rural misclassifications are very high.

5.3 Meeting the study objectives

The objectives of the study as mentioned above and in Chapter 1 can be broken down as follows:

- Classification of areas using appropriate statistical methods to determine urban and rural areas in the country
- Definitions for urban and rural by investigating common characteristics from the results obtained from the statistical methods
- The overall urbanisation for the country

Has the study met the objectives?

- *Classification of areas using appropriate statistical methods to determine urban and rural areas in the country*

  The classifications were achieved and are strictly that of the chosen approach for this research study, that is, supervised classifications applying both non-spatial and spatial statistical methods. For the non-spatial statistical

methodologies, the unknown status areas were classified into urban or rural based on the models derived from the sample data sets of known areas. The spatial statistical methodologies classified unknown status areas into urban or rural based on their neighbourhoods and probabilities. In other words, this research study includes five different classifications (classifications were done per province and for South Africa as a whole, as well as for each sample, i.e. sample 1 and 2).

- *Definitions for urban and rural by investigating common characteristics from results obtained from statistical methods*

  The study approaches did not explicitly derive definitions for urban and rural. Census attributes (from a selection of those available from the census) that have significance on the classifications, can in general be used to describe the characteristics of urban and rural (see Chapter 3). Studying the coefficients obtained from the linear logistic regression and discriminant analysis models to help infer new definitions of urban and rural, would be a useful extension of this study.

- *The overall urbanisation for the country*

  With this objective it was envisaged that aggregating population data from the 2001 census, based on the various classifications, could approximate the overall urbanisation. Fair (1982) describes *urbanisation as the geographic concentration of population* and non-agricultural activities in urban environments of varying size and form. Clarke (1972) states amongst the six definitions that urbanisation is the proportion of the total population living in urban centres. In line with the above, Tables 5.1 (a) and (b) show a summary of the population percentages for urban and rural, for each statistical method, for each province and South Africa as a whole, for sample 1 and 2.

5.4 Utilising the results of the study

The study approach (the utilisation of areas of known urban and rural status to model other areas that are not known) and methodologies (supervised classifications, non-spatial, i.e. linear logistic regression, classification trees and discriminant analysis, and spatial, i.e. straight-majority-rule and ICM) form the basis of this study and its results.

In general, the results of the study can be utilised to derive the following information on the subject:

- Comparisons of three different non-spatial statistical methods, applied to urban and rural classifications for each province and for South Africa for two samples. This is seen in the aggregations of population figures based on the classifications in tables 3.3.5 (a) and (b).
- Further refinement of classifications derived from the non-spatial methods by applying spatial methods.
- Comparisons of misclassifications.
- Comparisons of results with those obtained from the censuses.
- Census 2001 attributes that describe characteristics of urban, farm and tribal settlements.
- Spatial distributions of urban and rural (map analysis).
- Comparative outcomes of sampling methods on the study topic or generally the impact of sampling methodologies on statistical results.
- Finally, actual classification of each EA in South Africa as urban or rural.

5.5 Limitations of the study

The main limitation of the study was the method of drawing the samples of known areas, i.e. the use of census 2001 EA-types. This resulted in sample 1 covering 43% and sample 2 80% of the total number of EAs in South Africa. Therefore sample 2 covered a very small proportion of unknown areas that required classification.

5.6 Taking the study further

The study can be taken further in the following ways:

- Explore the opportunity of including a third classification for tribal areas, in addition to urban and farm settlements.
- Since this study explored only supervised methods of classification, the unsupervised methodologies might be explored as a different approach.
- Appropriate methodologies can be explored that can break down urban and rural into subcomponents or segments.
- The possibility can be explored of utilising other data sources, e.g. deeds, municipal and property value data, with census information in the classifications.

5.7 Chapter summary and conclusion

The study was about classifying and defining urban and rural in South Africa by means of different statistical approaches. This was achieved by applying supervised classifications, i.e. non-spatial and spatial statistical methodologies. The study has generated at least five different classifications, with aggregated population figures for each province and for South Africa as a whole for two sample data sets, and has identified significant census variables that are important in classifications into urban and rural.

Table 5.1 (a) Summary table for sample 1: Population percentages for urban and rural for each statistical method for each province and South Africa

			Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	RSA
Non-spatial	Linear logistic regression	% Rural	10	4	18	15	46	33	4	30	21	34
		% Urban	90	96	82	85	54	67	96	70	79	66
		TOTAL	100	100	100	100	100	100	100	100	100	100
	Classification trees	% Rural	10	6	18	15	31	11	2	18	7	10
		%Urban	90	94	82	85	69	89	98	82	93	90
		TOTAL	100	100	100	100	100	100	100	100	100	100
	Discriminant analysis	% Rural	10	33	18	37	41	36	3	30	27	28
		% Urban	90	67	82	63	59	64	97	70	73	72
		TOTAL	100	100	100	100	100	100	100	100	100	100
Spatial	Straight-majority-rule	% Rural	10	43	19	16	49	18	4	22	40	38
		% Urban	90	57	81	84	51	82	96	78	60	62
		TOTAL	100	100	100	100	100	100	100	100	100	100
	ICM	% Rural	10	40	18	14	42	39	3	30	39	29
		% Urban	90	60	82	86	58	61	97	70	61	71
		TOTAL	100	100	100	100	100	100	100	100	100	100

Table 5.1 (b) Summary table for sample 2: Population percentages for urban and rural for each statistical method for each province and South Africa

			Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	RSA
Non-spatial	Linear logistic regression	% Rural	10	63	19	25	58	62	4	60	90	44
		% Urban	90	37	81	75	42	38	96	40	10	56
		TOTAL	100	100	100	100	100	100	100	100	100	100
	Classification trees	% Rural	10	63	19	25	58	63	2	62	90	45
		% Urban	90	37	81	75	42	37	98	38	10	55
		TOTAL	100	100	100	100	100	100	100	100	100	100
	Discriminant analysis	% Rural	10	64	19	25	60	63	3	61	89	46
		% Urban	90	36	81	75	40	37	97	39	11	54
		TOTAL	100	100	100	100	100	100	100	100	100	100
Spatial	Straight-majority-rule	% Rural	10	63	19	25	57	63	4	61	90	45
		% Urban	90	37	81	75	43	37	96	39	10	55
		TOTAL	100	100	100	100	100	100	100	100	100	100
	ICM	% Rural	10	64	19	24	60	62	3	61	90	46
		% Urban	90	36	81	76	40	38	97	39	10	54
		TOTAL	100	100	100	100	100	100	100	100	100	100

REFERENCES

Agresti, A. (1990). *Categorical data analysis*. John Wiley & Sons. USA.

Besag, J. (1986). *On the statistical analysis of dirty pictures*. **Royal Statistical Society**. 48, No. 3, pp. 259 – 302.

Besag, J. (1989). *Digital Image Processing. Towards Bayesian image analysis*. **Journal of Applied Statistics**, vol. 16, No. 3.

Bundy, C. (1979). *The rise and fall of the South African peasantry.* London: Heinemann.

Cacoullos, T. (1973). *Discriminant analysis and applications*. Academic Press. New York and London.

Clarke, J. I. (1972). *Population Geography*. 2nd Edition. Pergamon Press. England.

Cressie, N. A. C. (1993). *Statistics for spatial data*. Revised edition. United States of America. John Wiley & Sons, Inc.

Christensen, R. (1997). *Log-linear models and Logistic regression*. 2nd Edition. Springer text in Statistics.

Christopher, A. J. (1992). *The final phase of urban apartheid zoning in South Africa.* **South African Geographical Journal**.

Davies, R. J. (1967). *The South African urban hierarchy*. **South African Geographical Journal**. Vol. 49: 9-19.

Davies, R. J. & Cook, G. P. (1968). *Reappraisal of the South African urban hierarchy.* **South Africa Geographical Journal**. Vol. 50: 116-132.

Davies, R. J. & Young, B. S. (1969) *The economic structure of South African cities.* **South African Geographical Journal**. Vol. 51: 19-37.

Fatti, P. (2003). *Automatic interaction detection (AID)*. (Unpublished paper).

Fernandez, G. (2003). *Data mining using SAS Applications*. Chapman & Hall/CRC.

Fair, T. J. D. (1982). *South Africa: Spatial frameworks for development.* South African Geographies and Environment Studies Series. Juta & Co, LTD.

Goodall, B. (1972). *The economics of urban areas*. Pergamon Press. Oxford.

Hastie, T., Tibshirani, R. & Friedman J. (2001). *The elements of statistical learning*. Springer Series.

Hoekveld, G. A. (1990). *Regional geography must adjust to new realities.* In *Regional Geography, current developments and future prospects*. Routledge series in Geography and Environment.

Hosmer, D. W. & Lemeshow, S. (2000). *Applied logistic regression*. 2nd Edition. Wiley Series in Probability and Statistics.

Isaaks, E. H. & Srivastava, R. M. (1989). *An introduction to applied geostatistics*. Oxford University Press.

Kass. SAS System Help, Tree Node. SAS Enterprise Miner. SAS Institute Inc., Cary, NC 27513, USA.

Manuel, T. A. (2005). *Budget Speech 2005*. ISBN: 0-621-35493-7. www.treasury.gov.za.

McLachlan, G. (1992). *Discriminant analysis and statistical pattern recognition*. John Wiley & Sons, Inc. Canada.

Montgomery, D. C. & Peck, E. A. (1992). *Introduction to linear regression analysis*. Wiley-Interscience, John Wiley & Sons, Inc. Canada.

Murray, C. (1987). *Displaced urbanization: South Africa's rural slums.* **African Affairs** 86, (344); 311-329.

Reif, B. (1973). *Models in urban and regional planning*. Leonard Hill Books. Great Britain.

SAS Enterprise Miner. SAS Institute Inc., Cary, NC 27513, USA.

Smit, P. (1979). *Urbanisation in Africa: lessons for urbanisation in the homelands.* **South African Geographical Journal**. Vol. 61: 3-28.

SPP. (1983). *Forced Removals in South Africa*, Vol. 1-4. The Surplus People's Project. Cape Town.

Statistics South Africa. (2003). *Investigations into appropriate definitions of urban and rural areas for South Africa* (discussion document).

SuperCross. Version 4.2. Space Time Research, Australia.

UKO Guide: United Kingdom Office for National Statistics. (2001). *Urban and Rural Area Definitions: A User Guide for their Census 2001.*

United Nations. (2006). *Principals and recommendations for population and housing censuses* (draft). Revision 2.

Webb, A. (1999). *Statistical Pattern Recognition*. Newnes. Great Britain.

White, M. J. (1987). *American neighbourhoods and residential differentiation*. A Census Monograph Series. Russell Sage Foundation. New York.

Wonnacott, T. H. & Wonnacott, R. J. (1981). *Regression: a second course in statistics*. John Wiley & Sons. USA.

Yawitch, J. (1982). *Betterment: the Myth of Homeland Agriculture.* Johannesburg, SAIRR.

APPENDICES

APPENDIX A
Census EA-types for 1996 and 2001

Census 1996 EA-type classification

EA-Type	Urban/ Semi-urban/ Rural	Urban/ Non-urban
11 Urban: formal 12 Urban: informal 13 Urban: hostels 14 Urban: institutions	Urban	Urban
21 Semi-urban: formal 22 Semi-urban: informal 23 Semi-urban: hostels 24 Semi-urban: institutions	Semi-urban	Non-urban
31 Rural: formal 32 Rural: formal/semi-formal 33 Rural: tribal villages 34 Rural: informal 35 Rural: hostels 36 Rural: institutions 37 Rural: farms 38 Rural: tribal excl. villages	Rural	

Census 2001 EA-type classification

EA-Type	Geography Type	Urban/Rural
0 Vacant 3 Small-holding 4 Urban settlement 6 Recreational 7 Industrial area 8 Institution 9 Hostel	Urban Formal	Urban
5 Informal settlement	Urban Informal	
2 Farm 3 Small-holding 6 Recreational 7 Industrial area 8 Institution 9 Hostel	Rural Formal	Rural
0 Vacant 1 Tribal settlement 6 Recreational 7 Industrial area 8 Institution 9 Hostel	Tribal area	

APPENDIX B
Results from linear logistic regression

The table below shows the coefficients of the estimates as obtained for both samples, i.e. Sample 1 (urban-farm) and Sample 2 (urban-farm-tribal), for each province. The table is split into two parts. Part 1 shows the results for the Western Cape, Eastern Cape, Northern Cape, Free State and KwaZulu-Natal, and Part 2 shows the results for North West, Gauteng, Mpumalanga, Limpopo and South Africa as a whole.

(Part 1) Results from linear logistic regression for the Western Cape, Eastern Cape, Northern Cape, Free State and KwaZulu-Natal

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	CONSTANT	0.3413	0.3413	3.1	-1.8181	0.247	-0.6419	-0.147116	0.7115	-0.983704	-0.6672
	Person										
X_1	Population Density	0.0106	0.0106		0.00132	0.0632	0.00658	0.0677	0.00102	0.00254	0.000424
Language	*(Language most often spoken at home)*										
X_2	Afrikaans				0.0431						0.0937
X_3	English										
X_4	IsiNdebele				0.3712						
X_5	IsiXhosa										
X_6	IsiZulu										
X_7	Sepedi										
X_8	Sesotho								-0.0345		
X_9	Setswana								0.0766		
X_{10}	Siswati										
X_{11}	Tshivenda										
X_{12}	Xitsonga										
Employment Status	*(Employment status of each person)*										
X_{13}	Employed	-0.0774	-0.0774		-0.0517						
X_{14}	Unemployed										0.0475
X_{15}	Scholar or student										
X_{16}	Home-maker or housewife				-0.336						-0.2202
X_{17}	Pensioner or retired person				0.0951				0.4223		
X_{18}	Unable to work due to illness or disability										
X_{19}	Seasonal worker not working presently										
X_{20}	Does not choose to work										
X_{21}	Could not find work										
Work Status	*(Main activity or work status of person)*										
X_{22}	Paid employee			-0.0824							-0.0401
X_{23}	Paid family worker										
X_{24}	Self-employed				0.2841					0.134	
X_{25}	Employer				0.1819				-0.2642		
X_{26}	Unpaid family worker										
Total Births	*(Total children ever born)*										
X_{27}	0-5 children						0.1321			0.0917	0.0682
X_{28}	6-10 children										

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{29}	more than 10 children										
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling	-0.1875	-0.1875			-0.2064				-0.0792	
X_{31}	Some primary								0.0728		
X_{32}	Complete primary								0.3104		
X_{33}	Some secondary										0.0414
X_{34}	Grade 12/ Std 10										0.068
X_{35}	Higher										
Household											
Household Size	*(Total number of persons in a household)*										
X_{36}	1-5 persons										
X_{37}	6-10 persons				-0.0512						-0.0372
X_{38}	More than 10 persons								-0.1632		
Housing Unit	*(Type of living quarters)*										
X_{39}	House or brick structure on a separate stand or yard										
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials								-0.054		
X_{41}	Flat in a block of flats										-0.0229
X_{42}	Town/ cluster/ semi-detached house										
X_{43}	House/ flat/ room, in backyard										
X_{44}	Informal dwelling/ shack, in backyard	0.1651	0.1651		0.0416						0.0299
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter										
X_{46}	Room/ flatlet not in backyard but on shared property										
X_{47}	Caravan or tent										
X_{48}	Private ship/ boat										
Rooms	*(Number of rooms that the household utilises)*										
X_{49}	1-3 rooms								0.1033		
X_{50}	4-6 rooms										
X_{51}	7-10 rooms										
X_{52}	More than 10 rooms								0.131		-0.0583
Access to Water	*(Type of access to water)*										
X_{53}	Piped water (tap) inside dwelling				0.0414						

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{54}	Piped water (tap) inside yard				0.0299						
X_{55}	Piped water on community stand: < 200 metres										0.0152
X_{56}	Piped water on community stand: > 200 metres										
X_{57}	Borehole										
X_{58}	Spring										-0.0923
X_{59}	Rainwater tank										
X_{60}	Dam/ pool/ stagnant water										
X_{61}	River/ stream										-0.0339
X_{62}	Water vendor					0.1089					0.07
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)	0.025	0.025	0.0644	0.0487						0.0392
X_{64}	Flush toilet (with septic tank)				0.0238						
X_{65}	Chemical toilet				-0.0375				-0.1037		
X_{66}	Pit latrine with ventilation (VIP)								-0.0809		
X_{67}	Pit latrine without ventilation				-0.0155				-0.1088		-0.00756
X_{68}	Bucket latrine				0.0357						
X_{69}	None								-0.0656		-0.0263
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{70}	Electricity										
X_{71}	Gas										
X_{72}	Paraffin										
X_{73}	Wood			-0.0559	-0.0207			-0.4154	-0.1021	-0.0369	
X_{74}	Coal										
X_{75}	Animal dung								-0.1792		
X_{76}	Solar										
Gender of Head of Household											
X_{77}	Male										
X_{78}	Female			0.0774							0.0297
Population Group of Head of Household											
X_{79}	Black African										-0.0565
X_{80}	Coloured										
X_{81}	Indian or Asian										
X_{82}	White	0.0628	0.0628							0.0594	
Occupation of Head of Household											
X_{83}	Legislators, senior officials and managers				-0.0739					-0.0793	

		W. Cape		E. Cape		N. Cape		F. State		KZN	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{84}	Professionals										
X_{85}	Technicians and associate professionals										
X_{86}	Clerks				0.1948						
X_{87}	Service workers, shop and market sales workers										
X_{88}	Skilled agricultural and fishery workers				-0.1858		-0.0613		-0.3647	-0.4028	-0.2525
X_{89}	Craft and related trades workers										
X_{90}	Plant and machine operators and assemblers										
X_{91}	Elementary occupations	-0.0361	-0.0361				-0.088		-0.0859	-0.0446	
X_{92}	Occupations unspecified or not elsewhere classified										
Annual Household Income											
X_{93}	No income						-0.1545				
X_{94}	R 1 - R 4 800	0.1187	0.1187		0.0335						
X_{95}	R 4 801 - R 9 600										
X_{96}	R 9 601 - R 19 200										0.0338
X_{97}	R 19 201 - R 38 400				-0.0391						
X_{98}	R 38 401 - R 76 800										
X_{99}	R 76 801 - R 153 600										0.0809
X_{100}	R 153 601 - R 307 200				-0.0587						0.0766
X_{101}	R 307 201 - R 614 400										
X_{102}	R 614 401 - R 1 228 800										
X_{103}	R 1 228 801 - R 2 457 600										
X_{104}	R 2 457 601 or more										

(Part 2) Results from linear logistic regression for North West, Gauteng, Mpumalanga, Limpopo and South Africa

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	CONSTANT	-1.598801	-2.2532	1.5435	1.5435	-0.523451	0.5784	-4.083585	-0.7982	0.2338	-0.7516
	Person										
X_1	Population density		0.000439	0.00238	0.00238	0.00259	0.000425	0.0157	0.000359	0.00311	0.00057
Language	*(Language most often spoken at home)*										
X_2	Afrikaans										
X_3	English									-0.0171	
X_4	IsiNdebele					-0.0411			0.076		0.0124
X_5	IsiXhosa										
X_6	IsiZulu						0.0332				
X_7	Sepedi										-0.0127
X_8	Sesotho									-0.0103	
X_9	Setswana			-0.043	-0.043						-0.0116
X_{10}	Siswati										
X_{11}	Tshivenda										-0.0146
X_{12}	Xitsonga					-0.1053	0.047		-0.0302	-0.0484	-0.0507
Employment Status	*(Employment status of each person)*										
X_{13}	Employed										
X_{14}	Unemployed					0.075		0.1512		0.0402	0.0415
X_{15}	Scholar or student										
X_{16}	Home-maker or housewife						-0.1309				
X_{17}	Pensioner or retired person									0.1055	0.0904
X_{18}	Unable to work due to illness or disability										
X_{19}	Seasonal worker not working presently										
X_{20}	Does not choose to work										
X_{21}	Could not find work										
Work Status	*(Main activity or work status of person)*										
X_{22}	Paid employee									0.0275	
X_{23}	Paid family worker									0.0722	
X_{24}	Self-employed									0.1284	
X_{25}	Employer										
X_{26}	Unpaid family worker										
Total Births	*(Total children ever born)*										
X_{27}	0-5 children	0.2052				0.0793	0.0682				0.023
X_{28}	6-10 children										

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{29}	More than 10 children										
Level of Education	*(Highest level of education the person completed)*										
X_{30}	No schooling									-0.0254	
X_{31}	Some primary					-0.1348					
X_{32}	Complete primary										
X_{33}	Some secondary										
X_{34}	Grade 12/ Std 10									0.0199	
X_{35}	Higher									0.0619	
Household											
Household Size	*(Total number of persons in a household)*										
X_{36}	1-5 persons										
X_{37}	6-10 persons									-0.0139	
X_{38}	More than 10 persons						-0.0585			-0.0253	-0.0279
Housing Unit	*(Type of living quarters)*										
X_{39}	House or brick structure on a separate stand or yard		-0.0317							-0.0117	
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials									-0.0195	
X_{41}	Flat in a block of flats									0.0237	
X_{42}	Town/ cluster/ semi-detached house										
X_{43}	House/ flat/ room, in backyard										
X_{44}	Informal dwelling/ shack, in backyard										
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter						0.0352		0.0333		0.0285
X_{46}	Room/ flatlet not in backyard but on shared property										
X_{47}	Caravan or tent			0.4339	0.4339						
X_{48}	Private ship/ boat										
Rooms	*(Number of rooms that the household utilises)*										
X_{49}	1-3 rooms										
X_{50}	4-6 rooms					0.0563	0.0194				
X_{51}	7-10 rooms										
X_{52}	More than 10 rooms										
Access to Water	*(Type of access to water)*										

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
X_{53}	Piped water (tap) inside dwelling									0.0153	0.0107
X_{54}	Piped water (tap) inside yard									0.0126	0.0084
X_{55}	Piped water on community stand: < 200 metres										
X_{56}	Piped water on community stand: > 200 metres										
X_{57}	Borehole					-0.2193					
X_{58}	Spring										
X_{59}	Rainwater tank										
X_{60}	Dam/ pool/ stagnant water					-0.1254	-0.1561				
X_{61}	River/ stream										
X_{62}	Water vendor								0.0225		-0.0334
Toilet facilities	*(Main type of toilet facilities)*										
X_{63}	Flush toilet (connected to sewerage system)		0.0492	0.0184	0.0184		0.0459		0.0449	0.016	0.0358
X_{64}	Flush toilet (with septic tank)			-0.069	-0.069				0.0381		0.015
X_{65}	Chemical toilet					0.0677					
X_{66}	Pit latrine with ventilation (VIP)		-0.0321								
X_{67}	Pit latrine without ventilation										-0.0121
X_{68}	Bucket latrine		0.0568				0.0363			0.0169	0.0366
X_{69}	None										
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*										
X_{70}	Electricity		0.0266						-0.0265		
X_{71}	Gas										
X_{72}	Paraffin						-0.0244				
X_{73}	Wood	-0.1034		-0.0463	-0.0463	-0.0252	-0.0273	-0.0794	-0.0392	-0.0147	-0.015
X_{74}	Coal								-0.0908		
X_{75}	Animal dung										
X_{76}	Solar										
Gender of Head of Household											
X_{77}	Male										
X_{78}	Female					0.0503					
Population Group of Head of Household											
X_{79}	Black African					-0.031	-0.0362		-0.0187		-0.02
X_{80}	Coloured										
X_{81}	Indian or Asian										
X_{82}	White										
Occupation of Head of Household											
X_{83}	Legislators, senior			0.1747	0.1747						

		N. West		Gauteng		MP		Limpopo		S. Africa	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	officials and managers										
X_{84}	Professionals										
X_{85}	Technicians and associate professionals									0.0549	
X_{86}	Clerks										
X_{87}	Service workers, shop and market sales workers										
X_{88}	Skilled agricultural and fishery workers			-0.4575	-0.4575	-0.1695	-0.1545			-0.1655	-0.1096
X_{89}	Craft and related trades workers										
X_{90}	Plant and machine operators and assemblers										-0.0329
X_{91}	Elementary occupations	-0.1405		-0.0357	-0.0357		-0.0534			-0.0371	-0.0357
X_{92}	Occupations unspecified or not elsewhere classified							0.0601			
Annual Household Income											
X_{93}	No income						-0.0223				-0.0205
X_{94}	R 1 - R 4 800										
X_{95}	R 4 801 - R 9 600										
X_{96}	R 9 601 - R 19 200									0.0137	
X_{97}	R 19 201 - R 38 400						-0.025				
X_{98}	R 38 401 - R 76 800										
X_{99}	R 76 801 - R 153 600								0.0585		
X_{100}	R 153 601 - R 307 200										
X_{101}	R 307 201 - R 614 400										
X_{102}	R 614 401 - R 1 228 800										
X_{103}	R 1 228 801 - R 2 457 600										
X_{104}	R 2 457 601 or more										

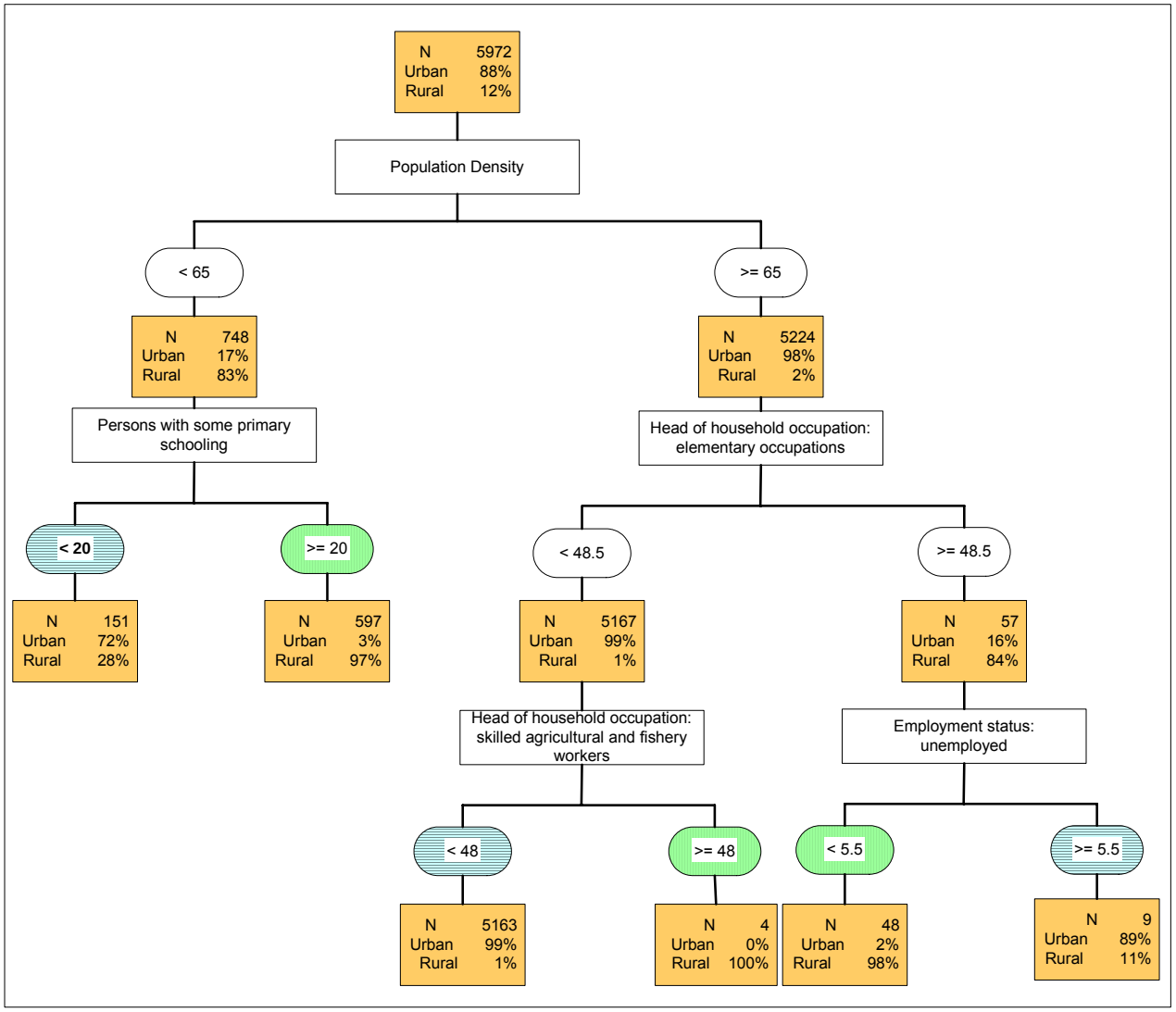
APPENDIX C

Results from classification trees

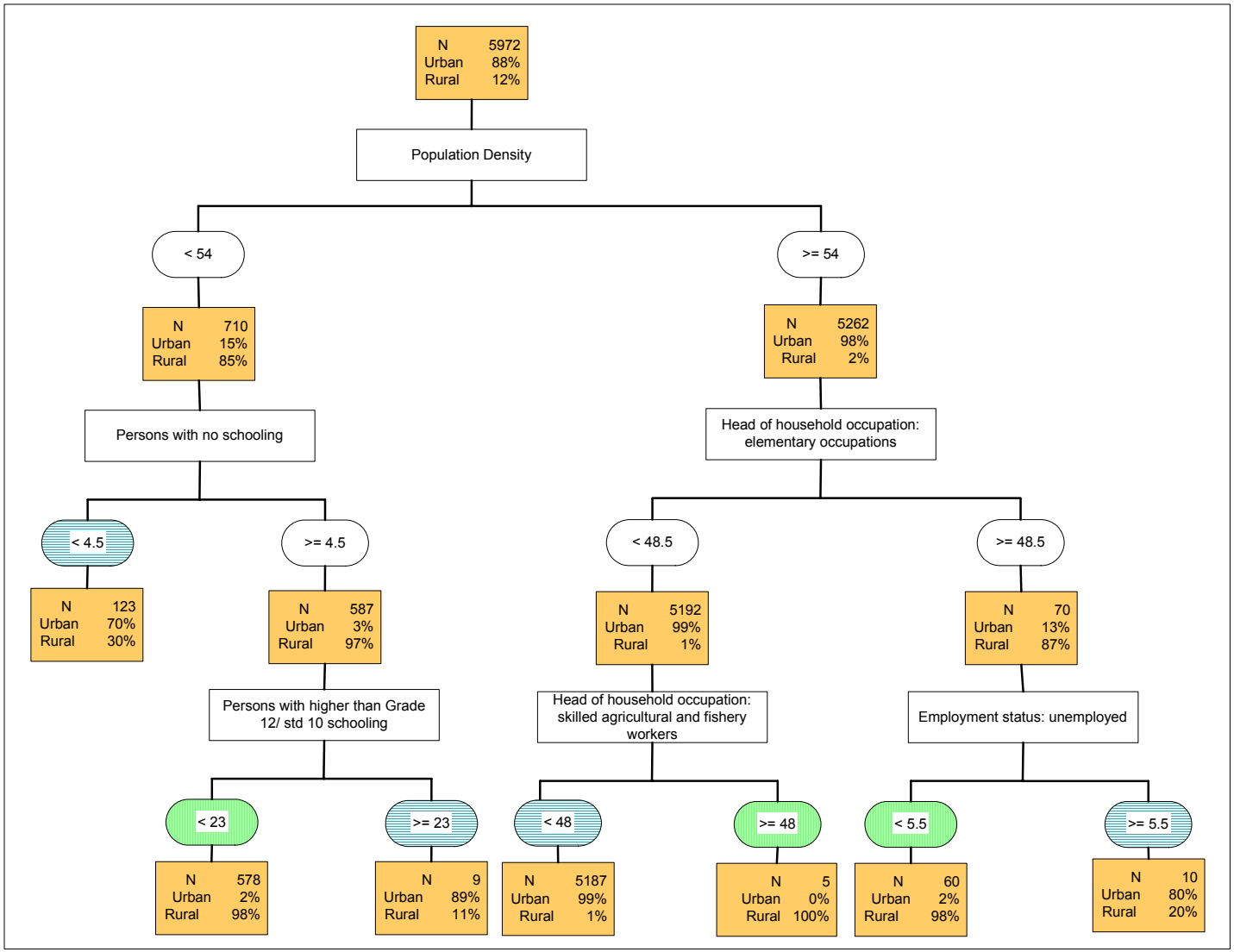
Tree diagrams, showing the significant variables and how they split, for each province and for South Africa as a whole, are given below for both samples. Urban final nodes are indicated in blue (vertical lines) and rural final nodes in green (horizontal lines).

Units for all variables are *persons* (standardised by total population), with the exception of the variable *population density* where *persons per square kilometre*, is used.

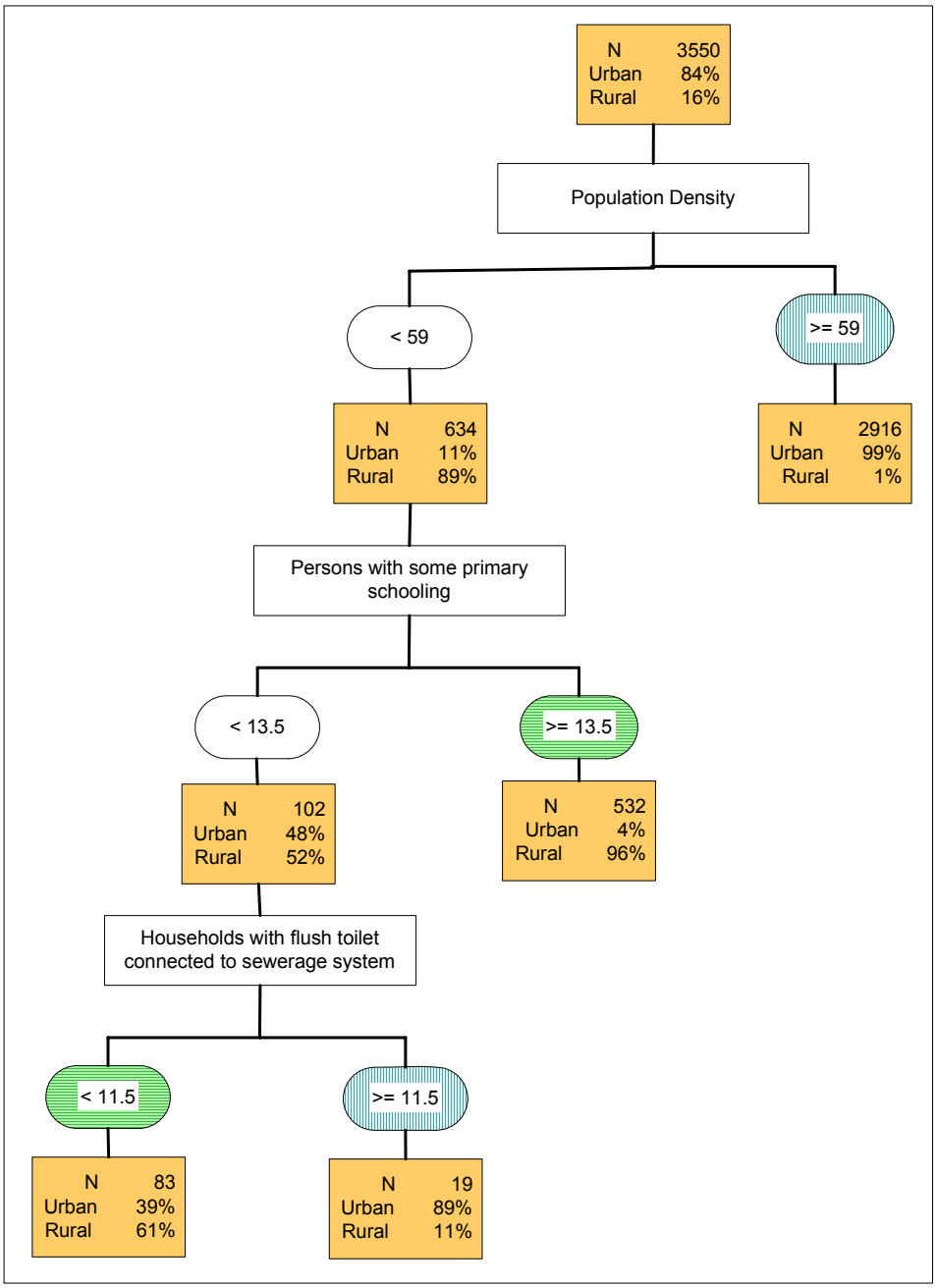
Tree diagram for the Western Cape (sample 1)



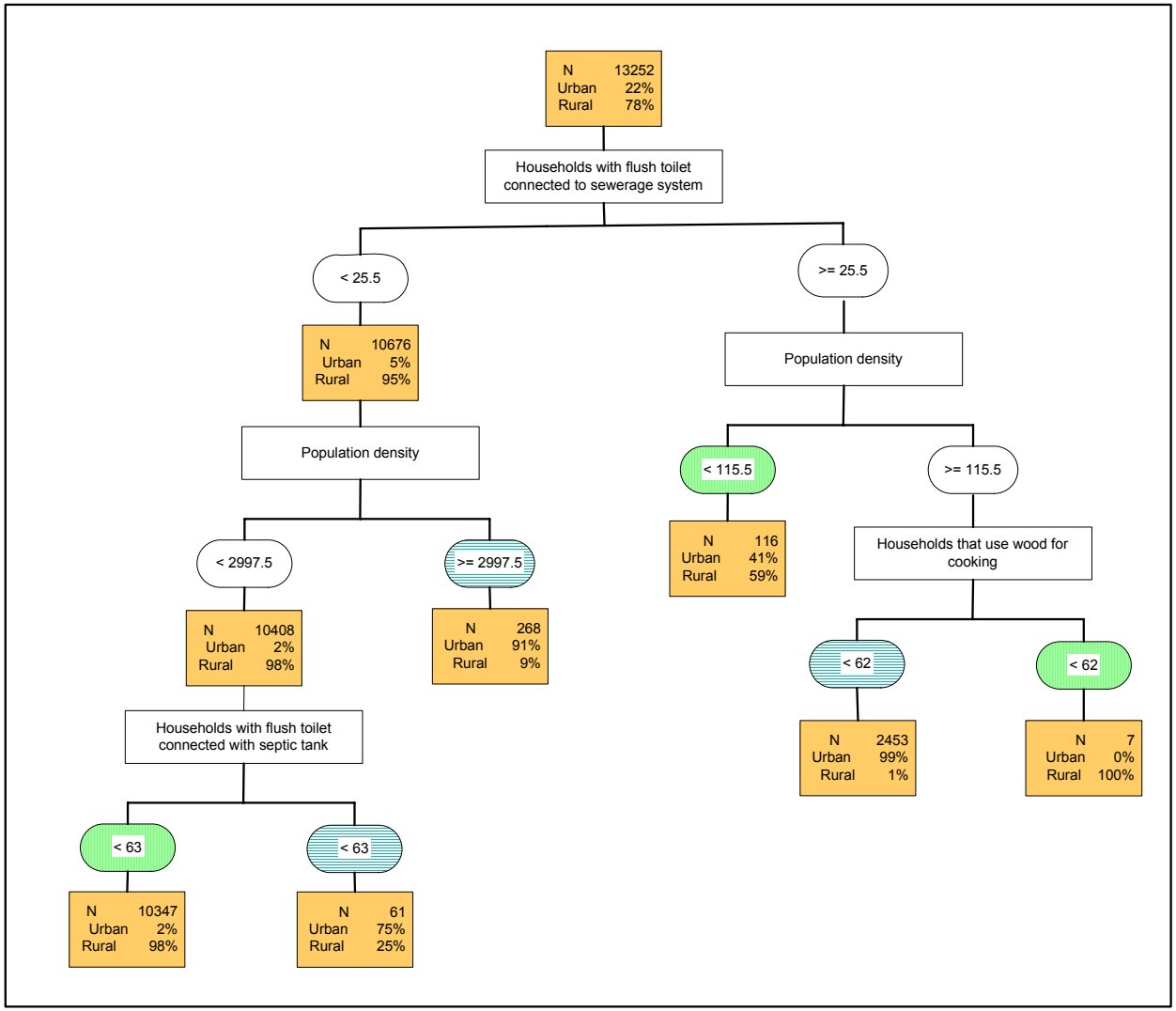
Tree diagram for the Western Cape (sample 2)



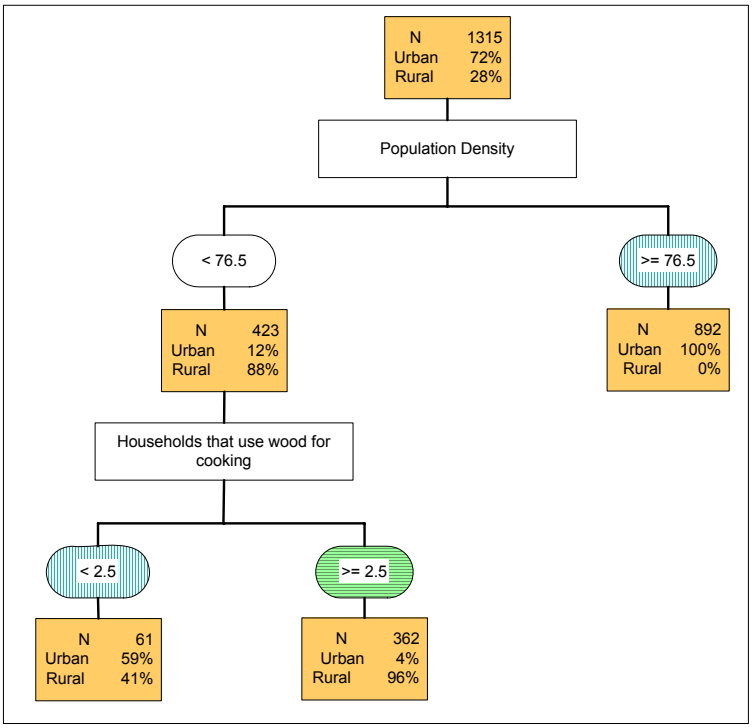
Tree diagram for the Eastern Cape (sample 1)



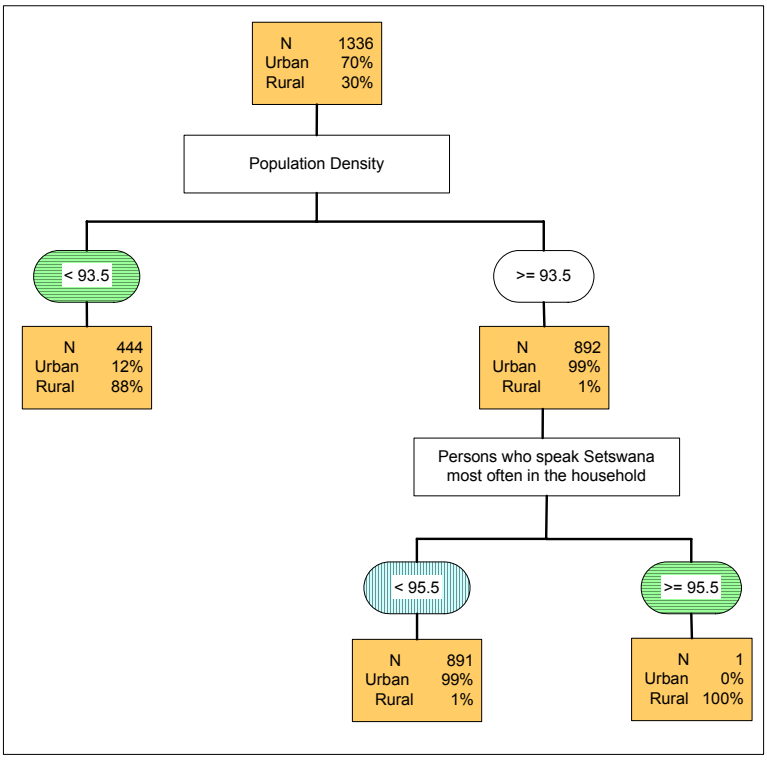
Tree diagram for the Eastern Cape (sample 2)



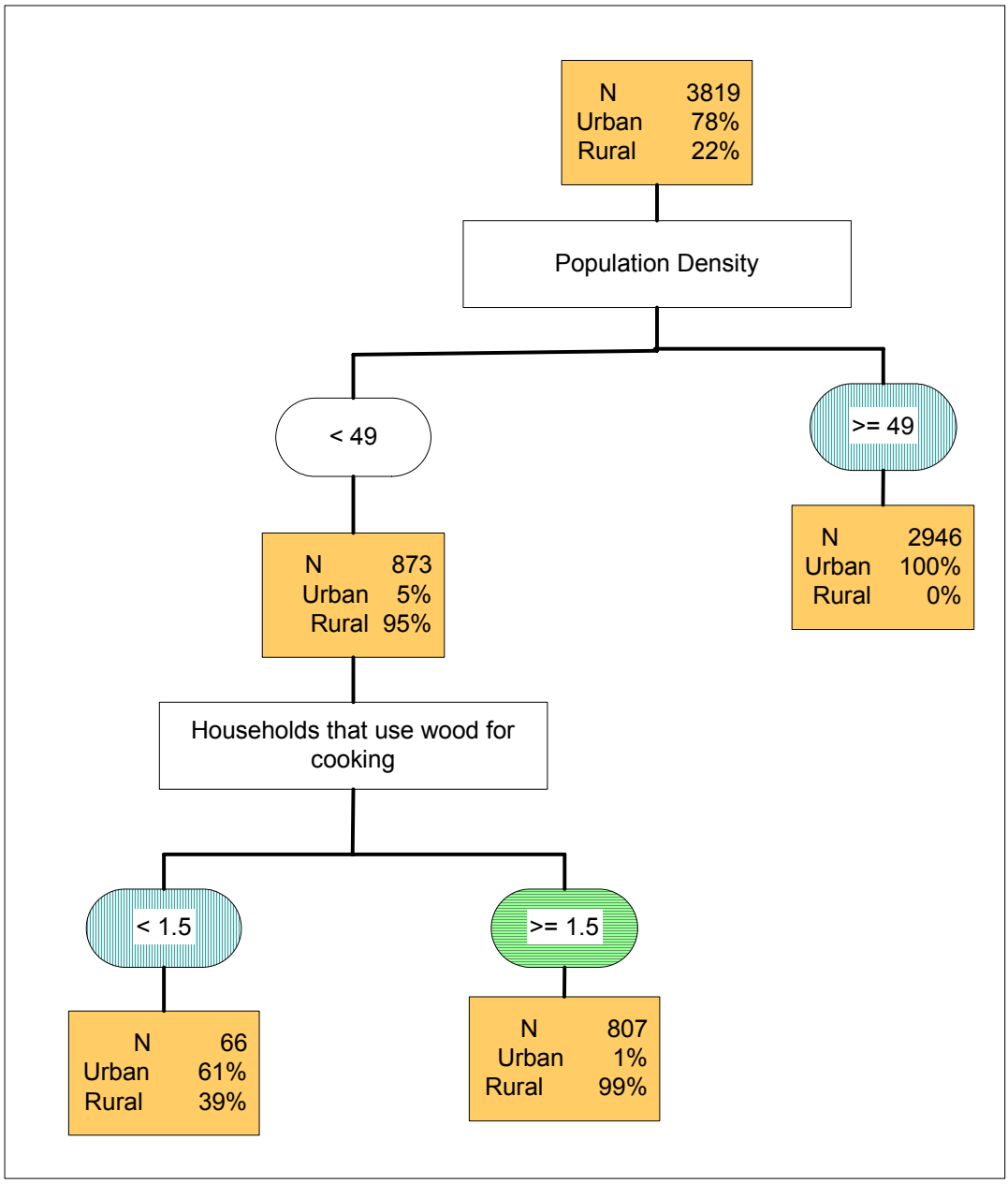
Tree diagram for the Northern Cape (sample 1)



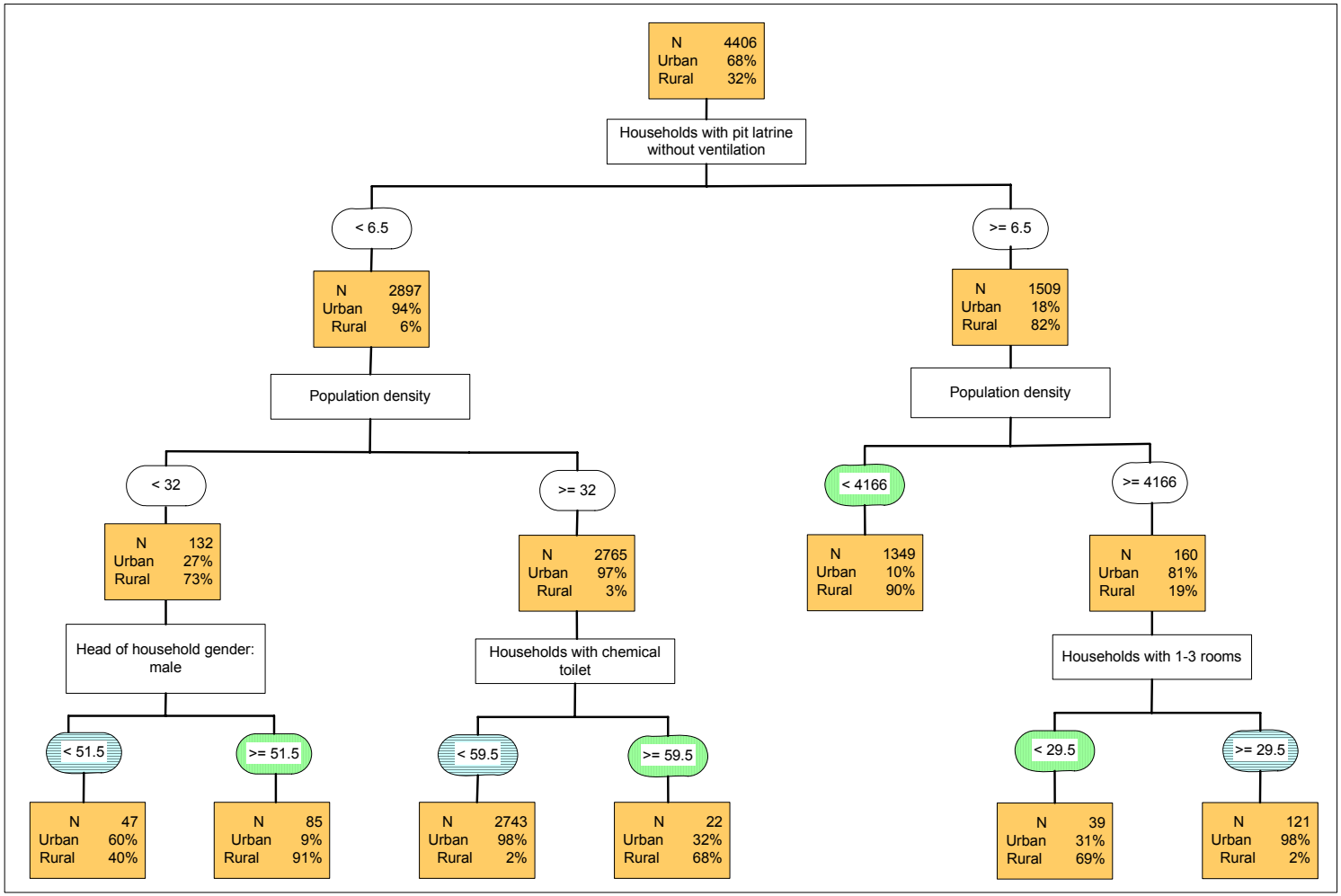
Tree diagram for the Northern Cape (sample 2)



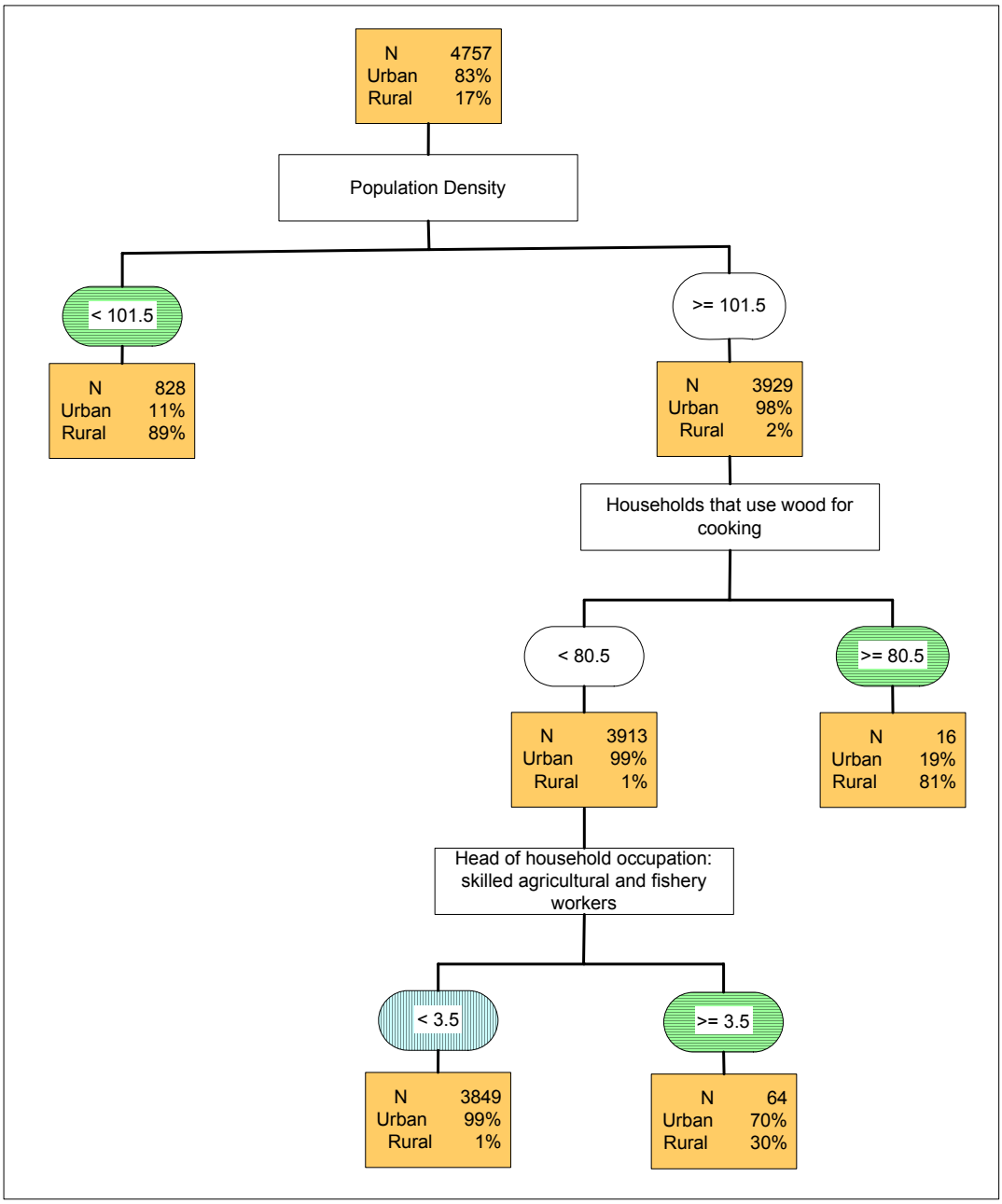
Tree diagram for the Free State (sample 1)



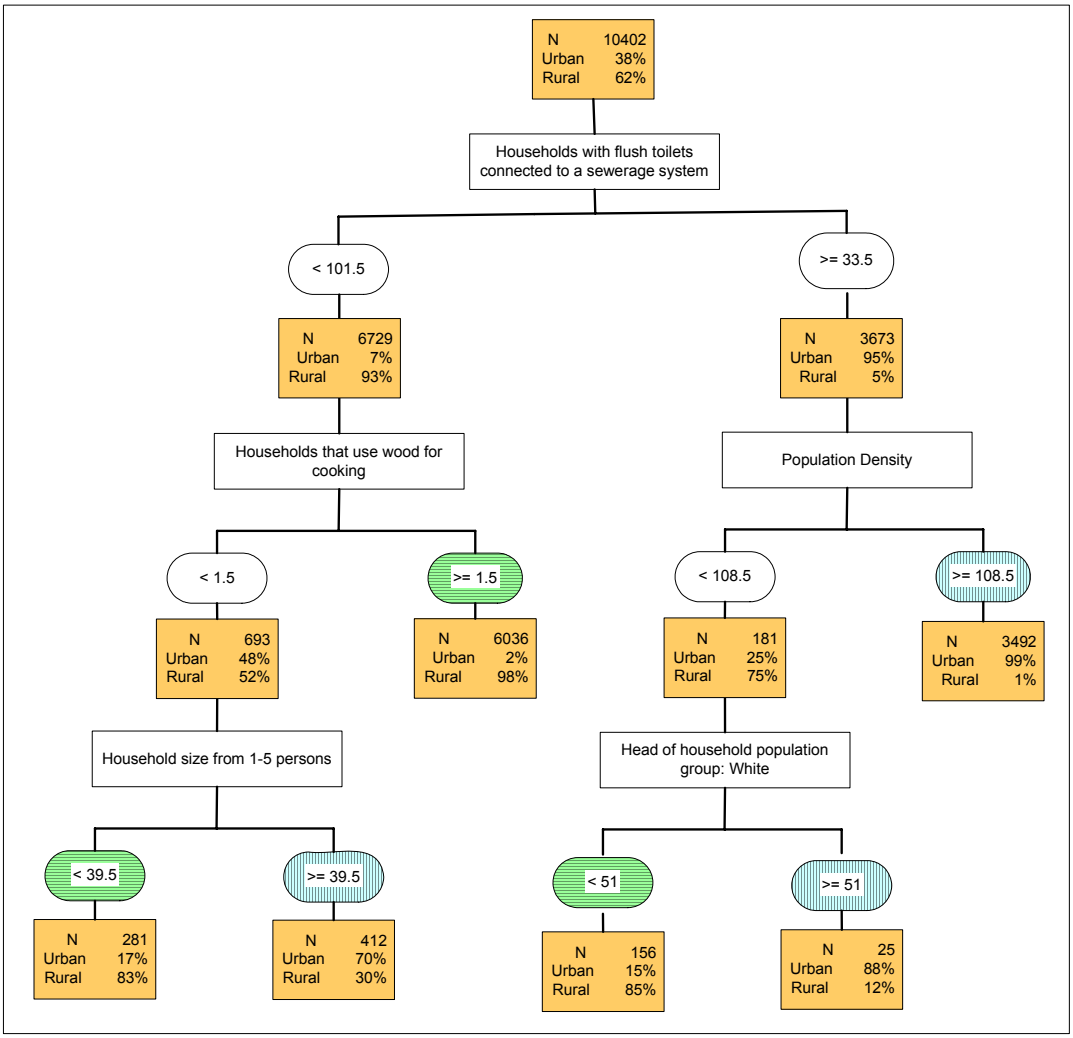
Tree diagram for the Free State (sample 2)



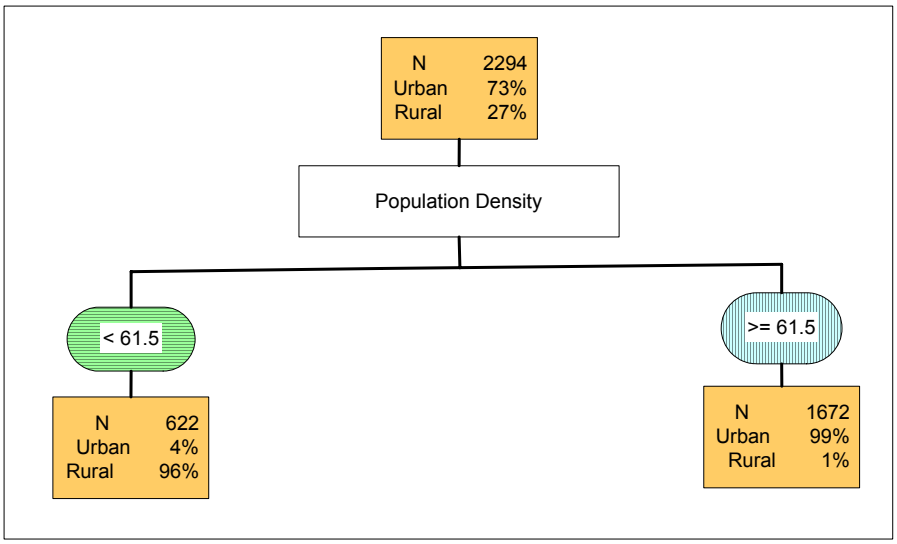
Tree diagram for KwaZulu-Natal (sample 1)



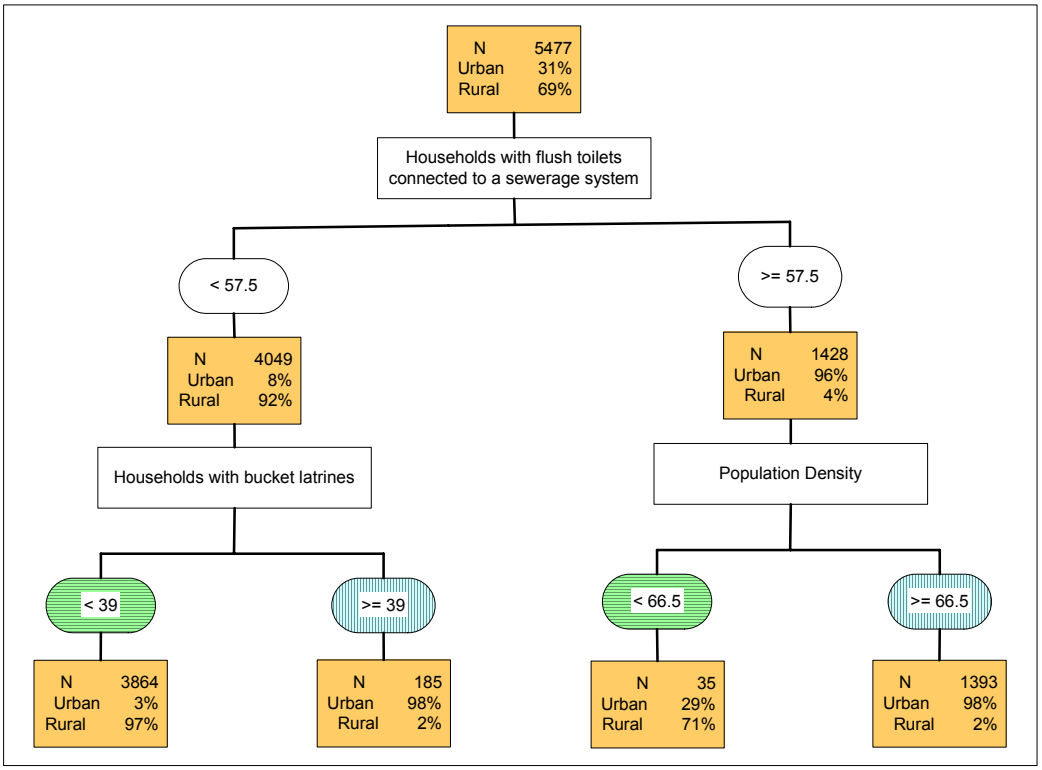
Tree diagram for KwaZulu-Natal (sample 2)



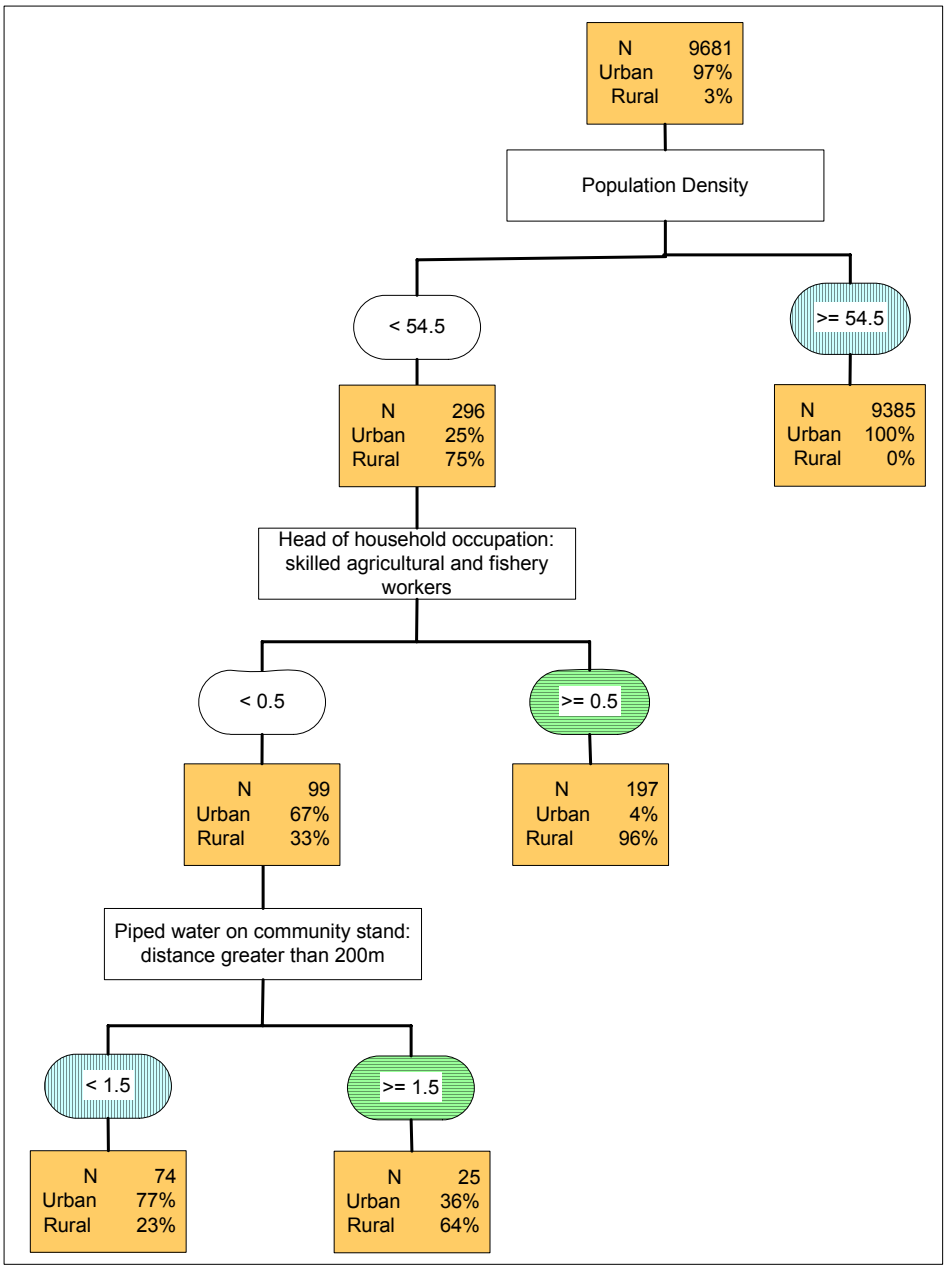
Tree diagram for North West (sample 1)



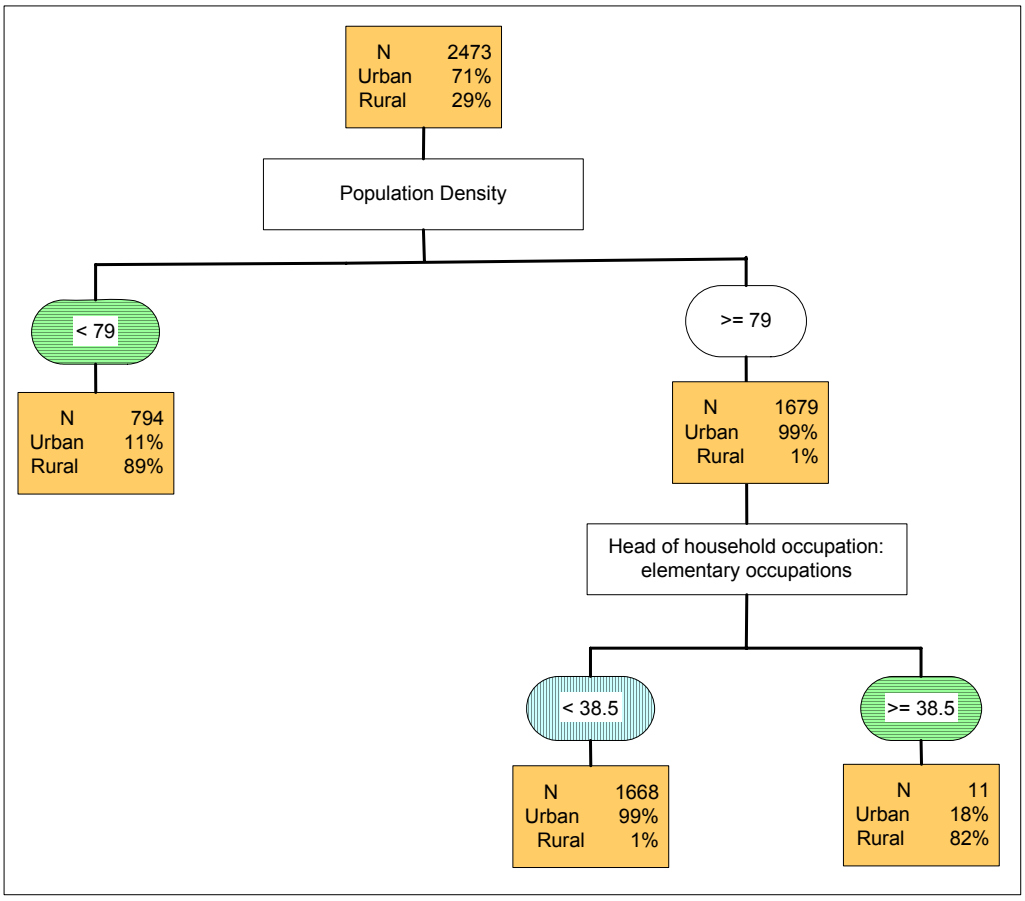
Tree diagram for North West (sample 2)



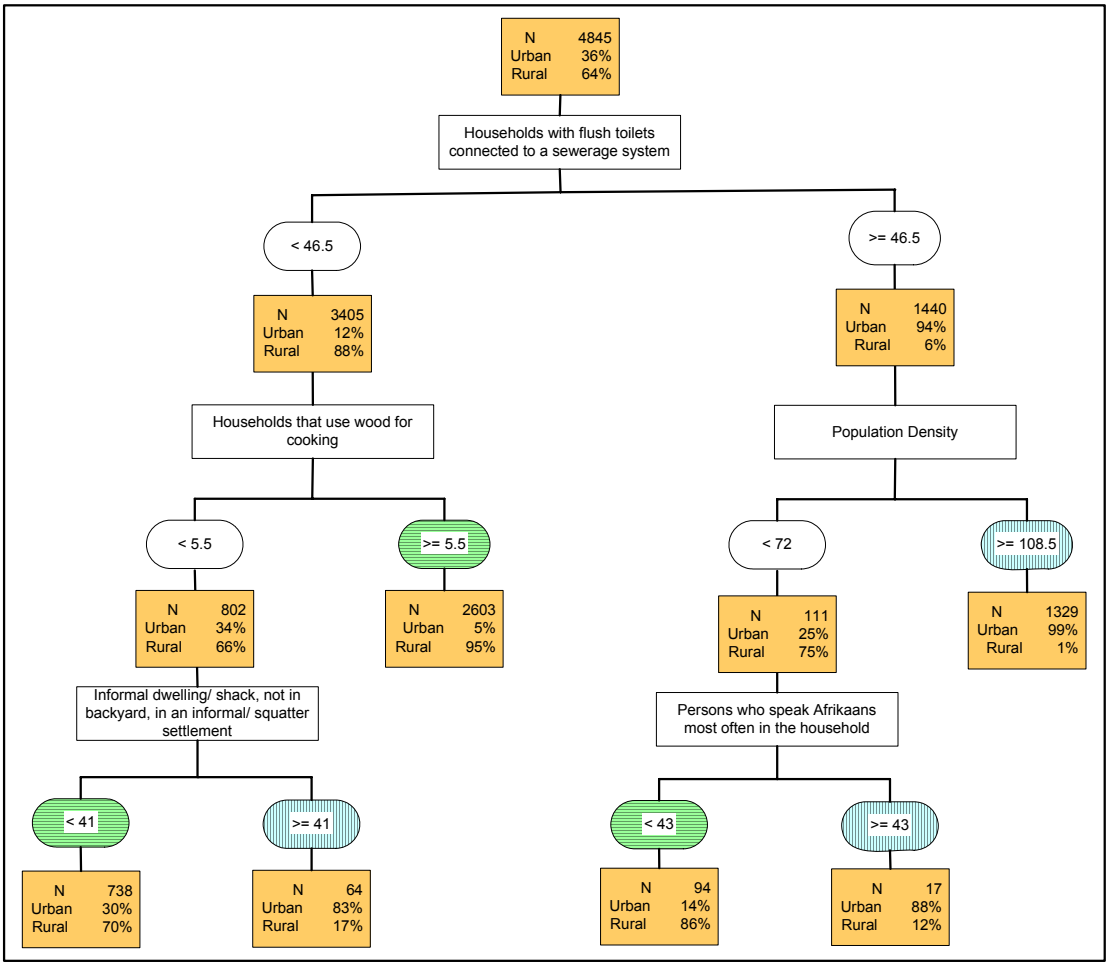
Tree diagram for Gauteng (samples 1 & 2)



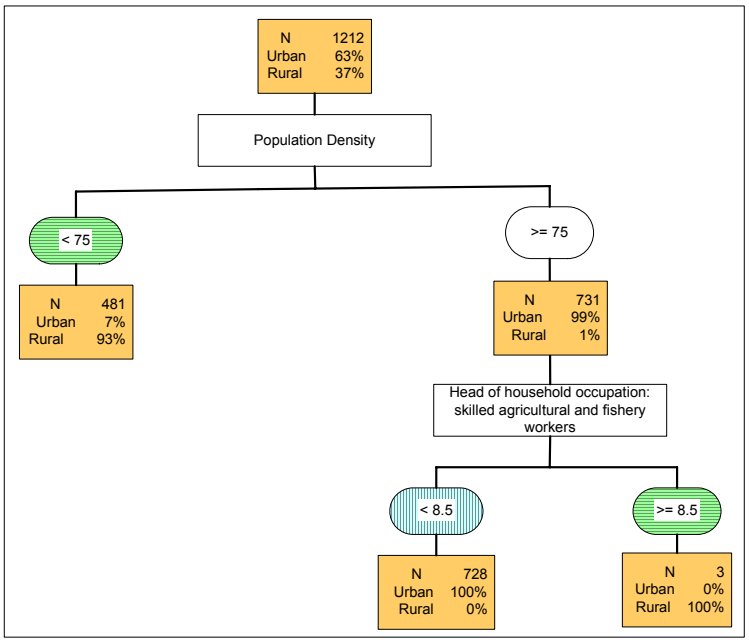
Tree diagram for Mpumalanga (sample 1)



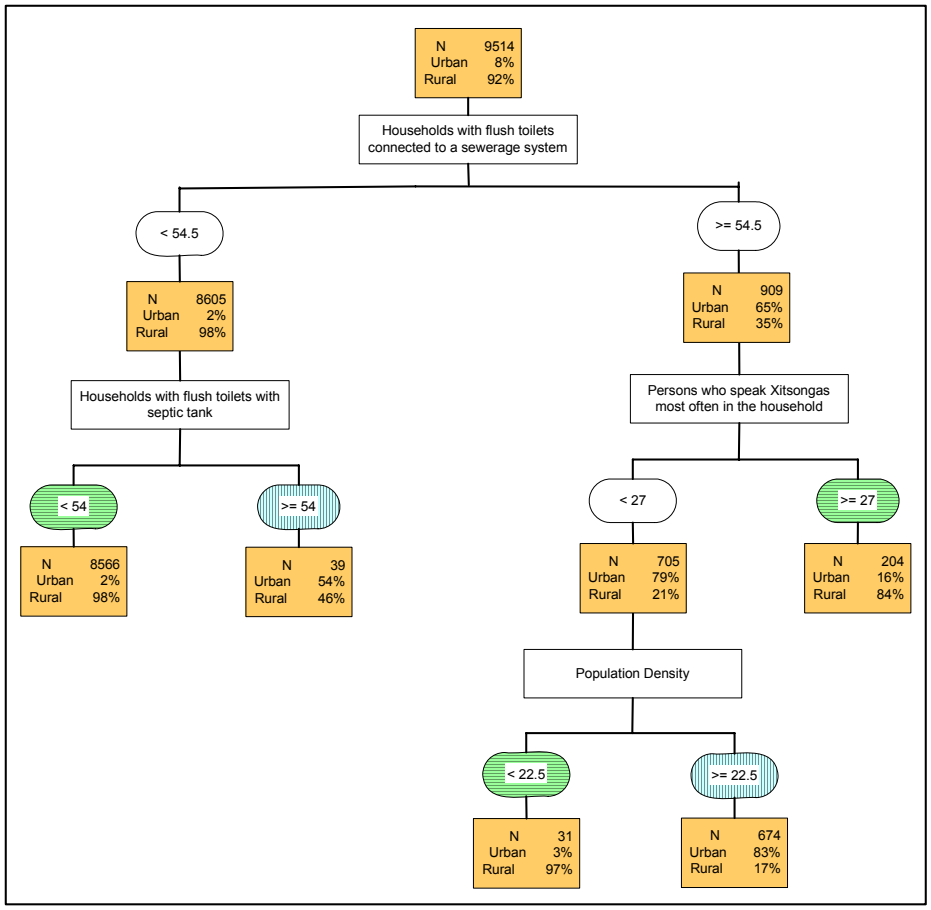
Tree diagram for Mpumalanga (sample 2)



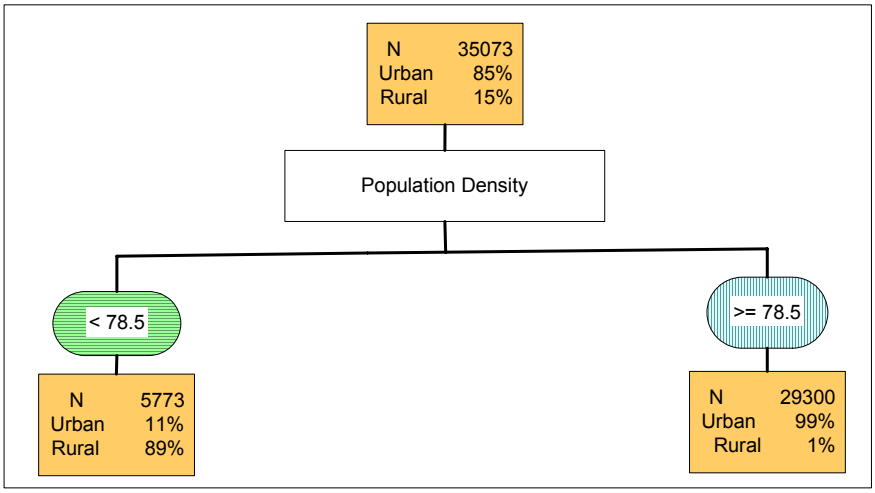
Tree diagram for Limpopo (sample 1)



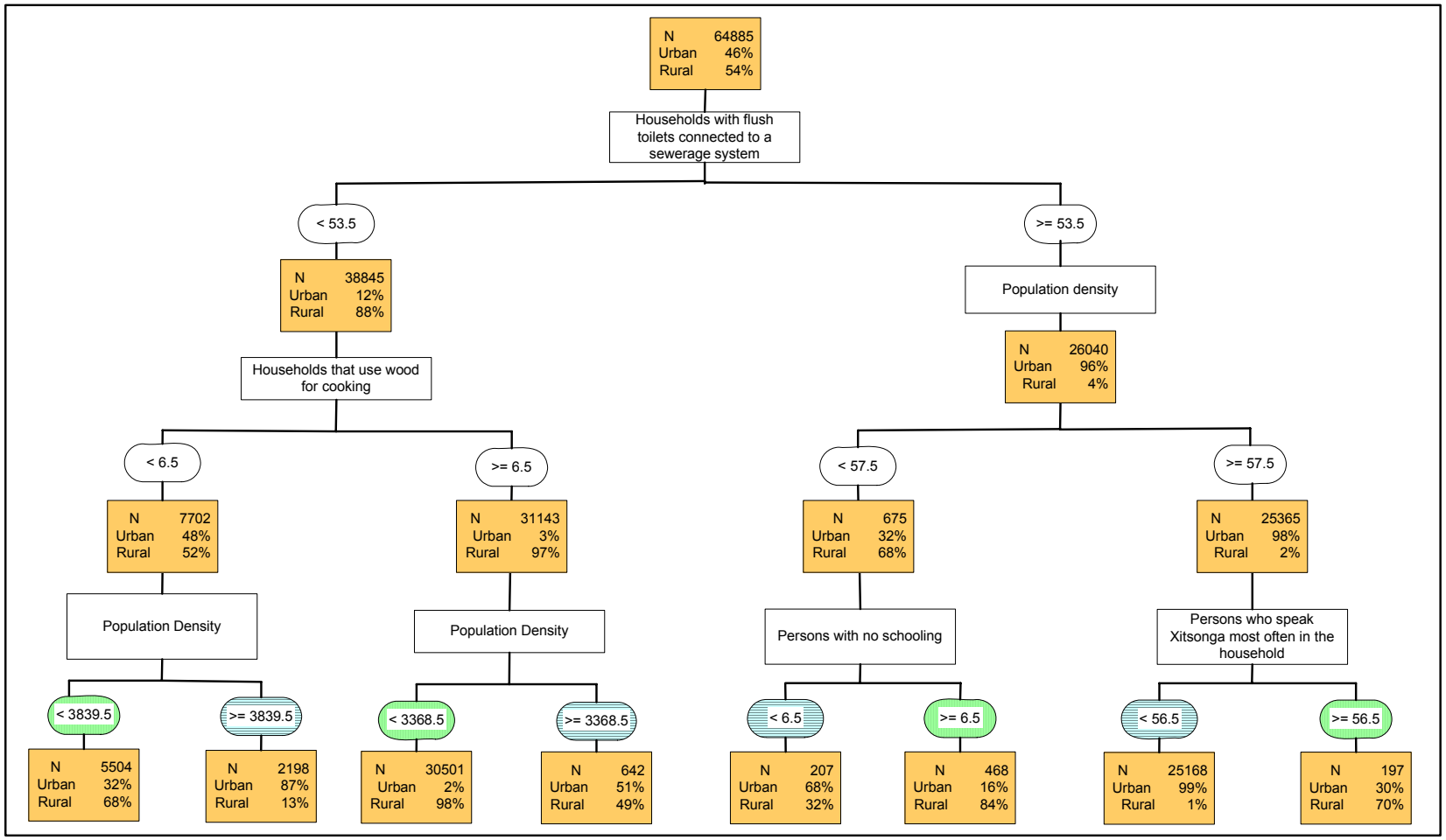
Tree diagram for Limpopo (sample 2)



Tree diagram for the RSA (sample 1)



Tree diagram for the RSA (sample 2)



APPENDIX D
Results from discriminant analysis

Stepwise discriminant analysis was used to select the most significant variables (at the 5% level of significance). Thereafter the linear discriminate functions were generated. The table that follows shows the coefficients of the significant variables for the linear discriminant functions, for urban and rural, per province for each sample; only the first 10 most significant variables are shown. The table is in 5 parts, i.e. Part 1 for the Western Cape and the Eastern Cape, Part 2 for the Northern Cape and the Free State, Part 3 for KwaZulu-Natal and North West, Part 4 for Gauteng and Mpumalanga and Part 5 for Limpopo and South Africa as a whole.

(Part 1) Coefficients of significant variables for the linear discriminant functions for the Western Cape and the Eastern Cape

		W. Cape				E. Cape			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	CONSTANT	-44.18537	-43.94055	-44.26657	-43.96753	-25.6351	-21.49215	-31.14049	-12.32054
	Person								
X_1	Population density							0.0004511	0.0000332
Language	*(Language most often spoken at home)*								
X_2	Afrikaans								
X_3	English								
X_4	IsiNdebele								
X_5	IsiXhosa								
X_6	IsiZulu								
X_7	Sepedi								
X_8	Sesotho								
X_9	Setswana								
X_{10}	Siswati								
X_{11}	Tshivenda								
X_{12}	Xitsonga								
Employment Status	*(Employment status of each person)*								
X_{13}	Employed	0.08611	0.28733	0.08288	0.2878				
X_{14}	Unemployed	0.15839	0.02106	0.1615	0.02374				
X_{15}	Scholar or student								
X_{16}	Home-maker or housewife								
X_{17}	Pensioner or retired person								
X_{18}	Unable to work due to illness or disability								
X_{19}	Seasonal worker not working presently								
X_{20}	Does not choose to work								
X_{21}	Could not find work								
Work Status	*(Main activity or work status of person)*								
X_{22}	Paid employee								
X_{23}	Paid family worker								
X_{24}	Self-employed								
X_{25}	Employer								
X_{26}	Unpaid family worker								

		W. Cape				E. Cape			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
Total Births	*(Total children ever born)*								
X_{27}	0-5 children								
X_{28}	6-10 children								
X_{29}	More than 10 children								
Level of Education	*(Highest level of education the person completed)*								
X_{30}	No schooling								
X_{31}	Some primary	0.01691	0.22204	0.015	0.22028				
X_{32}	Complete primary								
X_{33}	Some secondary								
X_{34}	Grade 12/ Std 10								
X_{35}	Higher								
Household									
Household Size	*(Total number of persons in a household)*								
X_{36}	1-5 persons								
X_{37}	6-10 persons								
X_{38}	More than 10 persons								
Housing Unit	*(Type of living quarters)*								
X_{39}	House or brick structure on a separate stand or yard								
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials								
X_{41}	Flat in a block of flats								
X_{42}	Town/ cluster/ semi-detached house								
X_{43}	House/ flat/ room, in backyard								
X_{44}	Informal dwelling/ shack, in backyard								
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter	0.02535	0.00447	0.02518	0.00378			0.16608	0.05604
X_{46}	Room/ flatlet not in backyard but on shared property								

		W. Cape				E. Cape			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
X_{47}	Caravan or tent								
X_{48}	Private ship/ boat								
Rooms	*(Number of rooms that the household utilises)*								
X_{49}	1-3 rooms								
X_{50}	4-6 rooms								
X_{51}	7-10 rooms								
X_{52}	More than 10 rooms								
Access to Water	*(Type of access to water)*								
X_{53}	Piped water (tap) inside dwelling							0.16103	0.00442
X_{54}	Piped water (tap) inside yard							0.18181	0.01467
X_{55}	Piped water on community stand: < 200 metres								
X_{56}	Piped water on community stand: > 200 metres								
X_{57}	Borehole								
X_{58}	Spring								
X_{59}	Rainwater tank					-0.07943	0.02456		
X_{60}	Dam/ pool/ stagnant water					-0.11573	0.10174		
X_{61}	River/ stream								
X_{62}	Water vendor								
Toilet facilities	*(Main type of toilet facilities)*								
X_{63}	Flush toilet (connected to sewerage system)	0.78327	0.55427	0.78517	0.55298	0.03857	-0.01507	0.31626	-0.00529
X_{64}	Flush toilet (with septic tank)	0.77919	0.59869	0.78013	0.59869			0.23039	0.0038
X_{65}	Chemical toilet								
X_{66}	Pit latrine with ventilation (VIP)								
X_{67}	Pit latrine without ventilation								
X_{68}	Bucket latrine					0.03047	-0.00791	0.34234	0.00269
X_{69}	None								
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*								

		W. Cape				E. Cape			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
X_{70}	Electricity								
X_{71}	Gas								
X_{72}	Paraffin								
X_{73}	Wood					-0.06447	0.0729	0.04324	0.07901
X_{74}	Coal								
X_{75}	Animal dung								
X_{76}	Solar								
Gender of Head of Household									
X_{77}	Male					0.43008	0.25324		
X_{78}	Female	0.09552	-0.004	0.0977	-0.00341	0.42503	0.2408		
Population Group of Head of Household									
X_{79}	Black African								
X_{80}	Coloured								
X_{81}	Indian or Asian								
X_{82}	White								
Occupation of Head of Household									
X_{83}	Legislators, senior officials and managers								
X_{84}	Professionals								
X_{85}	Technicians and associate professionals								
X_{86}	Clerks								
X_{87}	Service workers, shop and market sales workers								
X_{88}	Skilled agricultural and fishery workers	-0.00269	0.29326	-0.00188	0.2967	-0.21188	0.08882	-0.19771	0.00345
X_{89}	Craft and related trades workers	0.17792	-0.14739	0.18053	-0.14745				
X_{90}	Plant and machine operators and assemblers							-0.11163	0.02233
X_{91}	Elementary occupations	-0.12806	0.16806	-0.1271	0.1703	-0.17588	0.07788		
X_{92}	Occupations unspecified or not elsewhere classified								
Annual Household Income									
X_{93}	No income								
X_{94}	R 1 - R 4 800					0.08731	-0.04259		
X_{95}	R 4 801 - R 9 600								
X_{96}	R 9 601 - R 19 200								
X_{97}	R 19 201 - R 38 400								
X_{98}	R 38 401 - R								

		W. Cape				E. Cape			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	76 800								
X_{99}	R 76 801 - R 153 600								
X_{100}	R 153 601 - R 307 200								
X_{101}	R 307 201 - R 614 400								
X_{102}	R 614 401 - R 1 228 800								
X_{103}	R 1 228 801 - R 2 457 600								
X_{104}	R 2 457 601 or more								

(Part 2) Coefficients of significant variables for the linear discriminant functions for the Northern Cape and the Free State

		N. Cape				F. State			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	CONSTANT	-26.54567	-25.32	-15.29096	-11.39335	-39.20981	-52.00485	-20.33756	-22.60671
	Person								
X_1	Population density	0.0001050	-0.0001029	0.0002617	0.0001686	0.0000968	-0.0005273	0.000715	0.0003026
Language	*(Language most often spoken at home)*								
X_2	Afrikaans	0.01637	-0.00832	0.25373	0.16133				
X_3	English			0.26631	0.18647				
X_4	IsiNdebele								
X_5	IsiXhosa								
X_6	IsiZulu								
X_7	Sepedi								
X_8	Sesotho								
X_9	Setswana							0.04927	-0.01901
X_{10}	Siswati								
X_{11}	Tshivenda								
X_{12}	Xitsonga								
Employment Status	*(Employment status of each person)*								
X_{13}	Employed								
X_{14}	Unemployed	0.06852	-0.03531						
X_{15}	Scholar or student					0.33588	0.15295		
X_{16}	Home-maker or housewife								
X_{17}	Pensioner or retired person								
X_{18}	Unable to work due to illness or disability								
X_{19}	Seasonal worker not working presently								
X_{20}	Does not choose to work								
X_{21}	Could not find work								
Work Status	*(Main activity or work status of person)*								
X_{22}	Paid employee								
X_{23}	Paid family worker								
X_{24}	Self-employed								
X_{25}	Employer								
X_{26}	Unpaid family								

		N. Cape				F. State			
		Sample 1		Sample 2		Sample 1		Sample 2	
	worker								
Total Births	*(Total children ever born)*								
X_{27}	0-5 children	0.04775	-0.02377	0.21683	0.06926				
X_{28}	6-10 children								
X_{29}	More than 10 children								
Level of Education	*(Highest level of education the person completed)*								
X_{30}	No schooling							0.33334	0.37014
X_{31}	Some primary								
X_{32}	Complete primary								
X_{33}	Some secondary					0.37725	0.19211		
X_{34}	Grade 12/ Std 10								
X_{35}	Higher								
Household									
Household Size	*(Total number of persons in a household)*								
X_{36}	1-5 persons					0.01716	-0.02954		
X_{37}	6-10 persons								
X_{38}	More than 10 persons								
Housing Unit	*(Type of living quarters)*								
X_{39}	House or brick structure on a separate stand or yard								
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials								
X_{41}	Flat in a block of flats								
X_{42}	Town/ cluster/ semi-detached house								
X_{43}	House/ flat/ room, in backyard								
X_{44}	Informal dwelling/ shack, in backyard								
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter	0.01429	-0.00822					-0.00115	-0.02840
X_{46}	Room/ flatlet not in backyard but on shared property								

		N. Cape				F. State			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{47}	Caravan or tent			-0.20142	0.22181				
X_{48}	Private ship/ boat								
Rooms	*(Number of rooms that the household utilises)*								
X_{49}	1-3 rooms								
X_{50}	4-6 rooms								
X_{51}	7-10 rooms								
X_{52}	More than 10 rooms								
Access to Water	*(Type of access to water)*								
X_{53}	Piped water (tap) inside dwelling								
X_{54}	Piped water (tap) inside yard								
X_{55}	Piped water on community stand: < 200 metres								
X_{56}	Piped water on community stand: > 200 metres								
X_{57}	Borehole								
X_{58}	Spring								
X_{59}	Rainwater tank	-0.2028	0.17718						
X_{60}	Dam/ pool/ stagnant water								
X_{61}	River/ stream			-0.14207	0.09631				
X_{62}	Water vendor								
Toilet facilities	*(Main type of toilet facilities)*								
X_{63}	Flush toilet (connected to sewerage system)								
X_{64}	Flush toilet (with septic tank)								
X_{65}	Chemical toilet							-0.02266	0.10086
X_{66}	Pit latrine with ventilation (VIP)							-0.01476	0.05248
X_{67}	Pit latrine without ventilation	-0.04376	0.04348					-0.01795	0.13842
X_{68}	Bucket latrine								
X_{69}	None							-0.00333	0.05968
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*								
X_{70}	Electricity								

		N. Cape				F. State			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{71}	Gas								
X_{72}	Paraffin					0.04203	-0.05148		
X_{73}	Wood	-0.03138	0.03066	-0.02760	0.01929	-0.05808	0.27686	-0.07729	-0.0078
X_{74}	Coal								
X_{75}	Animal dung					-0.01613	0.17468	-0.10623	-0.01745
X_{76}	Solar								
Gender of Head of Household									
X_{77}	Male								
X_{78}	Female								
Population Group of Head of Household									
X_{79}	Black African			0.22019	0.15547				
X_{80}	Coloured								
X_{81}	Indian or Asian								
X_{82}	White								
Occupation of Head of Household									
X_{83}	Legislators, senior officials and managers								
X_{84}	Professionals								
X_{85}	Technicians and associate professionals								
X_{86}	Clerks								
X_{87}	Service workers, shop and market sales workers								
X_{88}	Skilled agricultural and fishery workers	-0.15278	0.10651	-0.10779	0.10002	-0.17093	0.31814		
X_{89}	Craft and related trades workers								
X_{90}	Plant and machine operators and assemblers					-0.14137	0.24485		
X_{91}	Elementary occupations	-0.10029	0.09497	-0.12539	0.06625	-0.12855	0.28095		
X_{92}	Occupations unspecified or not elsewhere classified								
Annual Household Income									
X_{93}	No income								
X_{94}	R 1 - R 4 800								
X_{95}	R 4 801 - R 9 600								
X_{96}	R 9 601 - R 19 200								
X_{97}	R 19 201 - R 38 400								
X_{98}	R 38 401 - R 76 800								
X_{99}	R 76 801 - R 153 600								

		N. Cape				F. State			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{100}	R 153 601 - R 307 200								
X_{101}	R 307 201 - R 614 400								
X_{102}	R 614 401 - R 1 228 800								
X_{103}	R 1 228 801 - R 2 457 600								
X_{104}	R 2 457 601 or more								

(Part 3) Coefficients of significant variables for the linear discriminant functions for KwaZulu-Natal and North West

		KZN				N. West			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	CONSTANT	-45.85524	-53.32265	-40.6216	-33.63047	-48.66572	-39.00236	-27.87796	-15.30619
	Person								
X_1	Population density			0.0000849	-0.0000969	0.0002281	-0.0001053	0.0000304	0.0007397
Language	*(Language most often spoken at home)*								
X_2	Afrikaans								
X_3	English								
X_4	IsiNdebele								
X_5	IsiXhosa								
X_6	IsiZulu								
X_7	Sepedi								
X_8	Sesotho								
X_9	Setswana								
X_{10}	Siswati								
X_{11}	Tshivenda								
X_{12}	Xitsonga								
Employment Status	*(Employment status of each person)*								
X_{13}	Employed								
X_{14}	Unemployed			0.19626	0.11307				
X_{15}	Scholar or student								
X_{16}	Home-maker or housewife								
X_{17}	Pensioner or retired person								
X_{18}	Unable to work due to illness or disability								
X_{19}	Seasonal worker not working presently								
X_{20}	Does not choose to work								
X_{21}	Could not find work								
Work Status	*(Main activity or work status of person)*								
X_{22}	Paid employee	-0.00266	0.25304						
X_{23}	Paid family worker								
X_{24}	Self-employed								
X_{25}	Employer								
X_{26}	Unpaid family								

		KZN				N. West			
		Sample 1		Sample 2		Sample 1		Sample 2	
	worker								
Total Births	*(Total children ever born)*								
X_{27}	0-5 children	0.1584	-0.01491						
X_{28}	6-10 children								
X_{29}	More than 10 children								
Level of Education	*(Highest level of education the person completed)*								
X_{30}	No schooling	0.06859	0.2421	0.34962	0.48961				
X_{31}	Some primary			0.61286	0.79096				
X_{32}	Complete primary								
X_{33}	Some secondary								
X_{34}	Grade 12/ Std 10								
X_{35}	Higher								
Household									
Household Size	*(Total number of persons in a household)*								
X_{36}	1-5 persons								
X_{37}	6-10 persons								
X_{38}	More than 10 persons								
Housing Unit	*(Type of living quarters)*								
X_{39}	House or brick structure on a separate stand or yard								
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials	0.03566	0.08137						
X_{41}	Flat in a block of flats			0.02498	0.05933				
X_{42}	Town/ cluster/ semi-detached house								
X_{43}	House/ flat/ room, in backyard								
X_{44}	Informal dwelling/ shack, in backyard							0.10448	0.00115
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter			0.11895	-0.01373			0.07987	0.00460
X_{46}	Room/ flatlet not in backyard but on shared property								

		KZN				N. West			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{47}	Caravan or tent								
X_{48}	Private ship/ boat								
Rooms	*(Number of rooms that the household utilises)*								
X_{49}	1-3 rooms								
X_{50}	4-6 rooms							0.10847	0.06954
X_{51}	7-10 rooms								
X_{52}	More than 10 rooms								
Access to Water	*(Type of access to water)*								
X_{53}	Piped water (tap) inside dwelling								
X_{54}	Piped water (tap) inside yard								
X_{55}	Piped water on community stand: < 200 metres								
X_{56}	Piped water on community stand: > 200 metres								
X_{57}	Borehole	-0.00958	0.22663						
X_{58}	Spring								
X_{59}	Rainwater tank								
X_{60}	Dam/ pool/ stagnant water								
X_{61}	River/ stream	-0.03528	0.09776						
X_{62}	Water vendor								
Toilet facilities	*(Main type of toilet facilities)*								
X_{63}	Flush toilet (connected to sewerage system)			0.21796	0.00824	0.09316	-0.04421	0.33024	0.03722
X_{64}	Flush toilet (with septic tank)			0.20664	0.0481			0.27736	0.11931
X_{65}	Chemical toilet								
X_{66}	Pit latrine with ventilation (VIP)					0.03258	-0.01551		
X_{67}	Pit latrine without ventilation							0.01818	0.05084
X_{68}	Bucket latrine					0.06057	-0.02716	0.31094	0.03748
X_{69}	None								
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*								
X_{70}	Electricity	0.79634	0.64658	0.09024	0.06435	-0.12828	0.0671		

		KZN				N. West			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{71}	Gas								
X_{72}	Paraffin								
X_{73}	Wood	0.70859	0.72466						
X_{74}	Coal								
X_{75}	Animal dung					-0.58017	0.29937		
X_{76}	Solar								
Gender of Head of Household									
X_{77}	Male								
X_{78}	Female								
Population Group of Head of Household								0.17357	0.22767
X_{79}	Black African								
X_{80}	Coloured								
X_{81}	Indian or Asian								
X_{82}	White								
Occupation of Head of Household									
X_{83}	Legislators, senior officials and managers								
X_{84}	Professionals								
X_{85}	Technicians and associate professionals								
X_{86}	Clerks								
X_{87}	Service workers, shop and market sales workers								
X_{88}	Skilled agricultural and fishery workers	-0.10151	0.28302	-0.23064	-0.07783				
X_{89}	Craft and related trades workers					-0.19415	0.09833		
X_{90}	Plant and machine operators and assemblers					-0.12408	0.06510		
X_{91}	Elementary occupations	-0.08997	0.00981			-0.184	0.09419	-0.07648	-0.02976
X_{92}	Occupations unspecified or not elsewhere classified					-0.24023	0.12628		
Annual Household Income									
X_{93}	No income								
X_{94}	R 1 - R 4 800								
X_{95}	R 4 801 - R 9 600								
X_{96}	R 9 601 - R 19 200								
X_{97}	R 19 201 - R 38 400								
X_{98}	R 38 401 - R 76 800								
X_{99}	R 76 801 - R 153 600								

		KZN				N. West			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{100}	R 153 601 - R 307 200								
X_{101}	R 307 201 - R 614 400								
X_{102}	R 614 401 - R 1 228 800								
X_{103}	R 1 228 801 - R 2 457 600								
X_{104}	R 2 457 601 or more								

(Part 4) Coefficients of significant variables for the linear discriminant functions for Gauteng and Mpumalanga

		Gauteng				MP			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	CONSTANT	-69.05159	-99.19904	-69.05159	-99.19904	-14.45368	-17.58319	-12.77307	-14.24335
	Person								
X_1	Population density					0.0002469	-0.0001784	-0.0002347	-0.0005404
Language	*(Language most often spoken at home)*								
X_2	Afrikaans								
X_3	English								
X_4	IsiNdebele	0.10901	-0.20477	0.1131	-0.15830				
X_5	IsiXhosa								
X_6	IsiZulu							-0.01113	-0.03646
X_7	Sepedi								
X_8	Sesotho								
X_9	Setswana								
X_{10}	Siswati								
X_{11}	Tshivenda								
X_{12}	Xitsonga								
Employment Status	*(Employment status of each person)*								
X_{13}	Employed								
X_{14}	Unemployed								
X_{15}	Scholar or student								
X_{16}	Home-maker or housewife								
X_{17}	Pensioner or retired person								
X_{18}	Unable to work due to illness or disability								
X_{19}	Seasonal worker not working presently								
X_{20}	Does not choose to work								
X_{21}	Could not find work								
Work Status	*(Main activity or work status of person)*								
X_{22}	Paid employee							0.1212	0.15877
X_{23}	Paid family worker								
X_{24}	Self-employed	-0.32926	-0.61633	-0.33510	-0.75026				
X_{25}	Employer								
X_{26}	Unpaid family worker								

		Gauteng				MP			
		Sample 1		Sample 2		Sample 1		Sample 2	
Total Births	*(Total children ever born)*								
X_{27}	0-5 children					0.18874	0.07598		
X_{28}	6-10 children								
X_{29}	More than 10 children								
Level of Education	*(Highest level of education the person completed)*								
X_{30}	No schooling								
X_{31}	Some primary								
X_{32}	Complete primary								
X_{33}	Some secondary								
X_{34}	Grade 12/ Std 10								
X_{35}	Higher								
Household									
Household Size	*(Total number of persons in a household)*								
X_{36}	1-5 persons								
X_{37}	6-10 persons								
X_{38}	More than 10 persons								
Housing Unit	*(Type of living quarters)*								
X_{39}	House or brick structure on a separate stand or yard								
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials					0.00353	0.04373		
X_{41}	Flat in a block of flats								
X_{42}	Town/ cluster/ semi-detached house								
X_{43}	House/ flat/ room, in backyard								
X_{44}	Informal dwelling/ shack, in backyard								
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter	0.11308	0.03723	0.11709	0.04646			0.02669	-0.01261
X_{46}	Room/ flatlet not in backyard but on shared property								
X_{47}	Caravan or tent								
X_{48}	Private ship/ boat								
Rooms	*(Number of rooms that the household*								

		Gauteng				MP			
		Sample 1		Sample 2		Sample 1		Sample 2	
	utilises)								
X_{49}	1-3 rooms								
X_{50}	4-6 rooms								
X_{51}	7-10 rooms								
X_{52}	More than 10 rooms								
Access to Water	*(Type of access to water)*								
X_{53}	Piped water (tap) inside dwelling								
X_{54}	Piped water (tap) inside yard								
X_{55}	Piped water on community stand: < 200 metres								
X_{56}	Piped water on community stand: > 200 metres								
X_{57}	Borehole	-0.0199	0.76721	-0.0199	0.76721	0.01375	0.17016		
X_{58}	Spring								
X_{59}	Rainwater tank								
X_{60}	Dam/ pool/ stagnant water								
X_{61}	River/ stream					-0.00111	0.07760		
X_{62}	Water vendor								
Toilet facilities	*(Main type of toilet facilities)*								
X_{63}	Flush toilet (connected to sewerage system)	0.18743	0.10889	0.18552	0.10444			0.11375	0.02013
X_{64}	Flush toilet (with septic tank)	0.17626	0.36646	0.17626	0.36646				
X_{65}	Chemical toilet								
X_{66}	Pit latrine with ventilation (VIP)								
X_{67}	Pit latrine without ventilation								
X_{68}	Bucket latrine							0.06127	-0.01039
X_{69}	None								
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*								
X_{70}	Electricity								
X_{71}	Gas								
X_{72}	Paraffin							0.02853	0.06783
X_{73}	Wood	0.02187	1.24367	0.02187	1.24367	0.00556	0.0472	0.00352	0.03528
X_{74}	Coal								
X_{75}	Animal dung								
X_{76}	Solar								
Gender of Head of Household									
X_{77}	Male								
X_{78}	Female								
Population Group of Head of Household									

		Gauteng				MP			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{79}	Black African							0.1742	0.22222
X_{80}	Coloured								
X_{81}	Indian or Asian								
X_{82}	White								
Occupation of Head of Household									
X_{83}	Legislators, senior officials and managers								
X_{84}	Professionals								
X_{85}	Technicians and associate professionals								
X_{86}	Clerks								
X_{87}	Service workers, shop and market sales workers								
X_{88}	Skilled agricultural and fishery workers	-0.12886	2.58179	-0.12886	2.58179	-0.06524	0.10064	-0.19090	-0.08819
X_{89}	Craft and related trades workers								
X_{90}	Plant and machine operators and assemblers					0.0126	0.0935		
X_{91}	Elementary occupations	-0.15157	0.21927	-0.15157	0.21927	0.00376	0.05354		
X_{92}	Occupations unspecified or not elsewhere classified								
Annual Household Income									
X_{93}	No income	0.11775	0.09273	0.13855	0.11880				
X_{94}	R 1 - R 4 800								
X_{95}	R 4 801 - R 9 600								
X_{96}	R 9 601 - R 19 200								
X_{97}	R 19 201 - R 38 400								
X_{98}	R 38 401 - R 76 800								
X_{99}	R 76 801 - R 153 600					-0.00844	-0.07137		
X_{100}	R 153 601 - R 307 200								
X_{101}	R 307 201 - R 614 400								
X_{102}	R 614 401 - R 1 228 800								
X_{103}	R 1 228 801 - R 2 457 600								
X_{104}	R 2 457 601 or more								

(Part 5) Coefficients of significant variables for the linear discriminant functions for Limpopo and South Africa as a whole

		Limpopo				RSA			
		Sample 1		Sample 2		Sample 1		Sample 2	
		LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)	LDF (Urban)	LDF (Rural)
	CONSTANT	-16.62465	-13.68195	-64.25581	-57.37735	-34.07552	-34.71215	-29.12101	-23.46501
	Person								
X_1	Population density			0.0006189	-0.0005445				
Language	*(Language most often spoken at home)*								
X_2	Afrikaans	0.15033	0.08441	1.17996	1.05291				
X_3	English			1.30677	1.12542				
X_4	IsiNdebele			0.14797	-0.01982				
X_5	IsiXhosa								
X_6	IsiZulu								
X_7	Sepedi								
X_8	Sesotho								
X_9	Setswana								
X_{10}	Siswati								
X_{11}	Tshivenda								
X_{12}	Xitsonga			-0.01369	0.00405				
Employment Status	*(Employment status of each person)*								
X_{13}	Employed								
X_{14}	Unemployed	0.32901	0.15108						
X_{15}	Scholar or student								
X_{16}	Home-maker or housewife								
X_{17}	Pensioner or retired person								
X_{18}	Unable to work due to illness or disability								
X_{19}	Seasonal worker not working presently								
X_{20}	Does not choose to work								
X_{21}	Could not find work	0.48525	0.19063						
Work Status	*(Main activity or work status of person)*								
X_{22}	Paid employee								
X_{23}	Paid family worker								
X_{24}	Self-employed								
X_{25}	Employer								
X_{26}	Unpaid family worker								

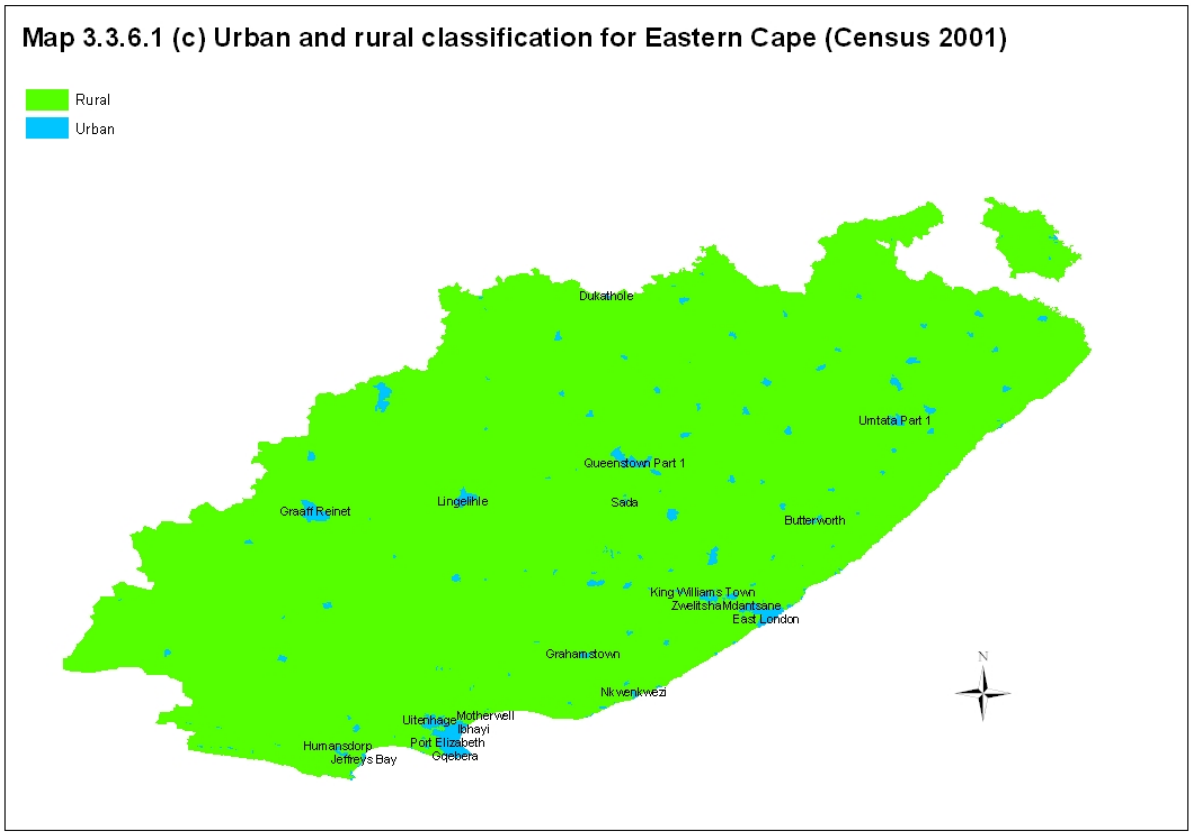
		Limpopo				RSA			
		Sample 1		Sample 2		Sample 1		Sample 2	
Total Births	*(Total children ever born)*								
X_{27}	0-5 children								
X_{28}	6-10 children								
X_{29}	More than 10 children								
Level of Education	*(Highest level of education the person completed)*								
X_{30}	No schooling								
X_{31}	Some primary								
X_{32}	Complete primary								
X_{33}	Some secondary								
X_{34}	Grade 12/ Std 10								
X_{35}	Higher								
Household									
Household Size	*(Total number of persons in a household)*								
X_{36}	1-5 persons								
X_{37}	6-10 persons	0.07952	0.0005374						
X_{38}	More than 10 persons								
Housing Unit	*(Type of living quarters)*								
X_{39}	House or brick structure on a separate stand or yard					0.01002	0.00181		
X_{40}	Traditional dwelling/ hut/ structure made of traditional materials								
X_{41}	Flat in a block of flats								
X_{42}	Town/ cluster/ semi-detached house								
X_{43}	House/ flat/ room, in backyard								
X_{44}	Informal dwelling/ shack, in backyard							0.07004	0.00412
X_{45}	Informal dwelling/ shack, not in backyard, informal/ squatter					0.04097	-0.0000317	0.10551	0.02211
X_{46}	Room/ flatlet not in backyard but on shared property								
X_{47}	Caravan or tent								
X_{48}	Private ship/ boat								
Rooms	*(Number of rooms that the household*								

		Limpopo				RSA			
		Sample 1		Sample 2		Sample 1		Sample 2	
	utilises)								
X_{49}	1-3 rooms								
X_{50}	4-6 rooms								
X_{51}	7-10 rooms								
X_{52}	More than 10 rooms								
Access to Water	*(Type of access to water)*								
X_{53}	Piped water (tap) inside dwelling								
X_{54}	Piped water (tap) inside yard								
X_{55}	Piped water on community stand: < 200 metres								
X_{56}	Piped water on community stand: > 200 metres								
X_{57}	Borehole								
X_{58}	Spring								
X_{59}	Rainwater tank								
X_{60}	Dam/ pool/ stagnant water								
X_{61}	River/ stream					-0.03509	0.08867		
X_{62}	Water vendor								
Toilet facilities	*(Main type of toilet facilities)*								
X_{63}	Flush toilet (connected to sewerage system)			0.16491	0.00852	0.00482	0.05628	0.21709	0.06066
X_{64}	Flush toilet (with septic tank)	0.01816	0.07992					0.18751	0.09307
X_{65}	Chemical toilet								
X_{66}	Pit latrine with ventilation (VIP)								
X_{67}	Pit latrine without ventilation							0.03325	0.05721
X_{68}	Bucket latrine	-0.15112	0.05774			0.05972	0.01552	0.16831	0.02298
X_{69}	None								
Energy source for cooking	*(Type of energy/ fuel mainly used for cooking)*								
X_{70}	Electricity								
X_{71}	Gas								
X_{72}	Paraffin			0.06726	-0.02421	-0.00683	0.14897	0.02675	0.06034
X_{73}	Wood	-0.03418	0.06317						
X_{74}	Coal								
X_{75}	Animal dung							0.03831	0.07508
X_{76}	Solar								
Gender of Head of Household									
X_{77}	Male								
X_{78}	Female	0.15381	0.08890			0.53218	0.42717		
Population Group of Head of Household									

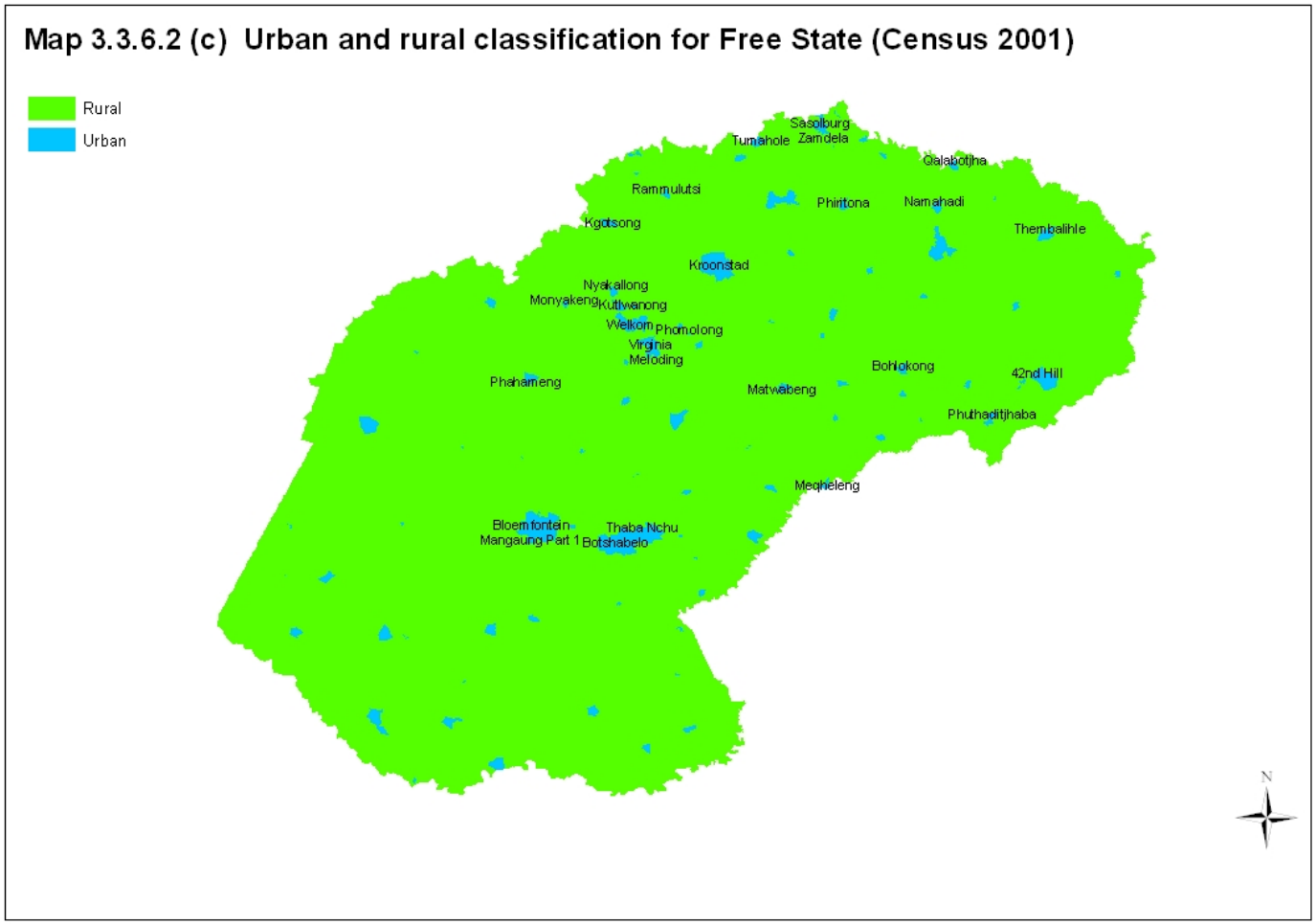
		Limpopo				RSA			
		Sample 1		Sample 2		Sample 1		Sample 2	
X_{79}	Black African			1.09025	1.15109				
X_{80}	Coloured								
X_{81}	Indian or Asian								
X_{82}	White								
Occupation of Head of Household									
X_{83}	Legislators, senior officials and managers								
X_{84}	Professionals								
X_{85}	Technicians and associate professionals								
X_{86}	Clerks			0.16627	-0.12140				
X_{87}	Service workers, shop and market sales workers								
X_{88}	Skilled agricultural and fishery workers	0.02680	0.16340	-0.15475	-0.01240	-0.1156	0.22591	-0.06498	0.08107
X_{89}	Craft and related trades workers								
X_{90}	Plant and machine operators and assemblers					-0.05328	0.10939		
X_{91}	Elementary occupations					-0.0793	0.15901	-0.06075	0.02462
X_{92}	Occupations unspecified or not elsewhere classified								
Annual Household Income									
X_{93}	No income								
X_{94}	R 1 - R 4 800								
X_{95}	R 4 801 - R 9 600								
X_{96}	R 9 601 - R 19 200								
X_{97}	R 19 201 - R 38 400								
X_{98}	R 38 401 - R 76 800								
X_{99}	R 76 801 - R 153 600	0.31775	0.17439						
X_{100}	R 153 601 - R 307 200								
X_{101}	R 307 201 - R 614 400								
X_{102}	R 614 401 - R 1 228 800								
X_{103}	R 1 228 801 - R 2 457 600								
X_{104}	R 2 457 601 or more								

APPENDIX E

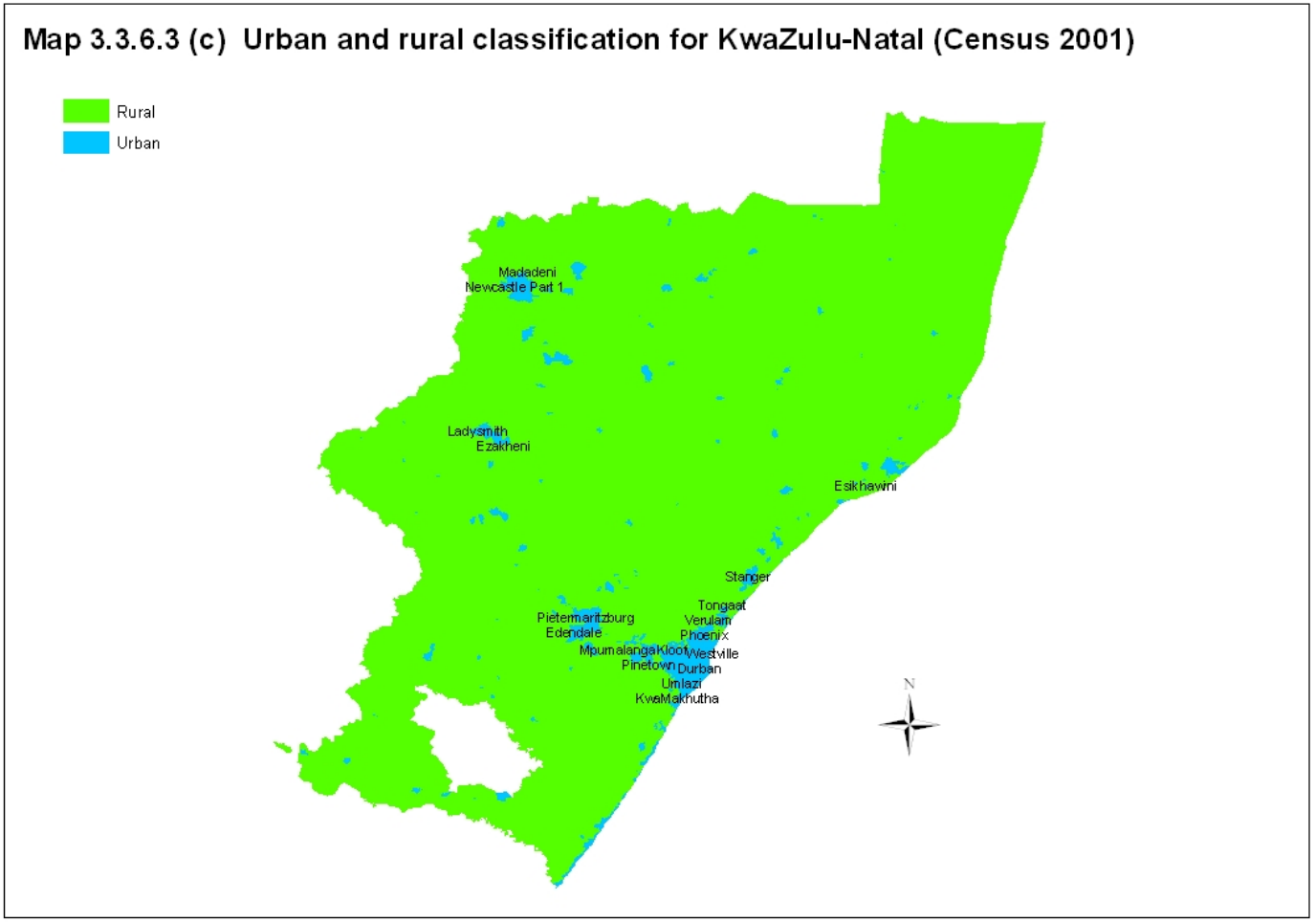
Maps illustrating the provincial urban and rural classification



Map 3.3.6.2 (c) Urban and rural classification for Free State (Census 2001)



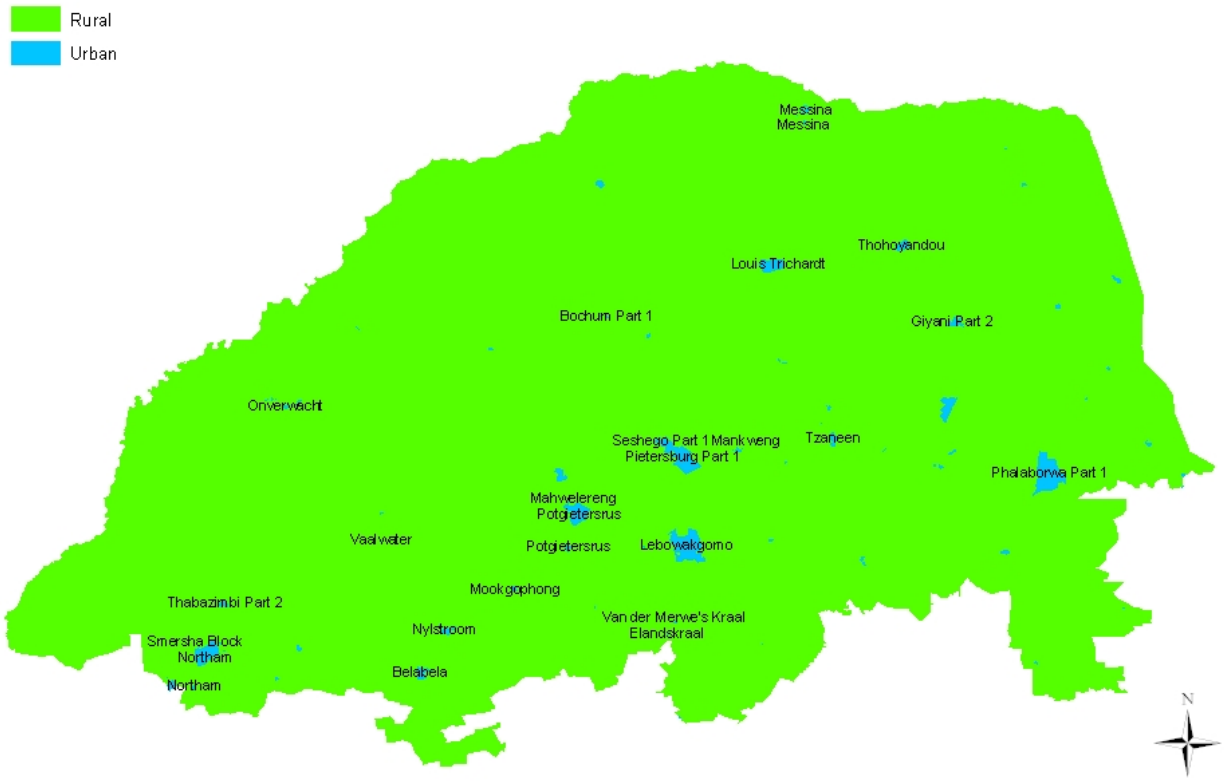
Map 3.3.6.3 (c) Urban and rural classification for KwaZulu-Natal (Census 2001)



Map 3.3.6.4 (c) Urban and rural classification for North West (Census 2001)

Map 3.3.6.5 (c) Urban and rural classification for Mpumalanga (Census 2001)

Map 3.3.6.6 (c) Urban and rural classification for Limpopo (Census 2001)



Map 3.3.6.7 (c) Urban and rural classification for the RSA (Census 2001)