ENVIRONMENT AND CULTURE: AN ANALYSIS OF SETTLEMENT PATTERNS IN STONE WALLED STRUCTURES LOCATED IN SOUTHERN GAUTENG, SOUTH AFRICA.

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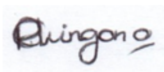
Declaration by candidate

I, Paidamoyo Hazel Chingono declare that this Dissertation is my own 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 at this or any other university.



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Abstract

Pre-colonial Stone Walled Structures (SWS) in southern Africa have been studied since the 17th Century. Studies focused on establishing the origins of SWS, classification and other socio-economic components associated with these settlements. The physical environment played a significant role in shaping these communities, therefore making it important to establish the correlation between these pre-colonial cultures and the physical environment. Using Google Earth and GIS Sadr and Rodier (2012) undertook a settlement analysis of a 350 km^2 area near the Suikerbosrand nature reserve in southern Gauteng. They observed that settlement patterns revealed a shift from small and dispersed egalitarian societies to more stratified communities between the 15th and 19th century. Using the same techniques that Sadr and Rodier (2012) employed, a settlement pattern analysis was conducted on the rest of the research area in southern Gauteng which is slightly under 9000km^2. Results from an exploratory and a statistical analysis from the research area revealed observations made by Sadr and Rodier 2012 from a 350 km^2 concur with the observations made from the rest of the study area.

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CHAPTER ONE

Introduction

Stone Walled Structures (SWS) have played an important role in shaping pre-colonial communities in Southern Africa. According to Sadr 2012, there is an estimate of a few hundred thousand Stone Walled structures scattered across southern Africa. The most popular of these SWS are the Great Zimbabwe Ruins located in southern central Zimbabwe. The study of SWS in southern Africa began as early as the late nineteenth century, with Theodore Bent (1892) who began excavations at Great Zimbabwe. The beginning of the twentieth century saw an influx of archaeologists who were interested in establishing the origins and functions of these structures (Hall, 1905; McIver, 1906 & Caton-Thompson, 1931). In South Africa systematic studies of SWS began in the mid-1900s (Van Riet Lowe, 1927; Walton, 1956; 1958 & Mason, 1968). These researchers were among other things interested in identifying the origins of these structures, classifying the structures and determining the significance of these structures in southern African pre-history. This was achieved partly by conducting settlement pattern analysis of the SWS (Garlake 1983, Huffman 1996, Beach, 1998). Settlement pattern analysis refers to the process of studying the relationship between and within sites and also considers the relationship between the sites and the surrounding environment (Fagan, 1996). The study of settlement patterns particularly in SWS provides insight on the economic, political and social aspects of life of these pre-colonial communities in southern Africa (Sadr and Rodier, 2012).

The study of SWS in southern Africa began as early as 1892 with scholars like Theodore Bent. They mainly focused on the identification and classification of the walls. Attention was also given to their origins and possible contractors (Mason, 1968; Taylor 1979; Huffman, 2007). A lot of information has been gathered concerning the settlement patterns within the SWS (Boeyens 2003, Huffman 2007). Over the years, a lot of has changed in terms of methodology in analysing SWS in southern Africa. Initially scholars would map the SWS by physically surveying and using aerial photographs of the research area (Mason 1968). Caton-Thompson was the first scholar in southern Africa to use aerial photography to map and spatially analyse the relationships within and between sites (Caton- Thompson 1931). This was later adopted by other scholars throughout the rest of the region and the technique was applied in South Africa by scholars like (Walton, 1956; Mason, 1968 & Maggs, 1976). However with advancement of technology and the introduction of more accurate and precise spatial tools like Geographic Information Systems (GIS), there is need to revisit the spatial analyses that were done on SWS. With the availability of Lidar, Google Earth and various GIS software, it is now easier to acquire process and analyse any spatial data with high precision. With this in mind, Sadr and Rodier (2012) used these techniques to analyse the spatial characteristics of SWS in southern Gauteng. However useful, their study only focused on limited 350 sq. km area, Pam 1, and came up with very interesting results. It therefore becomes important, to establish if the results and conclusions generated from Pam 1 will be similar to that of the research area.

Research Area

The research area is located in the southern half of Gauteng Province, South Africa (**Figure 1**). The research area is just under 9000 sq. km and over 5000 SWS have been identified and digitized on Google Earth Satellite imagery by analysts in South Africa and India (Sadr and Rodier 2012; Sadr in press). The research area includes the Rietspruit river basin, Suikerbosrand river basin and Klip river basin. It also includes the Suikerbosrand Nature reserve. According to Birss and Green (2007) rainfall ranges between 650-700 mm per annum. According to Mason (1968) a good number of the SWS that are located within this area belong to the Iron Age and Sadr (in press) attributes the SWS to the 2nd millennium AD. Sadr (in Press) also notes that a fairly large number of the SWS that were identified are rectilinear and presumably of European origin. These structures are believed to be of European origin is based on the distinct architectural characteristics, these appear to be rectilinear in shape which is not a common feature in Southern African SWS which are more circular in shape (Sadr, in press).

Research Problem

Sadr and Rodier's (2012) study concerned only the ca. 350 sq km parcel labelled Pam 1. Their conclusions based on the settlement patterns of sites in Pam 1 show a sequence from more egalitarian and pastoral settlements and social organization in the earliest part of the sequence (Group I) to hierarchical, densely nucleated agricultural towns (Group II). According to Sadr and Rodier (2012) Group I sites are attributed to the period between the 15th and 17th century and Group II sites are attributed to the period between the 17th and 19th century. Taylor (1979) however notes that there is no substantial evidence which suggest if Group II and Group III were contemporary but it is clear that Group III suggest a period of transition between Group I and Group II communities (Sadr and Rodier 2012). These conclusions rest on a limited sample of the sites in a small portion of the overall research area which is just less than 9000 sq. km.

Research Question

Will a settlement pattern study of the entire study area support the conclusions reached by Sadr and Rodier (2012) concerning the social, economic and political organization of Group I and Group II sites in this area?

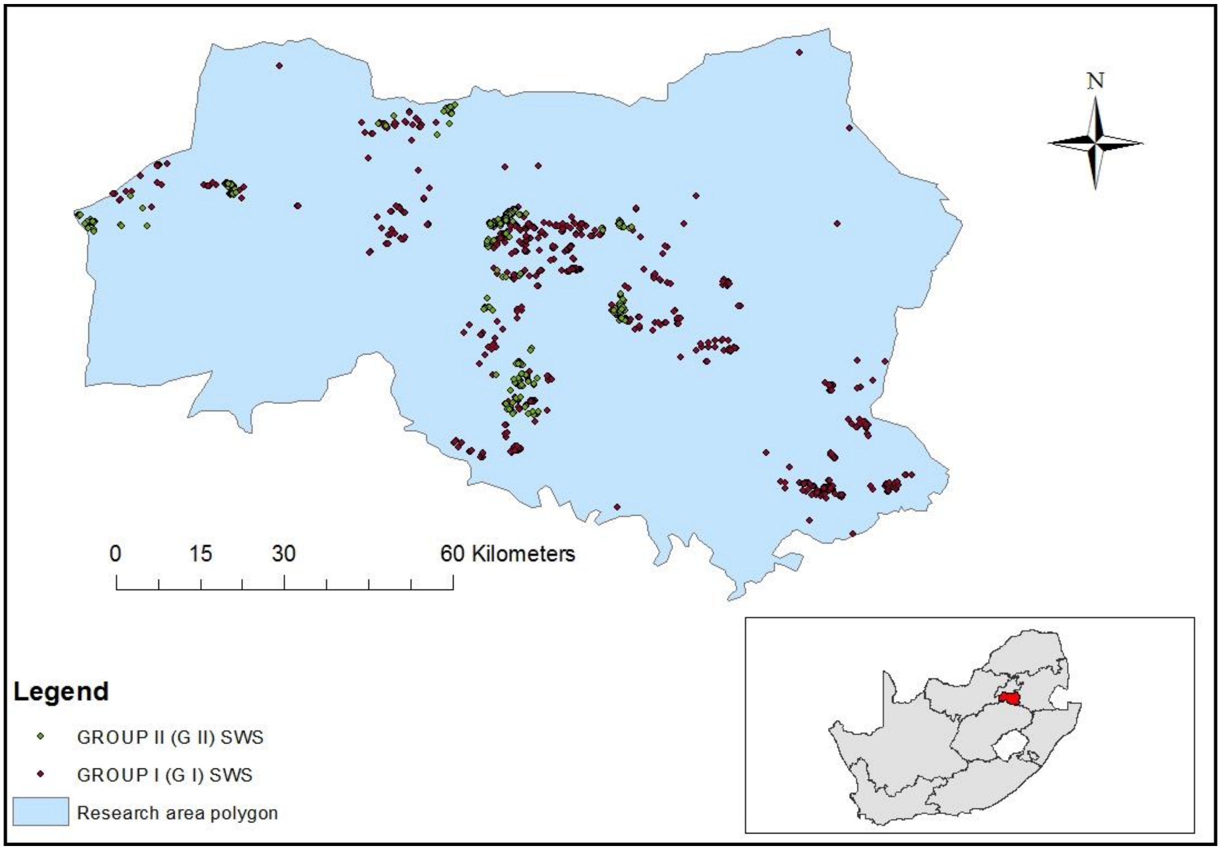

Figure 1. Showing the distribution of Group I and Group II SWS and the location of the research area in South Africa

1.2 Research Objectives

Aim

The aim of this research is to conduct locational analyses on the Group I and Group II ruins in the entire study area to test the conclusions reached by Sadr and Rodier (2012) in their smaller sample.

Objectives

1. Map the spatial distribution of a host of relevant physical environmental as well as modern cultural features (such as best arable soils, grazing potential, urban developments which might

affect distribution of ruins, etc.) in the southern Gauteng. (Modern cultural features refers to all infrastructural and land developments in the contemporary society)

2. Map the distribution of all Group I and Group II SWS in the study area.
3. Analyse the nature and the extent of the relationship between the distribution of SWS and the physical environmental and modern cultural features.
4. Conduct appropriate statistical tests to determine the significance of any relationships observed in objective 3.
5. Test Sadr and Rodier's (2012) conclusions by comparing settlement patterns of Group I and Group II SWS from across the entire study area to their sample.

1.3 Thesis overview

The thesis is focused on settlement pattern analysis of SWS located in southern Gauteng province in South Africa. It is organised in a series of 5 chapters which includes Chapter 1 which deals with introducing the thesis to the reader. Chapter 2 focuses on the literature review and theoretical framework. The chapter starts by looking at the origins of settlement pattern studies in archaeology and subsequently the various methods that were used to study settlement patterns in archaeology. These methods will include a review of spatial statistics and the use of GIS in studying settlement patterns in archaeology. The chapter will also give detail on previous research that has been done in southern Africa concerning SWS especially those that are believed to have been constructed by the Sotho-Tswana people. The second chapter also reviews literature by scholars who among other things excavated and studied SWS in South Africa. Lastly the chapter will review Sadr and Rodier's (2012) article which is essential to this research.

Chapter 3 gives particular attention to the different methods of data acquisition and processing that were used during the course of the research. The chapter starts by describing the objectives of the research and methods are written per objective. This is to say that for each objective a detailed explanation is given on the methods that were used to execute that objective. The methods are given in detail explaining the theories behind each method and generally clarifying how the method works. Attention is also given to the advantages and disadvantages of the methods that were used. Alternative methods are provided in certain circumstances and some cases; both methods are used for better clarity or precision. In this chapter three main tools (ArcGIS, QGIS and R software) are used for data processing and analysis. ArcGIS and QGIS are used alternatively depending on which software performs better than the other in different situations. R software was used for statistical analysis like the Kolmogorov-Smirnov test and the Mann –Whitney test.

Chapter Four centres on presentation and analysis. Analysis of distribution maps and statistics is conducted to understand the spatial organisation of the research area. The chapter starts by making reference to Sadr and Rodier's (2012) publication which focuses on the use of GIS and Google Earth imagery in analysing spatial patterns of SWS in southern Gauteng. Results from Sadr and Rodier's (2012) Pam 1 are compared with results generated from the research area. This is done in order to determine if the conclusions they made on Pam 1 are applicable for the entire study area. Apart from a comparative analysis, Chapter four also considers other physical parameters that were not considered in Sadr and Rodier's (2012) analysis. This includes distance from rivers, geology and further elevation analysis. Chapter four concludes with a statistical test of significance where Group I and Group II SWS are statistically tested to determine if they come from the same sample group, in simpler terms to determine if Group I and Group II SWS were constructed by the same cultural group.

Chapter five focuses on the discussion of the results and conclusion of the thesis. It provides a summary of how the research was conducted and the archaeological interpretation of the research area. The results generated from the current research are provided and are contextualized within the archaeological frame work. Possible explanations are provided for the nature of the results and these are compared with what previous scholars have noted concerning the same topics. The chapter provides challenges that were faced in the course of the research and some of the limitations of the research. The chapter concludes by providing suggestions for future research.

CHAPTER TWO

Literature Review and Theoretical Framework

Introduction

Settlement pattern analysis provides information on the political, economic and social organisation of any given community. The broader topic of settlement pattern analysis has facilitated the evolution of both archaeological theory and methodology in order to better understand past communities (Johnson, 1977). This chapter will first focus on the origins of settlement pattern analysis from cultural ecology and the various theories which made up settlement pattern studies. The chapter will also present detailed descriptions of spatial analysis and spatial statistics in settlement pattern analysis and the different methods and theories that have been used in studying spatial systems. Attention will be also given to the application of GIS in archaeology and the advantages and disadvantages of GIS particularly in archaeology. The chapter will conclude by focusing on earlier research of the Sotho-Tswana communities and how SWS have been studied throughout Southern Africa particularly in southern Gauteng.

2.1Cultural Ecology

Cultural ecology can be defined as the study of the relationship between human behaviour and ecology (Steward, 1955). According to Frake (1962) cultural ecology presents a point of departure from traditional anthropology by Julian Steward who opposed many views and opinions by traditional anthropologist. Traditional anthropologists were of the view that, the only way to understand culture was through an in-depth analysis of the culture itself (Steward, 1955). They believed that there was no other way that could explain how different cultures developed and evolved through time and space (Steward, 1955). They emphasised that more than anything else, historical factors initiated and shaped culture (Frake, 1962). Cultural anthropologists argued that environmental factors had a minimal effect on shaping culture, let alone developing culture and they acknowledged that the environment allowed cultures to evolve at a certain degree but did not result in the development of culture (Steward, 1955).

Influenced by scholars like Forde (1949) who argued that most of the world economic developments were facilitated by the nature of their surrounding environments and that world cultures would evolve by means of adaptation to the physical environment, Julian Steward pioneered cultural ecology. Unlike his fellow anthropologists, Steward adapted the use of ecological evolutionary theories to explain human complexity (Steward 1955). According to Steward (1955) the aim of cultural ecology was to study and analyse the extent of the relationship between human culture, biology and the physical environment. Cultural ecology was also considered as a method to investigate how cultures adapted to different environments and how these changes affected the entire culture (Steward 1955). Steward suggested that if there was a way of understanding how pre-historic communities made a living, it would become easier to understand how past cultures adapted to the environment and evolved (Steward 1955).

Traditional anthropologists proposed a unilinear evolution model suggesting that all cultures were the same and they all passed through the same stages of development (Steward 1955). Steward however suggested a different model, a multilinear evolution model suggesting that each and every culture is different and should be treated individually. He explained that different cultures went through different stages of evolution and this is determined by the culture type and the surrounding environment (Steward, 1955). Steward emphasised the importance of the environment in shaping culture, and demonstrated how each culture type was clearly an expression of the culture's adaptation to its surrounding environment (Frake, 1962). According to Steward, the pillar of cultural ecology is the adaptation of the culture to the environment and the key to adaptation is technology (Steward, 1955). Hawley (1950) agrees by noting that, some of the ways of observing that there is change in culture is through internal specialisation.

However just like any other theory cultural ecology had a number of criticisms that needed to be addressed. Steward acknowledged that there are some aspects of culture that are not determined by the physical environment and technological developments and gives examples such as political opinion, way of dressing, religion and language (Steward, 1955). He explains that even though a group of people may live in the same environment they might borrow certain words from each other but they do not adopt the whole language (Steward, 1955). Another criticism that cultural ecology faced is the fact that it cannot account for the variation of culture in areas with the same environmental conditions (Earle, 1980). Balée (1996) argued that, cultural ecology could only explain societies that were egalitarian and could not explain culture in more complex societies. He further argues that not only can it not explain culture in State systems; it is only effective when explaining where there is limited culture evolution rather than where there is actual cultural evolution (Balée, 1996).

In spite of these criticisms, Steward's approach was embraced by scholars like Leslie White (1959), Marvin Harris (1966), Robert Netting (1977) and Roy Rappaport (1968) who also showed an appreciation of the influence of environmental factors on culture. Steward's notion of cultural ecology was able to lay a foundation for many theories and studies that were to follow for example, ecological anthropology and most importantly provide solutions to criticisms. In the 1960s, scholars like Rappaport believed that culture was part of an ecosystem. He used aspects such as biology, carrying capacity and the use of energy to explain the nature and extent of spatial distribution of humans and animals (Rappaport 1968). This new method was able to prove that culture was not entirely shaped by the physical environment but rather these two factors reciprocally depended on each other and this lead to historical ecology (Panakhyo & McGrath, 2009). According to Barfield (1997) historical ecology explains the relationship between culture and the physical environment. It explores how the two correlate to each other and how they mutually influence the other's outcome over time (Barfield, 1997). Unlike environmental determinism which suggests that, cultural evolution is caused by factors that have to do with the physical environment, historical ecology states that culture and environment can both negatively or positively affect the course of the other (Panakhyo & McGrath, 2009).

Leslie White developed the notion that culture evolution was a result of technological advancement and the amount of energy that humans could harness from the physical environment (White, 1959). In 1979, Harris developed cultural materialism which alluded to White's notion that improvement in technology facilitated culture change (Harris, 1979). Cultural materialism was based on the premise that a combination of economic growth, technology and the way a community adapted to its natural environment influenced the overall culture of that community (Harris, 1979). However cultural materialism faced criticisms because Harris' notion of adaptation to the environment made his argument deterministic (Milton, 1997). Among other things, cultural ecology also laid a foundation for human behavioural ecology (Winterhalder & Smith, 2000) in the mid-1970s and most importantly to this study, Spatial Settlement Analysis.

2.2 Spatial settlement analysis

Based on Steward's (1955) theory that humans adapt to the nature of their physical environment and this in turn shaped the outcome of the culture, Gordon Willey was encouraged to undertake research that involved studying how archaeological sites and material culture were organised in space in relation to the physical environment (Willey, 1953). Willey's research in the Viru Valley, Peru was aimed at analysing how humans interacted amongst themselves and with their environment in the past. This research pioneered what is now termed spatial settlement analysis. Willey (1953) defines a settlement pattern as a demonstration of how human behaviour is displayed in a given landscape. It includes how structures and features are located within space in relation to each other and the surrounding physical environment (Willey 1953). Fagan (1996) also defines a settlement pattern as a manifestation of human interaction among themselves as well as the physical and social environments surrounding them. Both definitions emphasize the importance of the physical environment in shaping human behaviour but also acknowledge the fact that culture should be considered because it distinguishes human from animal behaviour.

According to Connah (1987) when studying settlement patterns in prehistoric and historic communities, it is very important to pay attention to the physical environment surrounding the archaeological sites. He explains that emphasis should be given to the soil type, water sources, the geology of the area, vegetation cover, rainfall and temperature characteristics among other things. Connah (1987) explains that, these variables have a bearing on the culture of the people as they affected most, if not all the activities that occurred within a given society. Like traditional anthropologists, Connah (1987) agrees that as much as the environment may have influenced human behaviour and activities, the environment did not initiate the development of culture. However he acknowledges that the environment plays a pivotal role in shaping how culture evolved through time and space. Connah (1987) suggests that the environment and people have a dynamic relationship where the environment provides resources to the humans, sometimes in a limited way. Humans then must find the means and technology to extract resources. Sometimes the methods they use for extraction have a negative effect on the environment.

Settlement pattern analysis has helped us understand ancient social complexity and stratification. Garlake (1973) and Huffman (1996b) were able to observe the nature of social stratification at Great Zimbabwe and how social classes were expressed in space. Garlake (1973) observed that, the lower classes were located in the low lying valley flows and the area was generally over populated. This observation was made after an analysis of the hut floors that are still visible in the area. Huffman (1996b) also noticed the elite classes including the king inhabited higher areas (the hill complex) and the settlements were not as congested as those for the lower classes. From a spatial analysis of the ruins, Huffman (1996b) also observed other dichotomies of the people's cultures; for example how they expressed gender, life and death, back and front, poor and rich through left and right sides within a given space. As an example Huffman (1996b) observed that at great Zimbabwe the front space of a homestead was considered as a public domain, where visitors could sit and children play. The back space of that household was considered as a private domain where family rituals could take place and other private activities.

Settlement pattern analysis is important in archaeology in so many ways; it can show social stratification and other aspects of the social organisation. It also shows population changes and how the community was economically organised (Steward & Seltzer, 1938). Settlement pattern analysis does not only help us understand past man-land relationships (Willey, 1953) but also help us understand a number of social aspects like cosmology (Burrough & McDonnell, 1998), discover patterns and test hypotheses (Hodder and Orton, 1979). In other studies, spatial analysis in archaeology has enabled archaeologists to understand and explain the role of the environment in shaping culture (Wiley, 1953). Spatial analysis also facilitated archaeologists to understand past religions (Palka, 2014), economic activities (Trigger, 1976), architectural styles (Cutting, 2003) and political activities (Brown and Witschey, 2001).

Systematic settlement pattern analysis in archaeology began as early as the 1950s by Willey (Willey, 1953). From its inception in the 1950s, settlement pattern analysis has evolved methodologically. McCoy and Ladefoged (2009) note that, systematic settlement analysis began with simple aerial photography (Willey, 1953) and grid based excavations (Wheeler 1956). With the help of formal sampling strategies, Willey used aerial photographs and topographic maps to conduct settlement analysis in the Viru Valley (Willey, 1953). These techniques were useful during their time but however it was difficult dealing with aerial photographs and paper maps considering the huge amounts of data which was required. In addition, there was nothing more one could do with these static data sources but to make visual interpretations and conclude their work (Kvamme, 2005). However, this all changed in the 1960s with the advent of New Archaeology which advocated for the use of quantitative methods to solve archaeological problems (Fagan, 1996).

2.2.1 Statistics in Settlement Pattern Analysis

New archaeologists argued that using statistics in archaeology would eliminate the bias associated with human error in archaeology (Binford, 1989). Binford was one of the first archaeologist to apply statistics in archaeological spatial analysis (Binford, 1989). He used a multivariate approach on spatial data and he was able to reconstruct Palaeolithic settlements in Biscayan regions (Binford, 1989). Over the years archaeologists have explored the endless possibilities that statistics offers to archaeological methods and theory. Bevan and Conolly (2006) indicated that, the use of statistics in archaeology enables archaeologists to understand the correlation between sites within a particular settlement (intra-site). The use of statistics also enables archaeologists to understand spatial relationships between two or more settlements (inter-sites). New archaeologists also observed that statistics can help solve problems when compiling huge data bases especially with different scales and resolutions (Bevan & Conolly, 2006). However they acknowledge that, as much as statistical methods offer undisputable solutions in archaeology, most of these methods have their own disadvantages and there is need for one to understand the basic theories of spatial statistics in order to overcome those disadvantages (Bevan & Conolly, 2006). With this in mind, it is important to review some of the statistical methods that can be used in analysing spatial data and establish which one of these will be adequate to use for the this research.

2.2.2 Spatial statistics

Rumsey (2010) defines statistics as a process of analysing data, which includes the use of scientific methods to help solve different problems. She further explains that statistics includes the processes of data collection, data analysis, data presentation and finally drawing a conclusion based on the outcome of the data (Rumsey, 2010). Spatial statistics therefore refers to the process of using statistical methods to analyse spatial data. Spatial statistics is defined as the use of mathematical methods to study space and spatial relationships using for example distance and orientation to conduct different types of analyses like settlement pattern analysis, surface modelling, statistical comparison and spatial regression (ESRI Dictionary, 2017). According to Cressie (1991) spatial statistics are based on the premise that attributes located close together are more correlated or have more similarities than those attributes that are further apart (Cressie, 1991). This can help us understand the nature and distribution of attributes; for example spatial statistics can help us analyse the distribution of SWS and give possible explanation on the factors that might have influenced the distribution of the structures.

Statistics can be basic such as calculating sum, average, median, mode, range and standard deviation. Spatial statistics can be more complex as well; we rely on spatial regression analysis to understand the cause of an event (Anselin, 2003, 2005; Drennan 2009). In archaeology, statistical tests are used to bridge the gap between human error and interpretation (Kvamme 1988). According to Delicado (1999) there are a number of problems in archaeological research that need statistics to solve them. These range from data collection sampling techniques to problems of qualitative and quantitative data (Delicado, 1999). Delicado also notes that statistical analyses are used regularly in archaeology, from radio carbon dating to establishing typology (Delicado, 1999).

According to Shennan (1988) spatial statistics through regression analysis plays a major role in determining relationships and strengths of relationships between dependent and independent variables. In archaeology, these variables need to be quantified and it is important that both variables should be continuous and least one of them has to be spatial (Conolly and Lake, 2006). According to Conolly and Lake (2006) Spatial regressions enable us to understand human behaviour and location preferences in relation to the physical environment. This can be achieved through logistic regression of independent variables (environmental parameters) against dependent variables (SWS) or by simply observing spatial dependency (autocorrelation) within the given dataset. Autocorrelation is achieved through calculating statistical indexes like the Moran's test. According to Woodman (2000) logistic linear regression is used to establish the relationship between two continuous variables and relationships are stated in terms of degrees. In linear regression relationships can either produce a positive correlation, a negative correlation or a zero correlation (Conolly and Lake, 2006).

However there are other methods of establishing the relationship between variables which do not involve any form of regression analysis. According to Hauke and Kassowski (2011) relationships can be measured using different types of coefficients. The most commonly used are the Pearson Product Momentum Correlation Coefficient (PPMCC), Spearman's Rank Correlation Coefficient (SRCC) and Kendall's Tau Coefficient (Hauke & Kassowski 2011). Hauke and Kassowski (2011) acknowledge that even though

Spearman's correlation coefficient and Kendall's Tau Coefficient have similar assumptions the underlying logic is different as well as the computational formulae (Hauke and Kassowski, 2011:87). Of particular interest to this research is the relationship between Group I SWS and Group II SWS. The significance of any relationship can be tested by a Mann-Whitney U test and/ or a Kolmogorov-Smirnov test. According to Shennan (1988) the Kolmogorov-Smirnov test is a non-parametric test that shows how similar the distributions of two samples are (Shennan, 1988). However the K-S test works with more than forty elements within a given sample. The Mann-Whitney test is used to evaluate how similar the means of the two samples are (Shennan, 1988). According to Ripley (2005) the Mann-Whitney test is able to highlight the significance of any differences in the means between two samples. All of the stated methods are very useful in analysing relationships but a test which tests the significance of relationships is more adequate, hence this research will use the Mann-Whitney U test and the Kolmogorov-Smirnov test. The research used two samples of sites Group I and Group II sites and it is important to analyse the relationship between these sites and most importantly to test the significance of that relationship. These tests will be explained in detail in the following chapter. Due to the advancement in technology, most of the statistical tests that have been mentioned if not all of them can be performed easily with a push of a button. Advancement in technology saw the advent of statistical softwares like SSPS, R, PAST etc., and most importantly softwares that are able to handle vast amounts spatial data like Geographical Information Systems (GIS).

2.3 Geographic Information Systems in Archaeology

From the 1980s-1990s there was technological advancement which facilitated the availability of both computer hardware and software. This lead to the development of spatial databases and powerful computer based softwares, applications and techniques like Geographic Information Systems (GIS), Laser mapping, remote sensing and Geophysical surveys (Fagan, 1996). With the advent of GIS spatial analysis become easier in archaeology as GIS offered the possibilities of applying quantitative methods on digital data which could be manipulated in so many ways as compared to the analogue data which was used during the 1950s (Fagan, 1996).

Konecny (2003: 183) defines GIS 'as a computer system for the input, manipulation, storage and output of digital spatial data'. Tantillo (2007) defines GIS as a tool capable of creating, managing, capturing, integrating, analysing and presenting georeferenced data. GIS as a computer based system enables us to analyse different data sets simultaneously and has the ability to correlate different data sets and find trends, patterns and relationships (Kvamme 2005). Kvamme (2005) also explains that GIS has the ability to handle large amounts of data, it is interactive and data is easily understood. According to Conolly and Lake (2006) GIS is different from other information systems because it is based upon two descriptors which other information systems do not have. One of these descriptors is attribute data which refers to what is at a given location and the other descriptor is the location data which refers to where a given attribute is located (Conolly and Lake, 2006). They further explain that, all forms of spatial analysis are based on the concept of space and how material is distributed within a given space. They also note that, attribute and locational data within GIS makes GIS the best tool for spatial analyses (Conolly and Lake, 2006).

2.3.1Uses of GIS in Archaeology

Despite all the limitations that are associated with it, GIS has significantly contributed to settlement pattern analysis in archaeology, it is now easier and less time consuming to deduce patterns from settlements, even without doing field work (Lock, 2001). GIS in archaeology has been used to handle large amounts of attribute and spatial data, to analyse different datasets simultaneously and it offers a cheap method of surveying large quantities of land (Kvamme and Kohler, 1988). Apart from that Wheatley and Gillings (2000) note that, GIS in archaeology has been used for data acquisition, storage, analysis and presentation .Neubauer (2004) explains that GIS is not just computer software used to create maps but it is a spatial database which can be used to relate different data sets and solve many problems given that the data is spatially referenced. GIS can be used for a variety of activities in archaeology, for example it can be used as an interface between archaeological prospecting and excavations (Neubauer, 2004). For more complex operations GIS has been used for spatial analysis, surface modelling, 3D visualisation of map features, ESDA (Exploratory Spatial Data Analysis) and predictive modelling (McCoy and Ladefoged, 2009).

Esri (2006) notes a few examples of GIS applications in archaeology like how then the department of Archaeological and Historic preservation in Washington collaborated with GIS experts and came up with a strategy of monitoring and managing oil spills in Washington (Esri, 2006). In Europe the European Union came up with *E.Europe* an Information Technology which uses GIS to document, monitor and protect cultural heritage in Europe (Tantillo, 2007). Modelling archaeological sensitivity models has been the most important contribution of GIS in archaeology (McCoy and Ladefoged 2009). GIS has facilitated some of the most successful models like the Vermont Archaeological Sensitivity Model (VTASM) (Esri, 2006) and the most extensive archaeological predictive model the Minnesota model (Mn Model) (Hudak et al, 2000). GIS has also fostered easier analyses in Archaeoastrology which is the study of celestial landscapes and how ancient people connected with the cosmic environment in association with other cultural data sources like archaeology and ethnography (Cerdeno et al, 2006). GIS then enables archaeoastrologists to integrate different data layers like environmental data, cultural data and the celestial landscape.

According to Gaffney and Van Lauesen (1995) most of the continents have now made GIS a standard tool for archaeological investigation, from surface simulation modelling, predictive modelling to simple documentation and monitoring of cultural heritage. However one can easily observe that Africa as a continent is still lagging behind in terms of GIS applications in archaeology. The slow development of GIS in Africa can be explained by a number of factors, for example poor economic development. As highlighted earlier on, GIS software is expensive therefore most institutions let alone individuals in Africa cannot afford to purchase the software and the hardware needed for GIS operations. Even though there are free GIS softwares like QGIS, the hardware required still need to be purchased for amounts that are expensive for most developing countries. Secondly there is limited GIS expertise in Africa. Knowledge of GIS in Africa is limited to a few academics and professionals. As a result many people in Africa are often unable to gain access to GIS skills due to the fact that they simply cannot afford the hard ware and software required.

However on a brighter note, countries like Nigeria, Kenya, South Africa and Zimbabwe have not lagged far behind in the application of GIS in archaeology. In Zimbabwe Pwiti (1996, 1997a) and Pikirayi (1993) pioneered the use of GIS in spatial settlement analysis and this was later adapted by scholars like Katsamudanga (2007) in analysing prehistoric settlement patterns in the Eastern highlands of Zimbabwe. In Nigeria GIS has been used in heritage management where a predictive model was used to identify a new site south of Ijaiye-Orile site in southwestern Nigeria (Olukole, 2007). In Kenya GIS has been used to conduct site catchment analysis on Pre- Historic sites in Loita- Mara, Kenya (Seitsonen, 2009). In South Africa a lot of ground has been covered concerning the use of GIS and remote sensing in archaeology. This has been mostly fostered by Sadr and his on-going projects on the use of GIS and remote sensing on pre-colonial Stone Walled Structures (SWS) in southern Gauteng province South Africa (Sadr &McQuilkan, 2009). These projects are mainly focused on the use of GIS and remote sensing of archaeological remains in the southern parts of Gauteng province (Sadr and McQuilkan, 2009; Sadr & Rodier, 2012; Sadr, 2012; Sadr & Hunt, 2014 & Sadr, 2015). Other GIS based archaeological projects in South Africa include the modelling of a Pleistocene caves along the southern coast of South Africa as an enquiry on the origins of humanity in the area (Fisher et al, 2010). Fisher et al (2010) also focused on reconstructing the environmental settings for them to understand how the hominids interacted with their environment.

However a number of scholars have criticized the use of GIS in archaeology. These disadvantages include for example, the many errors associated with GIS software due to the curvature of the earth. According to Graeff and Loui (2008) the earth's spherical shape presents a number of problems especially when dealing with large land area. They explain that when dealing with small areas the earth's curvature does not have much influence on the data produced. However when large extents of land are involved there is need to consider the curvature of the earth for one to come up with accurate results (Graeff and Loui, 2008). Other disadvantages include the fact that there is need for extensive training to master the techniques and the fact that both the software and hardware is expensive, hence in most cases the licence to these softwares are purchased by large organisations and universities. Graeff and Loui (2008) also allude that GIS is affected by errors which are sometimes unavoidable for example the errors associated with digitizing and the fact it is difficult to merge data with different formats in a GIS environment. Eiteljorg (2000) further argues that as much as GIS can be useful in analysing spatial data, the fact that GIS is a computer based program makes it very illusive in that it can produce data which can be seen as accurate but however meaningless depending on the input data and processes that were used to produce it. Conolly and lake (2006) also allude to this noting that GIS packages offers a lot of operational tools that can be easily carried out but only gives limited information on the relevance of that tool to the user. Therefore there is need to carefully consider the type of input data and the processes involved in data production. On a brighter note GIS has been able to address most of the criticisms especially in the field of geography (Schuurman, 2000).

2.4 Stone Walled Structures in southern Africa.

According to Huffman (2007) stone walled structures in southern Africa may have originated from the Zimbabwe pattern or the Central Cattle Pattern (CCP) between the Late Stone Age and the Early Iron Age. He explains that the Zimbabwe culture developed the Zimbabwe pattern of stone structures as early as AD1000 and 1220 at K2 and Mapungumbwe respectively (Huffman, 2000). Huffman (2000) explains that the Zimbabwe culture represents social divisions among classes and sacred leadership. After Mapungumbwe AD 1290, the Zimbabwe culture spread from the Shashi-Limpopo Basin towards the north into south- central Zimbabwe where the Great Zimbabwe state was established. Great Zimbabwe has been studied, mapped, excavated and documented from as early as 1892 by Theodore Bent (Bent, 1892). After Bent many scholars also studied the site using different methods and came up with different interpretations on the site (Hall, 1905; 1910; MacIver, 1906; Caton-Thompson, 1931; Garlake, 1973; 1982; Huffman 1986b; 1996; Beach 1998; Thorp 1998). It is important to clarify that the spatial arrangement represented by the Zimbabwe pattern is geographically located from Limpopo area going north into central Zimbabwe. Therefore this research will focus more on the CCP which according to Sadr (2012) occurs in southern Transvaal, geographically covering the research area of the project at hand.

Influenced by Adam Kuper's notion of the importance of cattle, spirituality and the role of men in the political sphere (Kuper 1982) Huffman coined the term CCP (Huffman, 1982). According to the CCP spatial organization can be found in north western South Africa. In his studies of Broederstroom, Huffman (1993) describes the CCP as a settlement pattern which "is characterized by an outer zone containing circular huts (with central fire-places), low status burials and privately owned grain bins, and an inner zone of stock kraals, high status burials, a men's court and communal grain storage facilities controlled by the leader of the settlement" (Huffman, 1993:220). According to Huffman the CCP spatial organization was first established at Moor Park, KwaZulu-Natal. The site was dated to AD 1300- AD 1500. Another site in the Free State Province at Ntsuanatsatsi was dated from AD 1500- AD 1700. CCP then spread into present day Gauteng, Free State, Northeast and Mpumalanga Provinces (Mason1968; Maggs, 1976; Taylor, 1979).

2.4.1 Research into the Sotho-Tswana and Stone Walled Structures.

According to Boeyens (2000) Settlement pattern analysis of the traditional Bantu-Speaking communities began as early as the 1820s with ethnographic studies of the Sotho-Tswana speaking people by Rev J Campbell. Rev Campbell visited the Harutshe people a Tswana group that inhabited one of the SWS capitals and he established that the Tswana were responsible for the construction of the SWS (Campbell, 1822). According to Steyn (2011:102) the Tswana people came into southern Africa from east Africa and they settled in present day Gauteng, Eastern Free State and Northwest provinces, South Africa. This view is also supported by Evers (1988) who argued that ,based on the ceramic sequence there is evidence that there was discontinuity in ceramic style showing the introduction of a new culture (Evers, 1988). According to Evers' migration theory the ceramic style spread into the area (Gauteng, eastern Free State and Northwest provinces) from the northeast towards the southwest. This concurs with Huffman's notion that the new culture was a tributary of the Urewe tradition (Huffman, 1989b).

Boeyens (2003) also attributes the SWS to the Sotho-Tswana speaking people. He notes a Late Iron Age ceramic style he terms Moloko which is associated with the Sotho-Tswana languages. He explains that archaeological evidence suggests that by the 15th century these people lived in small groups in valley floors and plains (Boeyens, 2003). However, there was a change in settlement location around the 17th century, from valley floors to hilltop settlements. This is supported by Campbell's ethnographic studies of the Tswana people. Campbell recorded that most of the settlements were located on hilltops and he explains that hilltop settlements were a defensive position to guard against frequent attacks from enemies (Campbell, 1822). Boeyens (2003) explains this change in settlement areas was a result of increase in population, the need for raw materials for SWS, and it also coincided with the Little Ice Age. Boeyens (2003) explains that early settlements were located near river banks preferably on the foothills or valley flows. They avoided settling on river banks because they associated rivers with spirits (Boeyens, 2003). Archaeological evidence from the Early Moloko sequence showed presence of burnt sorghum, cattle, sheep and goat. Furnaces were discovered a distance away from the SWS and there is evidence of external trade (Boeyens, 2003). From Boeyens' settlement pattern analysis he hypothesized that early SWS (15th to 17th century Group I sites) were located on low lying areas, near rivers and close to arable and grazing lands. Group II sites (18th and 19th century) were located on hilltops and they inhabited areas that were close to minerals, arable and grazing lands (Boeyens, 2003).

However in the 1950s Breutz (1952) attributed the SWS to be of foreign origin, either Hamitic or Cushitic in origin. This notion might have been influenced by the political atmosphere during that time (Boeyens, 2000). These claims were later dismissed by Mason (1968) who was studying the Tswana architectural attributes and concluded that the SWS in the old Transvaal Province were definitely built by the Sotho-Tswana speaking people. Taylor (1979) also supported the view that the SWS were built by the local communities rather than foreigners. Taylor (1979) suggested that his Group I SWS were built by the Sotho people who had migrated from the south and that Group II SWS were built by the Tswana people (Taylor, 1979). Therefore the current view on the origins of the SWS in precolonial southern Africa is that Group I and Group III were built by the southern Sotho-Tswana, while Group II by the western Sotho-Tswana (Huffman, 2007). Recently, Sadr (2012) through the Klip River Kraals (KRK) project observed that instead of two different populations building the SWS, spatial studies on the distribution of the SWS in the area suggests that the different SWS were constructed by the same people. He notes that these architectural styles suggest phases over time with Group I being the earliest, Group III in the middle and the latest Group II (Sadr, 2012). The results showed a sequence of cultural changes from a pastoral community to an agricultural community (Sadr, 2012:262).

From the 1960s, research focused mostly on the identification and classification of the SWS using aerial photography (Mason, 1968; Maggs, 1976; and Hall, 1981). In 1968 Mason noted a total of 6237 stone walled structures in the old Transvaal Province which he attributed to the Iron Age (Mason, 1968). He classified these structures into 5 main groups that is class 1 to class 5, with class 1 as the smallest and simplest class to class 5 as the largest and architecturally most complex (Mason, 1968). This classification was a result of studying a range of variation in plan-forms on aerial photographs. In analyzing settlement patterns in the research area Mason (1968) explains that dry stones were used to make cattle kraals and courtyards. Mason (1968) barely mentions the physical environment, he gives a brief description that SWS were in most cases located on elevated ground and near rock outcrops. From his explanation he hypothesized that SWS were located in areas with high elevation and preferably near rock outcrops.

The CCP can also be identified in works as early as 1976 by Maggs who was studying the Sotho-Tswana people. According to Maggs (1976) settlement pattern analysis of the SWS revealed that cattle enclosures were located in the center of the court yard. He explains that the men's meeting place was next to the cattle kraals and this architecture highlighted the importance that was placed in cattle and the domain of men (Maggs, 1976). Sadr and Rodier (2012) explain that the architecture of the SWS is characterized by two types of walls, the primary wall which was used for livestock and the secondary wall which was an outer wall which showed the extent of a house stead. According to Maggs there are four classes of SWS in the Free State Province, Type N, Type V, Type R and Type Z. Type V and N are the main classes as these sites occur in the larger numbers and Maggs gives a detailed description of the architectural characteristics of these two groups. Maggs' (1976) classification scheme of the SWS gave detail on the environmental characteristics of each class (see appendix, Table 16). Preference for certain site locations can be attributed to a number of aspects, for example cultural, social, political and economic ones.

Later on Taylor (1979) conducted a settlement pattern analysis of the Vredefort Dome area with the aim of establishing a sequence of archaeological events. He suggested that there were three classes of SWS in today's North West Province, which he named Group I, Group II and Group III. These groups were distinguished by different architectural styles. Chronologically Group I sites are the oldest dating from the 15th to the 17th century. Group II and III were from the 17th to the 19th century. According to Taylor (1979) Group I SWS were constructed by the southern Sotho-Tswana people and Group II by the western Sotho-Tswana. This will be analyzed and discussed later in the research to determine if indeed Group I SWS and Group II SWS were constructed by one group or two different groups. Taylor also gives a brief description on the environmental background of the SWS but like other scholars he did not dwell much on it (see appendix Table 16). He describes the area by noting that, generally there is a lot of eroded granite, the environment is treeless, SWS are located above 1550 m elevation, in areas where rainfall is between 570 mm and 650 mm (Taylor, 1979). The area cannot support intensive agriculture as only 19% of it is suitable for agriculture without irrigation. Fertile lands exist in patches and this might have required the inhabitants to travel a certain distance to exploit arable lands (Taylor, 1979).

Different scholars named SWS differently. Huffman (2007), for example refers to Taylor's (1979) Group I SWS as Type N and Group II SWS as Molokwane type. Classification was based on the architectural styles, shape and size of the SWS. Maggs (1976) explains that although classifications seem to coincide it is hard to match different classification schemes exactly. This is because different scholars use different methods and the way they define these structures is different. Furthermore, inter- analyst variability causes different people, no matter how experienced, to classify the same objects differently. There is therefore a need to find the most suitable solution to deal with the errors associated with classification. In this case Sadr (2016) suggest that the best way to go around this is to have three different analysts work on the same data set and compare the results. From the results one should select only the intersection of the three classifications, that is to say those SWS which were identically classified by all the analysts. Inevitably, this creates a smaller sample size.

Studies have also paid attention to the changes in the social structure of the people who inhabited the SWS. Boeyens (2000) suggested that these changes might have been caused by conflict and wars between neighboring Tswana chiefdoms as some of these sites were located on hill tops. Huffman (2007) alludes to this point by noting that Molokwane settlements were dated to the *Mfecane* period and therefore most of these sites were located on hill tops because they served defensive purposes. This argument however, could not be maintained as some of the settlements were located on low lying plains during the same period. Thus more recently Boeyens and Hall (2009) have concluded that, these hill top settlements were evidence of the beginning of socio-complexity among the pre-colonial Tswana. Most recently Sadr and Rodier (2012) used Google Earth and GIS to analyze the SWS with the aim of better understanding the origins and development of SWS. In their research they observed a sequence which suggested a trend from egalitarian societies to more complex societies in the Suikerbosrand Nature Reserve in southern Gauteng Province (Sadr and Rodier, 2012).

The research will give particular attention to the studies by Sadr and Rodier (2012) who used Google Earth and GIS to analyze the SWS with the aim of better understanding the origins and development of SWS. Sadr and Rodier's (2012) study concerned only the ca. 350 sq km parcel labelled Pam 1. In their research they used a number of tools in QGis for data manipulation, analysis and presentation. They observed that, the use of GIS enabled them to reveal a sequence which suggested a trend from egalitarian societies to more complex societies in the Suikerbosrand Nature Reserve in southern Gauteng Province (Sadr and Rodier 2012). Of particular interest to this research is the conclusion that Sadr and Rodier (2012) came up with concerning the settlement patterns in the research area. Their conclusions show a sequence from more egalitarian and pastoral settlement and social organization in the earliest part of the sequence (Group I) to hierarchical, densely nucleated agricultural towns (Group II). However, these conclusions rest on a limited sample of the sites in a small portion of the overall study area. This research will therefore, conduct a spatial analysis on the entire research area and will test if Sadr and Rodier's (2012) conclusion applies to the whole study area. The current research will also emphasis the aspects of cultural ecology concerned with the research area. This will include a detailed analysis on the environmental conditions associated with the SWS and the extent at which these environmental parameters influenced settlement choices and general human behaviour in the precolonial period.

Throughout time, different scholars (Steward, 1955; White, 1959; Harris, 1979) have proposed different theories which have led to the development of culture. As highlighted earlier on, Traditional anthropologists suggested that in all communities culture was the same and it passed through the same stages of development. In 1955, Steward proposed a different theory of culture evolution in which he noted that each and every culture is different and should be treated individually (Steward, 1955). Steward (1955) emphasised on the fact that humans adapted to their surrounding physical environment and this directly or indirectly influenced culture. Later on, Leslie White proposed that culture evolution was a result of technological advancement and the amount of energy that humans could harness from the physical environment (White, 1959). With this in mind, Willey (1953) defined a settlement pattern as an expression of human culture is displayed in a given landscape. It includes how structures and features are located within space in relation to each other and the surrounding physical environment (Willey 1953). Fagan (1996) also defines a settlement pattern as a manifestation of human interaction among themselves as well as the physical and social environments surrounding them. It is against this background that this research will focus on the importance of the physical environment in shaping human behaviour and how it is expressed through different settlement patterns in SWS located in southern Gauteng.

This will be achieved through the use of spatial statistics in analysing settlement patterns. There are a number of statistical analyses that can be used in studying settlement patterns for example regression analysis which according to Shennan (1988) can be used in determining relationships as well as strengths of relationships between dependent and independent variables. Other statistical methods that can be used to measure relationships is through the use of different types of coefficients (Hauke and Kassowski, 2011). These include the Pearson Product Momentum Correlation Coefficient (PPMCC), Spearman's Rank Correlation Coefficient (SRCC) and Kendall's Tau Coefficient (Hauke & Kassowski 2011). All of the stated methods are very useful in analysing relationships but a test which tests the significance of relationships is more adequate, hence this research will use the Mann-Whitney U test and the Kolmogorov-Smirnov test. The research used two samples of sites Group I and Group II sites and it is important to analyse the relationship between these sites and most importantly to test the significance of that relationship.

2.5 Technological Differences

Technology plays a significant role in any form of study. The availability and ability to use technology makes work easier and results more accurate and precise. Initially archeologists the world over used analogue data and paper maps for spatial analysis and these had serious problems especially when it came to dealing with vast amounts of data (Fagan, 1996). The use of aerial photographs in archaeological began as early as the 1920s and systematic settlement pattern analysis using aerial photographs began in the 1950s with Wiley in the Viru valley, Peru (Wiley, 1953). In southern Africa Caton-Thompson was the first archaeologists to use aerial photography at Great Zimbabwe in 1931 (Caton-Thompson, 1931). It was only around the 1980s when technological advancement facilitated the availability of computer hardware and software which lead to the development of GIS. It is important to note that, nowadays modern technologies like remote sensing techniques enable archaeologist to record and digitize more accurate and precise data than aerial photographs (**Figure 2** and **Figure 3**). It is much easier to capture the coordinates, elevation, temperature etc. for as many points as one may choose using a GPS (Global Positioning System).

Back in the days aerial photographs could not produce as much information as a GPS, Google earth image or Lidar image. Today, through the use of DEMs one can easily obtain the altitude at any given point and through spatial analysis soft wares like ArcGIS and one can also easily generate the slope and aspect among other things. Therefore it becomes equally important to note that some of the differences that are shown in the results between previous researches (Mason, 1968; Maggs, 1976; Taylor 1979; etc.) can be influenced by changes in technology. While the previous researches used tradition methods to analyse the spatial distribution of SWS in South Africa including parts of the research area, the current research used modern methods for data acquisition, processing and analysis. As much as certain distribution tendencies are restricted to certain areas and not necessarily in everyplace with SWS, some of the variation in results is caused by the difference in technology that was used on SWS between the 1960s- 1980s and wat is being used now.

There is therefore need for future researchers to apply these new methods and techniques which have proved to more accurate on a larger scale. This might include a detailed spatial analysis of all the SWS in South Africa and perhaps the whole of southern Africa and establish if the same results can be achieved. If not this will open up new avenues for different theories which might help us understand the state of things during the precolonial era. **Figure 2** is an example of some of the aerial photographs that were used by scholars like Mason (1968) to study the distribution of SWS in South Africa. Although one can notice the infrastructural developments like roads and buildings and physical features like mountains, hills, trees and water sources it becomes difficult to identify SWS. Even if one zooms in on the image it would require patience and skill to identify and record the location of the SWS in the image **Figure 3** is a Google Earth image showing parts of the SWS in the North West Province. The image shows the date that is was captured, the coordinates of the place, the elevation of the place and the altitude at which the image was taken. Comparing it to the aerial photograph (Figure 2), the SWS in the Google Earth image are more visible and clearer.

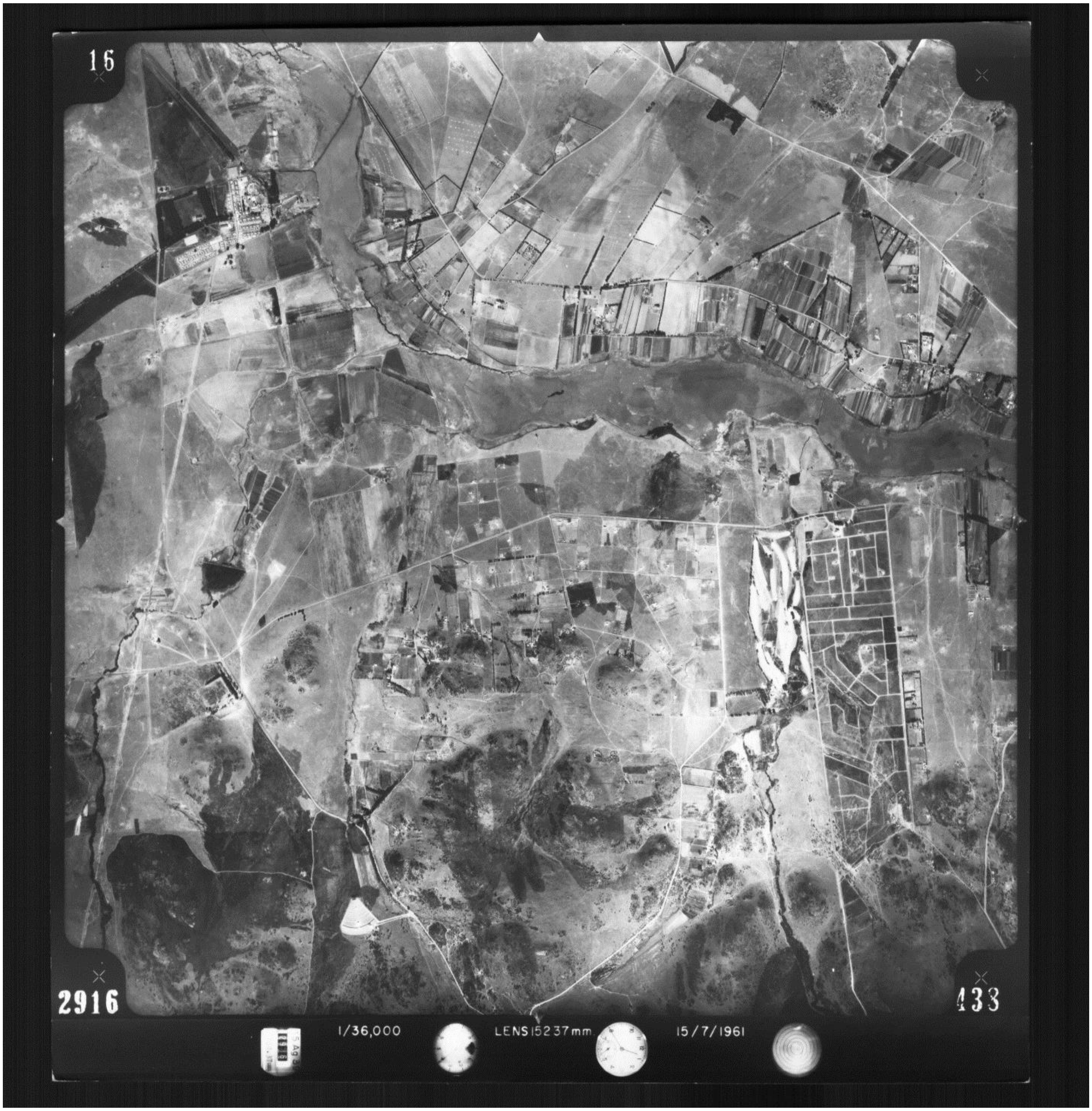

Figure 2. An aerial photograph showing parts of southern Gauteng. Image was taken in July 1961. Source: National Geo-Spatial Information (NGI)

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Figure 3. A Google Earth image showing parts of the Molokwane SWS in the North West Province. Image taken July 2014. Source: Google Earth

CHAPTER THREE
METHODOLOGY

Introduction

The methodology chapter is arranged in a way that best suits the objectives that were outlined in the introductory chapter. The chapter starts by explaining the aim of the first objective and detail is also given on the type and source of data that were used in the first objective. The procedure of how objective 1 was achieved is outlined in a series of steps. Objective 2 starts by giving details on the source of the SWS (Stone Walled Structures) and the issues that surround classification and sampling techniques of the SWS. Detail is also given on the analyses that were used for example the nearest neighbour analysis. Objective 3 gives more details on the methods of spatial analysis like density analysis, site catchment analysis terrain analysis etc. Objective 4 explains the statistical methods that were used for determining relationships and correlations. Objective 5 includes hypothesis testing of data generated by Sadr and Rodier (2012) and data generated in this research. A comparative analysis of the data will also be conducted.

3.1 Objective 1

The first objective of the research was to map the spatial distribution of a host of relevant physical environmental parameters in the research area. These included elevation, rivers, arable lands/soils and geology. Data on geology, arable lands and rivers was collected from Agricultural Geo-Referenced Information System (AGIS) an organisation that collects spatial data generated by different individuals and organisations (for more details on the source, scale etc. see appendix table 2). AGIS was selected as a primary source of data because environmental data can be acquired as shapefiles from their website. Data which already exists in shapefile format is compatible with GIS software which removes room for errors associated with converting other data formats into shapefile format. However it is equally important to acknowledge possible sources of error when AGIS was compiling the data, changing it from paper format to digital format. Elevation data was obtained from Consortium for Spatial Information (CGIAR; CSI) in the form a Digital Elevation Model originally sourced from NASA's Shuttle Radar Topographic mission (SRTM) with a resolution of 90m. A DEM with such resolution was selected because it was adequate for the regional scale of this study and that all the information that could be required for this study could be easily retrieved with such a resolution, scale and dates on which they were acquired (see appendix **table 17 & 18**). Two GIS softwares, Esri's ArcGIS 10.3 and Quantum GIS 2.16.0 (QGIS) were used to map the spatial distribution of the relevant environmental parameters. These were used alternatively throughout the research depending on their ability to perform different tasks. In some cases, one software could perform better than the other. With all the data on the relevant environmental variables gathered, the steps outlined in the following flow chart diagram (**Figure 4**) were done to achieve objective 1

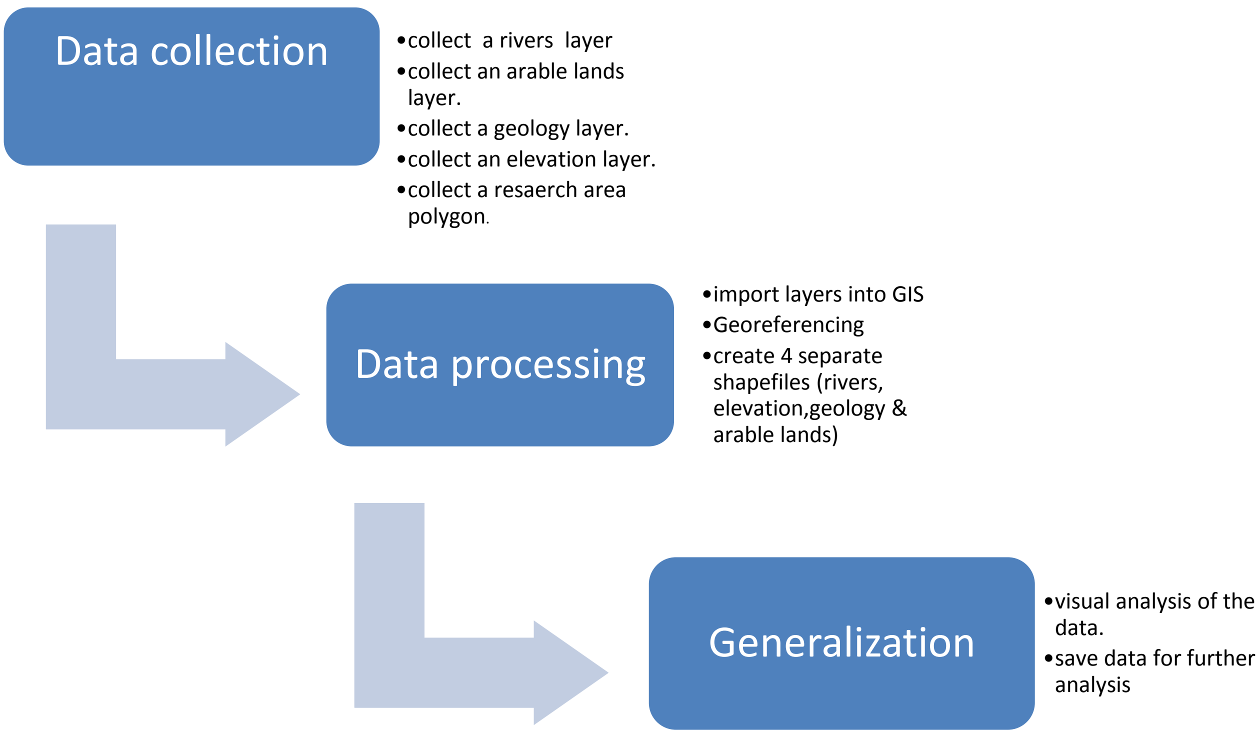

Figure 4. Flow chart describing the processes and techniques used to achieve objective 1.

1. A shapefile of the research area was imported into ArcGIS 10.3 and projected to UTM 35S.
2. Environmental data was imported into ArcGIS 10.3 software and projected to UTM 35 S to complete the georeferencing process and also to make sure that all shapefiles were in the same coordinate system. (This includes a rivers, geology, arable lands and elevation data).
3. Four separate shapefiles were created which showed the spatial distribution of rivers, elevation, arable lands and geology in the research area.
4. The resulting shapefiles were saved for further analyses.

3.2 Objective 2

The second objective was to examine the distribution of Group I and Group II SWS in the greater study area. Data on Group I and Group II Stone Walled Structures (SWS) was obtained from the Southern Gauteng Stone Walled Structures (SGSWS) database. The database has more than 5000 SWS that have been recorded and digitized by researchers in South Africa and India (Sadr & Rodier 2012). The database contains different classes of SWS, (Group I, Group II, Group III, Group IV and rectilinear stone walls) and these can be further classified into two broad groups Precolonial and Colonial SWS. The research at hand used the k & t union sample from the SGSWS database. This sample was from an intersection of three analysts' classification. According to Sadr (2015) the k & t union sample represented a fairly accurate representation of the spatial distribution of the different SWS in the research area. The different classes of the SWS exist in the form of point and polygon data. Similar to Pam 1 data and all the data in SGSWS database the x; y coordinates of all the sites were taken from the centres of each site. This research will define a site according to Maggs' (1976) definition who notes that a Structure is 'Any of the basic structural elements including huts, large enclosures, pieces of walling, stone circles etc.' and he also defines a Settlement unit as 'The group of structures, including both huts and livestock pens, which forms the module from which the settlement as a whole is built up' (Maggs, 1976:25). The second objective was achieved through a series of steps highlighted in flow chart diagram (**Figure 5**).

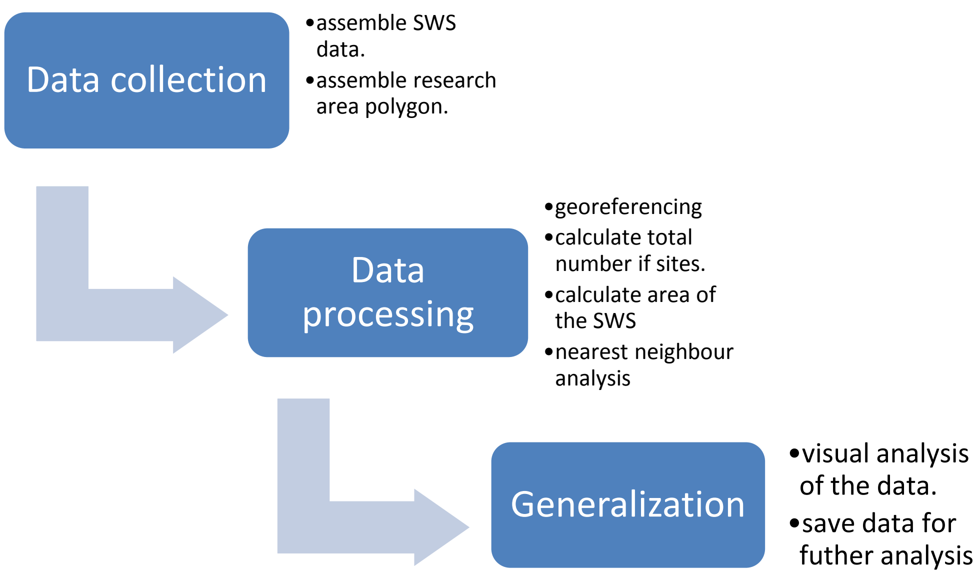

Figure 5. Flow chart describing the processes and techniques used to achieve objective 2.

1. A shapefile of the research area was imported into ArcGIS 10.3.

2. Shapefiles with all the relevant point and polygon data on the SWS from the SGSWS database were imported into ArcGIS 10.3 and projected them to UTM 35 S to complete the georeferencing process.
3. A Group I shapefile was created which had a Group I layer over laying the research area polygon. This shapefile showed how the Group 1 SWS were spatially distributed in the research area. The same was also done for Group II SWS.
4. The total number of the sites for each group was calculated in ArcGIS. This was done by recording the total number of sites in the attribute table for each group.
5. There were two shapefiles with SWS, a polygon shapefile and a point shapefile. Using the SWS polygon shapefile, area for each SWS polygon was calculated in their respective shapefiles (Group I & Group II) using the field calculator function in QGIS 2.16.0.
6. In order to understand the spatial distribution (for example if they are clustered or dispersed) of the SWS within their respective groups, a nearest neighbour analysis through the analysis tool in QGIS 2.16.0 and a kernel density analysis using ArcGIS 10.3 was also conducted on the two classes.

3.2.1 Site clustering.

As highlighted earlier on, distribution of sites can be achieved through a neighbourhood analysis. This will determine if sites are clustered or dispersed by calculating the average distance between nearest neighbours. A nearest neighbour analysis was conducted in ArcGIS 10.3 and the resulting Z-scores were used to determine if sites were clustered or dispersed. A site catchment analysis was also done to determine clustering. According to Vita- Finzi and Higgs (1970) site catchment refers to the geographic area surrounding a site in which resources like food and raw materials are obtained by the inhabitants of the site. Therefore a site catchment analysis refers to the methods of reconstructing the economy of sites using the available resources with a considerable distance (Vita-Finzi and Higgs, 1970). However this model has been criticized by scholars like Bailey and Davidson (1983) noting that the 5km distance for farming communities and 10km for hunter-gatherers was a very long distance and would take a lot of travelling time. They also note the distance was also affected by the terrain of the landscape and 5km on gentle terrain required less effort than 5km on rugged or steep terrain (Bailey and Davidson, 1983). Despite having these critiques, the model particularly for this research proved to be useful and adequate. Sadr and Rodier (2012) used a 200m buffer for analysing site clustering in Pam 1 and a 200m buffer was also calculated around each site in the research area. Buffers that intersected were merged and then dissolved to form one group of clusters. The clusters were then measured using the field calculator and then the clusters were ranked according to their size. Sadr and Rodier (2012) hypothesised that the bigger the site or cluster, the more important it may have been in the hierarchy. The smaller the site the less important the site is in terms of hierarchy. As for site distribution relative to best arable lands, a site catchment analysis was conducted to understand the distribution of sites relative to best arable lands. A 5km and a 2km buffer were calculated and the total number of sites that were located in these areas was calculated using the select by location tool in ArcGIS 10.3. After the results were normalised in Excel, they were exported into R software for further analysis.

3.2.2 Nearest neighbour analysis

In archaeology there are two main methods of measuring distribution of points in a given area, these are the Quadrat method and the Nearest Neighbour Analysis (NNA). According to Wheatley and Gillings (2002) the quadrat method is able to measure the distribution of points and determine the randomness or clustering of features. Wheatley and Gillings (2002) explain that the quadrat method works by applying a grid over a set of points in a given area. The grid is equally spaced and points in each cell are compared to the points in the other cells. However this method according to Hodder and Orton (1979) has a number of disadvantages which include the effect of the Quadrat size and their regular shape. According to Stark and Young (1981) the Nearest Neighbour Analysis is used to determine how points are distributed within a given area. Distribution can be random, regular or clustered. According to Wheatley and Gillings (2002) the NNA is a better method of analysing spatial distribution of points because it measures the distance between one point and the closest point to it. This can be traced to the argument that points that are geographically close to each other have more things in common than points that are further apart (Keller et al, 1985; Conolly and Lake, 2006).

In 1985, Keller et al noted that the nearest neighbour analysis makes use of an algorithm which uses the average distance between features for classification (Keller et al, 1985). Initially a number of archaeologists were faced with a number problems that were associated with the use of the nearest neighbour analysis like what Pinder et al (1979) termed the boundary effect. This meant that the analysis could not account for the shape or size of the research area and this affected the results. Another limitation was that it treated all the features in a sample equally regardless of their differences in terms of their significance (Keller et al, 1985). Over the years, scholars altered the algorithm in an effort to address all the challenges that were introduced by this method in analysing spatial data (Pinder et al, 1979 & Keller et al, 1985). However this all changed with the advent of GIS techniques in archaeology. The software could easily conduct the analysis with a push of the button in ArcGIS. In ArcGIS 10.3 the Average Nearest Neighbour (ANN) uses the following equation:

$$ANN = \frac{\bar{D}_O}{\bar{D}_E}$$

Where $\overline{D}_O$ = is the observed mean distance between each point and its nearest neighbour and is calculated using the following equation:

$$\overline{D}_O = \frac{\sum_{i=1}^{n} d_i}{n}$$

$\overline{D}_E$ = is the expected mean distance for the features given the random pattern and is calculated with the following equation:

$$\overline{D}_E = \frac{0.5}{\sqrt{n/A}}$$

Where d_i = distance between feature *i* and its nearest neighbour.

n= total number of features.

A= is the minimum area of the enclosing rectangle around features.

The average nearest neighbour z-score is calculated as:

$$\text{Z-score} = \frac{\overline{D}_{O} - \overline{D}_E}{SE}$$

Where SE = $\frac{0.26136}{\sqrt{n^2/A}}$ (*Adopted from Esri 2016)*

According to Esri the nearest neighbour function works by measuring the distance between any points in a given area and calculates the average distance between all the points in that area(Esri, 2016) . The nearest neighbour function works on the premise that all the points in the survey area are independent from each other and there is no form of boundary between these points (Esri, 2016).

3.2.3 Kernel density analysis

The kernel density analysis works by calculating the density of points in a given area (Esri 2016). Wheatley and Gillings (2002) note that, the Kernel Density Estimate calculates a density estimate based on adding the ‘circles centred at each point’ using a density function (Wheatley and Gillings, 2002:186). According to Esri (2016) the kernel density can be used for both line and point features and it basically shows where features are clustered in that area. The kernel density uses the kernel function which uses a radius algorithm based on the following equation:

$$\textit{Search radius} = 0.9*\min\left(Sd\sqrt{\frac{1}{1n(2)}} * Dm\right) * n^{-0.2}.$$

Where Sd = Standard Distance.

Dm=Median Distance.

n = Number of points if population is used or sum of the population field values.

Min= whichever of the two options that results in a smaller value will be used.

(Adopted from Esri 2016).

Basically the algorithm starts by calculating the mean centres of the inputs points in this case the Group I and Group II SWS. The distance from the mean centres are calculated for all the points and then the mean distances from each point are calculated (Wheatley and Gillings 2002). After that, the algorithm calculates the standard distance from each point to the other and this produces a population density surface which shows where sites are clustered (Esri 2016). Alternative methods of analysis include the point density and the line density. However both methods have limitations in that, the point density analysis calculates magnitude per unit area from points within a given neighbourhood (Esri 2016). The line density on the other hand calculates density of line features within a given radius (Esri 2016). The kernel density was selected for this research because it uses the kernel function which calculates density of either point or line features within a given radius and neighbourhood (Esri 2016). Wheatley and Gillings (2002) agree, noting that the Kernel Density is capable of producing 'smoother surfaces' compared to the line density and point density analysis. For this research a kernel density analysis for each group was done separately. This density analysis showed where Group I and Group II were concentrated in relation to rivers in the research area. The results from this analysis were recorded and saved for future use. The resulting shapefiles, Jpeg maps and statistics were saved for further analyses.

3.3 Objective 3

The third objective was to determine the nature and extent of the relationship between the distribution of SWS and the physical environment as well as the modern cultural features such as urban development which may have influenced the distribution of sites that we see today. The third objective was achieved through a series of steps highlighted in the flow chart diagram (**Figure 6**).

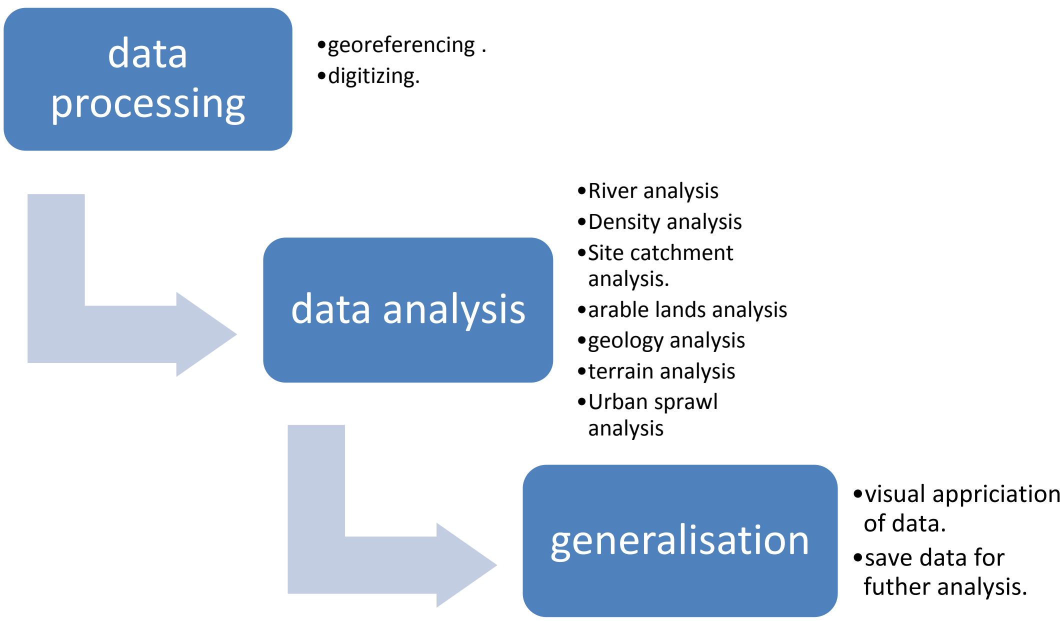

Figure 6. Flow chart describing the processes and techniques used to achieve objective 3.

3.3.1 River analysis

1. A river layer was imported into ArcGIS 10.3 and two layers (Group I and Group II) were over laid on the river layer. This was done to establish the spatial distribution of the SWS in relation to the rivers in the research area. An understanding of the relationship between the SWS and the rivers in the study area can help us deduce if the occurrence of sites might have been attracted by the location of rivers in certain areas.
2. With the river layer and the SWS layers over laid the next step was to conduct a density analysis of the sites. Kernel density method was selected to establish the distribution of Group I and Group II SWS in relation to distance from rivers. This was done to establish if sites were clustered closer to rivers or dispersed.
3. Buffers were created to conduct a site catchment analysis on the rivers layer.

3.3.2 River buffers

This analysis was done in ArcGIS 10.3 where tools such as buffering are used to establish catchment areas. In this case it was importance to establish the relationship between sites and available resources in this case water sources which were mostly in the form of rivers. Other forms of site catchment analysis were also done relative to arable lands and geology and will be discussed later in the relevant sections. Under Geoprocessing tools the buffer icon was selected and a 1km buffer was created along rivers. Another 2km buffer was created along the rivers. With the SWS layer overlaid on the buffered rivers layer the next stage was to calculate the number of Group I sites that were located within the first kilometre then a 2km distance from the rivers. This was done through the selection tool and in the pop up dialogue box the select by location icon was chosen. The command was given to select only the Group I sites that were located within the first kilometre then the 2km buffer and the results were recorded in the attribute table. The procedure was repeated on the Group II sites and the results were also recorded in the attribute table. A 5km buffer was also created around the rivers and all the sites that were located within a 5km distance from the rivers were record for both group I and Group II sites. The results from this analysis were recorded and saved for future use.

An alternative approach which is more sophisticated than buffering which could have been used is the Mobility Cost Surface (MCS). A MCS is more useful than buffering because unlike buffering, which works on the assumption that the terrain is homogenous, MCS considers the difference in elevation and terrain ruggedness between any two points (Wheatley and Gillings 2002). The use of this method by archaeologists has evolved in the past few decades (Krist and Brown, 1994; Lock and Harris, 1996; Llobera, 2000; Van Leusen, 2002& Howey 2007). MCS create movement cost maps by simulating the least cost path around site clusters (Cooper, 2010). This solves the problem which is presented by buffering which is the assumption that for example 2km on a smooth/ level terrain is the same as 2km going up or down hill. According to Howey (2007) for one to fully appreciate the social aspect of any past community is they should understand how the people moved throughout the landscape. She explains that regardless of the terrain, bad weather conditions or mode of transport, prehistoric communities moved from one place to another and it is crucial to understand these patterns of movement (Howey,2007). This can be done using the cost distance function under the spatial analyst tool in ArcGIS 10.3. This method of analysis however useful to the study could not be used because there were too many sites (1001) and rivers to consider given the time frame which is required to finish this research. This is so because the MCS methods works by establishing the cost of travel between a point or a small cluster of sites in relation to a certain feature or site. Therefore this would mean calculating the cost of each of the 1001 sites in relation to all the other sites and all the minor and major rivers. This would take a lot of time calculating the cost surface for each and every SWS in the region. If the points were fewer then this method would have been more appropriate but given the limited time this would need an entire research of its own to establish the mobility cost surface of each of the 1001 points. Even if centres were calculated for each group the results will be just for those weighted centres and not necessarily represent the entire sample.

4. A distance analysis was also conducted on the river layer. Distance was calculated using the Euclidean distance function under the distance tools in the ArcTool box. According to Esri (2007) Euclidean distance refers to the shortest distance between two points. This test was essential because it showed the exact distance where a point is from the rivers. The resulting data was recorded and saved for further analysis.

3.3.3 Arable lands analysis

1. An arable lands layer was imported into ArcGIS 10.3 and two layers (Group I and Group II) were overlaid on the arable lands layer. This was done to establish the spatial distribution of the SWS in relation to the location of the arable lands in the research area. An understanding of the relationship between the SWS and the arable lands in the study area can help us deduce if sites might have been attracted by the availability of arable lands in certain areas.
2. A density analysis was conducted on the sites in relation to the distribution of the arable lands in the research area. This was guided by the same principles and procedures as in the river analysis.
3. A catchment analysis was also conducted on the arable lands layers where a 2km and 5km buffer was created on the arable lands layer.
4. Using the select by location function in ArcGIS 10.3 all sites that were located within a 2km and a 5km distance from the arable lands were recorded from the attribute table. The select by location function automatically selects all the sites that fall within a 2km and 5km radius from the boundary of the arable lands when commanded. The number of sites that where located within the arable lands boundary were also recorded and saved. This was done for both Group I and Group II respectively.
5. Resulting tables, maps and figures were saved for further analysis.

3.3.4 Elevation Analysis

1. A Digital Elevation Model (DEM) with a 90m resolution was imported into QGIS 2.16.0 and was georeferenced to UTM 35S. Two layers (Group I and Group II) were overlaid on the DEM. This was done to establish the spatial distribution of the SWS in relation to the topography of the research area. An understanding of the relationship between the SWS and the elevation in the study area can help us deduce if sites occupants might have been attracted by the nature of the terrain in the area under study.
2. Two DEMs were required to cover the research area that is SRTM 27 and SRTM 28.
3. Using the point sampling tool in QGIS 2.16.0 downloaded from the QGIS plugin repository, a point sampling analysis was conducted and the resulting attribute table was saved for further analysis.

The point sampling analysis provided elevation, aspect, ruggedness and hill shade for each and every site.

4. The resulting shapefiles, Jpeg maps and attribute tables were saved for further analysis.

3.3.5 Urban Sprawl

According to Hayden (2000a:8) urban sprawl is “a process of large-scale real estate development resulting in low-density, scattered, discontinuous car-dependent construction, usually on the periphery of declining older suburbs and shrinking city centers.” Urban sprawl can also be defined as the spread of infrastructure like road networks, housing, industrial and commercial buildings into agricultural lands or forests (Bourne, 2001). Concerning the research area, Sadr (in Press) notes that the southward expansion of the city of Johannesburg has had significant effects on the SWS located in the region. Basing on maps (Petermann’s 1868 and Merensky’s 1875) aerial photographs and Google Earth imagery taken over the past few decades Sadr (in Press) was able to conclude that around 20% of the SWS between the Vaal River and the Witwatersrand ridge have been lost due to the effects of the urban sprawl in the area. As a result of the effects of urban sprawl it is important to note that the current distribution of sites is not a true representation of the SWS that were constructed during the precolonial and colonial times. This means that, the current distribution of SWS is also affected by the economic and social factors of contemporary times. As a result of urban sprawl Sadr (in press) notes that 20% of SWS in the research area have been lost, therefore it is important to account for these sites as they also attribute to the spatial distribution of SWS in the research area. Sadr (in press) notes that there are certain physiographic conditions that were affected more than others by contemporary infrastructural developments hence there a number of SWS that are missing therefore presenting a challenge of obtaining biased results from the spatial analysis of the research area.

3.4 Objective 4

The fourth objective was to establish relationships between Group I and Group II SWS and to determine any correlation between the SWS and the environmental parameters through a series of statistical tests. Objective 4 was achieved through a series of steps highlighted in the following flow chart diagram **(Figure 7**).

1. All attributes tables were imported into Microsoft excel to obtain basic statistical data such as sums, averages, standard deviations, percentages and so on.
2. Charts and graphs were also generated in Microsoft Excel to get an initial visual impression of relationships between the location of SWS and physical environment.

3. Using charts and graphs generated from Microsoft Excel data was compared between the spatial distribution of Group I and Group II SWS.
4. Using R statistical software two significance tests were run to establish any similarities in the spatial distribution between Group I and Group II SWS. Two tests were done, the Kolmogorov –Smirnov test and the Mann-Whitney test using the results obtained from the rivers, arable lands, geology and elevation analyses.

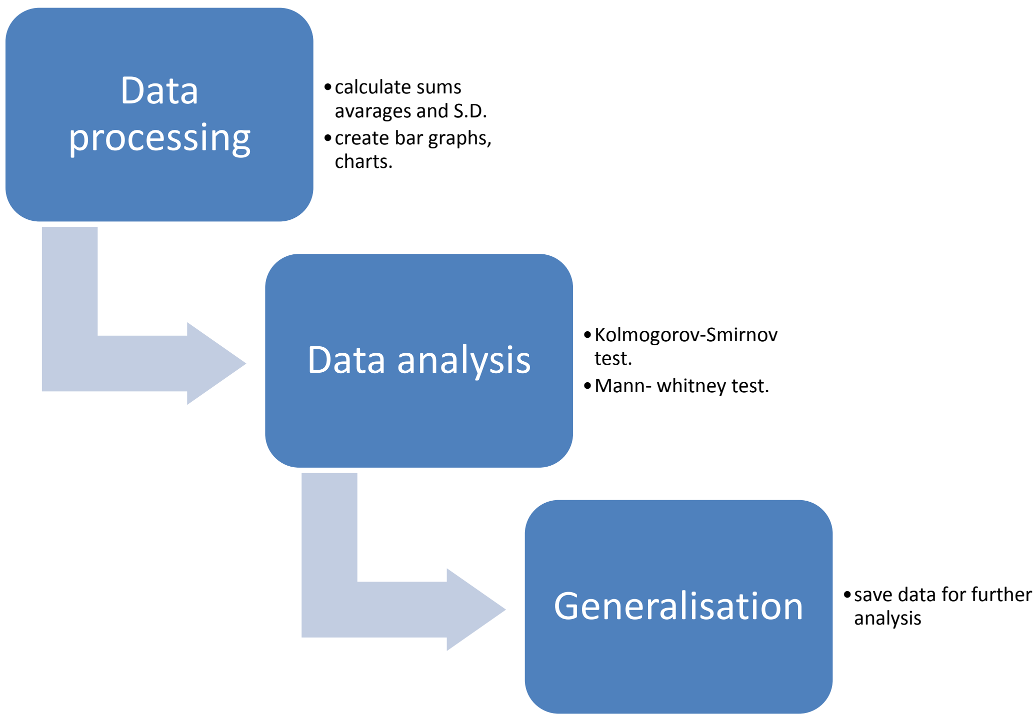

Figure 7. Flow chart describing the processes and techniques used to achieve objective 4.

3.4.1 Kolmogorov-Smirnov Test and Mann-Whitney test

According to Shennan (1988) significance test are used to determine if two samples are from the same population. This is achieved through testing if there is any difference between the central tendencies and distributions of the two samples. If the test shows that the samples are not really similar, there is need to quantify the difference and determine if the difference is large enough to be considered or be ignored (Shennan 1988). According to Massey (1951:1) a Kolmogorov-Smirnov test (K-S test) 'is based on the maximum difference between an empirical and a hypothetical cumulative distribution.' The test works basing on the assumption that 'observations should be divided into at least two mutually exclusive categories and that they should be measured at the ordinal level or above' (Shennan, 1988:55). Shennan

(1988) notes that, the K-S test works by first establishing a null hypothesis and an alternative hypothesis. The null hypothesis (H_0) generally states that the two groups originate from the same population (Shennan, 1988). The alternative hypothesis (H_1) states that they come from different samples (Shennan, 1988).

Although both the K-S test and the Mann- Whitney test are non-parametric tests, there are some differences between the two methods (Shennan, 1988). The K-S makes a comparison between the cumulative distributions of two samples, and then produces a P value that depends on the difference between the two distributions whereas Mann-Whitney considers how the values are ordered per distribution (Razali & Wah 2011). This means that unlike the K-S test the Mann-Whitney test arranges its values starting with the lowest to the highest value then calculates the p value based on the differences between average ranks of the two samples (Razali & Wah 2011).

Wheatley and Gillings (2002:137) note that the Mann- Whitney test can be used to understand the distribution of archaeological sites (random or clustered) and determine if they belong to 'the same statistical population'. They explain that the Mann-Whitney test can be used to determine if sites are randomly distributed or clustered within a certain environment (Wheatley Gillings 2002). Both methods according to Kvamme (1996) are limited in that they do not observe the nature of the sample from which the test groups are drawn but however GIS is capable of dealing with such issues. In GIS or R software the K-S test and the Mann-Whitney test produce a p- value which ranges between 0 and 1 (Shennan 1988). Any value between 0-0.05 (<0.05) is regarded as a small p value therefore the null hypothesis is rejected meaning to say that there is a significant difference between the two groups and they probably came from two different populations (Rumsey 2010). A p-value more than 0.05 (>0.05) suggest that there is no significant statistical difference and gives no reason to reject the null hypothesis therefore meaning the two samples probably came from the same population.

5. The p-values from the K-S test and the Mann-Whitney test were recorded and saved for further analysis.
6. The next test was to conduct statistical analyses to quantify the spatial relationship between SWS and the relevant environmental variables. The Spearman's rank correlation coefficient was used to measure the correlation between two variables.

3.5 Objective 5

Compare settlement patterns of Group I and Group II SWS from across the entire study area to the sample studied by Sadr and Rodier (2012). Using exactly the same analyses and set of measures that Sadr and Rodier (2012) used in their analysis of settlement distributions in the ca. 350 sq. km survey zone Pam 1, I analysed the settlement patterns of Group I and Group II SWS from across the entire study area to check whether the smaller sample provided a representative view. This mainly included the following comparative analyses: site altitude, site size, site clustering, site size ranking, and the site distribution relative to best arable lands. The figures obtained in my analysis were compared to those from Sadr and Rodier (2012). My null hypothesis is that the two sets of results are identical. This hypothesis can be tested using appropriate statistical methods. The following steps presented in the flow chart diagram (**Figure 8**) were taken to achieve the fifth objective.

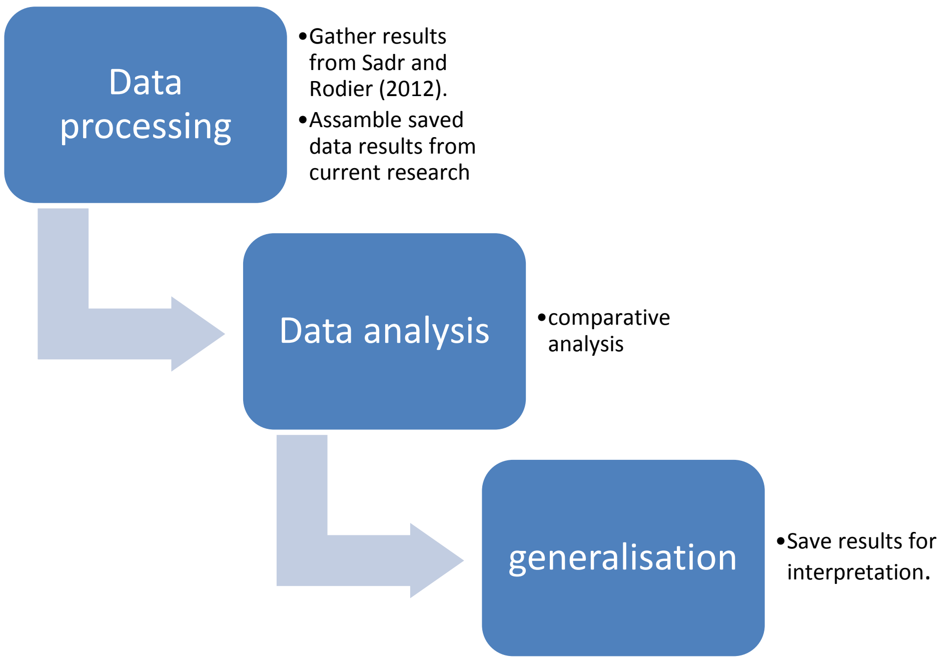

Figure 8. Flow chart describing the processes and techniques used to achieve objective 5.

CHAPTER FOUR
DATA PRESENTATION AND ANALYSIS

Introduction

Chapter four focuses on presenting and analysing data that was processed in the previous chapter (Chapter three). The chapter will begin with presenting and analysing results from Sadr and Rodier's (2012) Pam 1 and comparing them to the results of the current research area. This analysis is done in order to establish if the settlement pattern in Pam 1 is applicable to the rest of the study area. These comparisons will include altitude, clustering, hierarchical rankings and arable lands. After a comparison analysis of the two study groups, additional analysis that were not considered by Sadr and Rodier (2012) will also be presented and analysed in this chapter. These additional analyses will include distribution of Group I and Group II SWS in relation to rivers, other aspects of elevation and geology in the research area. With that being done, Statistical analysis will be applied to the processed data from the previous analysis. The Kolmogorov-Smirnov test and the Mann-Whitney test will be done to establish if Group I and Group II SWS are statistically from the same population or not. Data will be presented in form of distribution maps, tables and graphs.

Just as a reminder, the purpose of the study is to understand the relationship between SWS and environmental parameters in southern Gauteng. The aim also includes a comparison of results from Pam 1, which is a 350 sq km area within the research area which was analysed by Sadr and Rodier (2012) with results generated from the rest of the research area. This will be done through the following objectives:

1. Map the spatial distribution of a host of relevant physical environmental as well as modern cultural features (such as best arable soils, grazing potential, urban developments which might affect distribution of ruins, etc.) in the southern Gauteng. (Modern cultural features refers to all infrastructural and land developments in the contemporary society)
2. Map the distribution of all Group I and Group II SWS in the study area.
3. Analyze the nature and the extent of the relationship between the distribution of SWS and the physical environmental and modern cultural features.
4. Conduct appropriate statistical tests to determine the significance of any relationships observed in objective 3.
5. Test Sadr and Rodier's (2012) conclusions by comparing settlement patterns of Group I and Group II SWS from across the entire study area to their sample.

4.1.Classification

Sadr and Rodier (2012) start by classifying the SWS based on their architectural styles. They identified three morphological types of SWS, Group I, Group II and Group III based on Taylor's (1979) classification. According to Maggs (1976) SWS are characterised by two distinctive walls, the primary wall and the secondary wall. The primary wall is continuous, oval in shape and their purpose was to serve the most basic functions which include, providing shelter for the people and livestock (Maggs, 1976). The secondary wall was the last part of the building to be constructed and their main function was to connect the primary enclosures (Maggs 1976).Taylor (1979) notes that SWS are characterised by an elliptical outer wall which circumscribes the inner wall. Even though the shape is almost circular in all cultural groups, (Group I, Group II and Group III) the nature of the circular form of the outer wall is always different between the three groups (Huffman, 2002). The outer wall also marks the boundaries of the homestead (Walton, 1956). For the purpose of this research Group I and Group II SWS were used because Group III architectural style is difficult to identify objectively and the extreme amount of inter analyst variation has so far made it impossible to obtain a reasonably secure sample of these sites.

According to Taylor (1979) Group I (**Figure 10**) are characterised by an oval shape of the primary wall, the wall is continuous. Group I resembles Type N SWS according to Maggs' (1976a) classification. Maggs (1976a) notes that the settlement unit is defined by a number of primary walls that are connected by secondary walls. Huffman (2007) further explains that, this type of architecture is characterised by cattle kraals in the centre, a men's court close to the centre, residential units and in some cases small stock kraals were located on the perimeter wall. Hall (1987:49) notes that Group I units are usually distributed in clusters of up to a 100 units suggesting a significantly higher population. However, Huffman (2007:33) argued that Group I SWS were spatially arranged in a dispersed manner and a cluster of Group I SWS suggested an important site for example, a chief's residence.

Group II (**Figure 12**) have significantly different architectural styles from Group I SWS but the main features which include inner and outer walling for the livestock enclosures were retained (Hall, 1987). According to Taylor (1979) unlike the Group I perimeter wall which is continuous in nature, the perimeter wall of Group II is discontinuous in nature. Group II perimeter walls are characterised by a series of inward facing, arc shaped walls, which combine to form the perimeter wall of Group II walls (Taylor, 1979).

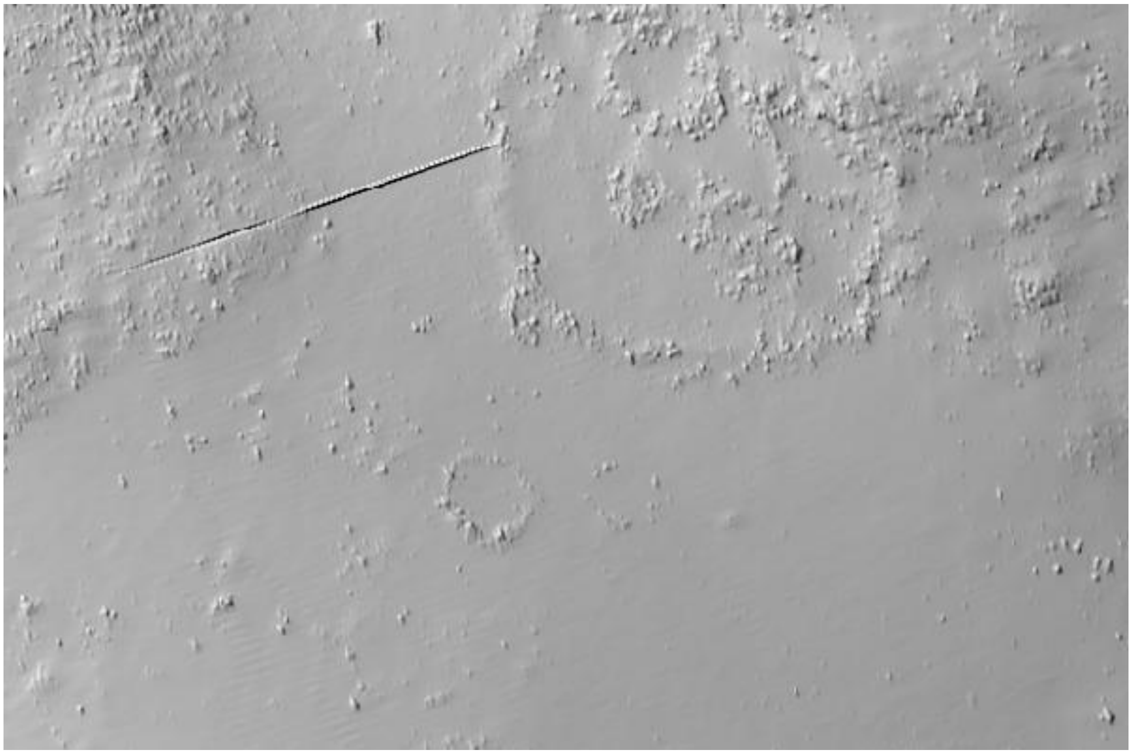

Figure 9. LIDAR (Light Detection and Ranging) imagery showing the appearance of Group I SWS taken from a pulsed laser.

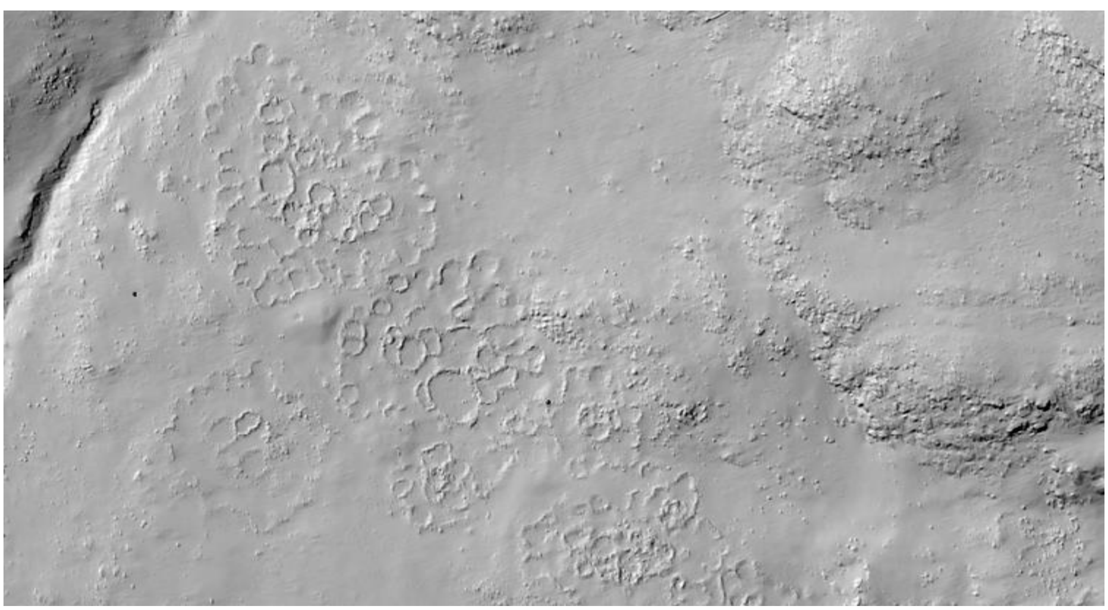

Figure 10. LIDAR (Light Detection and Ranging) imagery showing the appearance of Group II SWS.

4.2 Altitude

Relative site altitude has been at the centre of debate in southern African archaeology (Boeyens, 2003; Boeyens and Hall, 2009). A number of scholars have presented different reasons of why there were changes in locational preferences as far as elevation is concerned. Scholars like Pikirayi (2000) and Boeyens (2003) suggested that this shift from low lying areas to areas with higher elevation might have been a product of the Mfecane period which resulted in most of the communities in most parts of southern Africa taking refuge settlements on higher ground for defensive reasons. However other scholars suggest that it was rather a sign of change in ideology where people began to appreciate elevated areas as people changed from egalitarian communities to more stratified and complex societies (Garlake, 1983 & Beach, 1980). Whatever the reason, it is clear in the research area earlier settlements (Group I SWS) were located on higher ground compared to later settlements (Group II SWS) (**Figure 11 & Figure 12**). A comparison between the results from Pam 1 and the entire research area shows that in Pam 1 the average altitude for Group I (1705m) sites was higher than the average altitude for Group II (1637m) sites and this was the same scenario for the entire research area Group I (1642m) and Group II (1632m) (**Table 1 and Table 2**).

	Group I	Group II
n SWS	146	196
av altitude	1705	1637
median	1673	1619
st deviation	81.34	49.72
minimum	1542	1538
maximum	1868	1737

Table 1. Distribution of sites relative to elevation in Pam 1(Adopted from Sadr and Rodier, 2012)

Based on the results from the research area and Pam 1 (Sadr and Rodier, 2012) it is striking to observe, that distribution patterns of SWS in relation to elevation is notably different to what scholars had initially agreed on (Boeyens, 2003). Results indicate that (**Table 1** and **Table 2**), in both Pam 1 and the research area the maximum, median and average altitude for Group I is higher than that of Group II. Contrasting what is normally accepted of the distribution of earlier settlements (Group I) and Group II settlements. Scholars have established that Group I SWS are in most cases located in low lying areas where as Group II SWS are located on higher ground. Figure 32 (see appendix) shows that 62% of Group II SWS are located above 1600m from sea level in the research area where as 75% of Group I SWS are located above 1600m above sea level showing that, Group I SWS preferred higher ground as compared to Group II SWS.

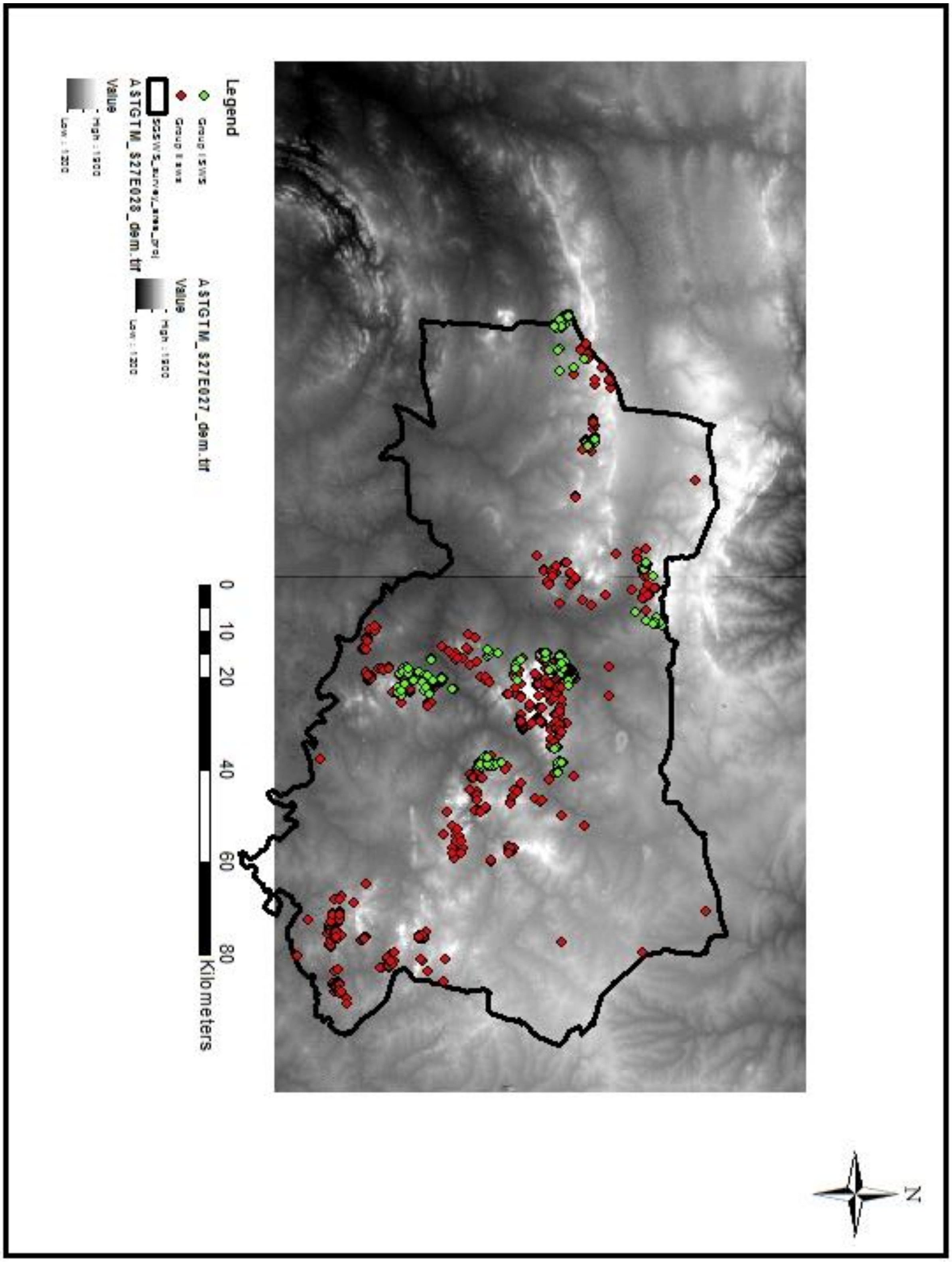

Figure 11. Distribution of SWS relative to elevation. (In metres above sea level)

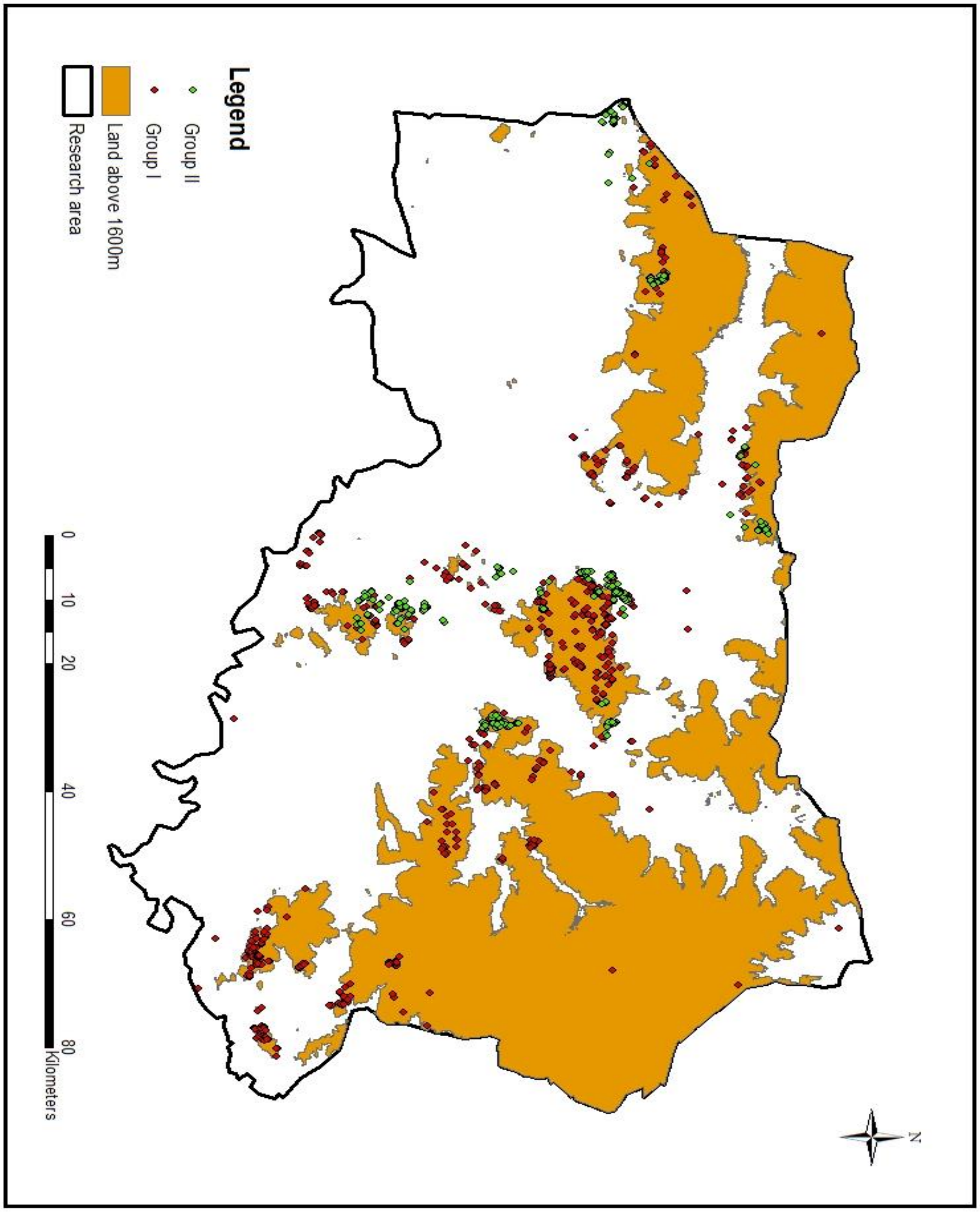

Figure 12. Distribution of SWS relative to height above 1600m from sea level.

	Group I	Group II
n SWS	703	298
av altitude	1642	1632
median	1638	1621.5
st deviation	70.16	73.32
minimum	1450	1466
maximum	1871	1783

Table 2.Distribution of sites relative to elevation in the research area. All elevation data in meters above mean sea level.

Similar to Sadr and Rodier’s (2012) analysis, Group I SWS have a wider range in the research area, the minimum elevation of Group I sites is 1450 which is a bit lower than that of Group II sites (1466). However the median (1638m) and maximum (1871) altitude for Group I sites is higher than Group II sites (1621m) and (1783m) respectively **Figure 11** and **Figure 12**. These measurements and calculations were done using Qgis’ point sampling tool which calculates the elevation, aspect, slope, hill shade and ruggedness for each and every point on the 90m DEM (see attribute table 18 in appendix).

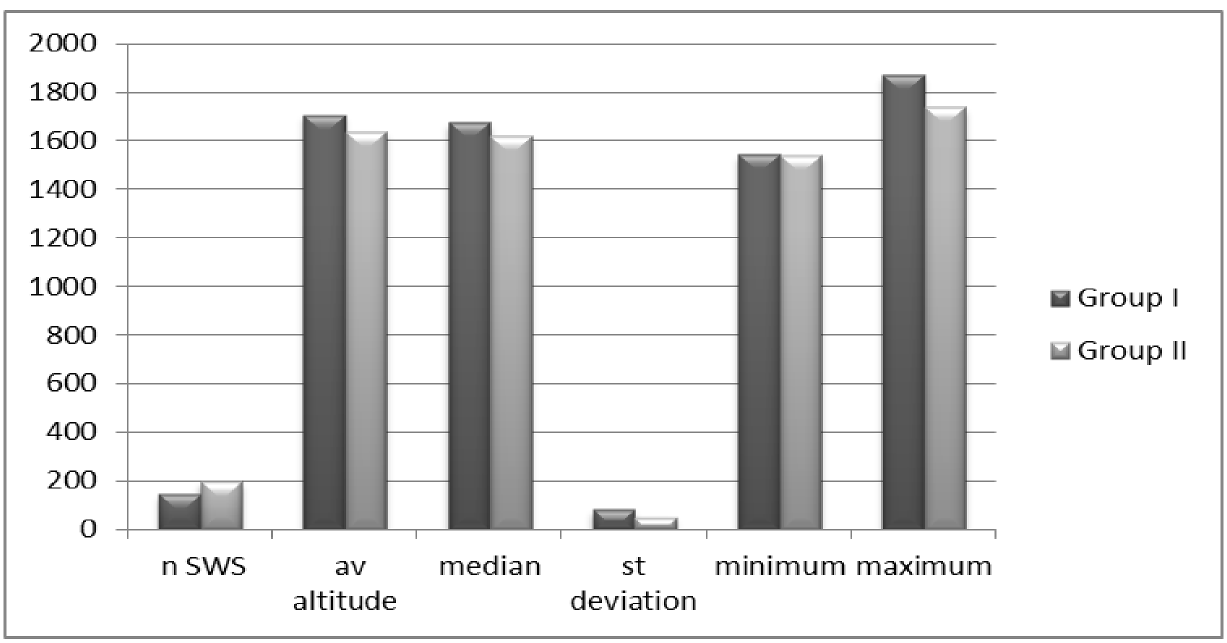

Figure 13. Distribution patterns of SWS in relation to elevation based on Sadr and Rodier's (2012) results.

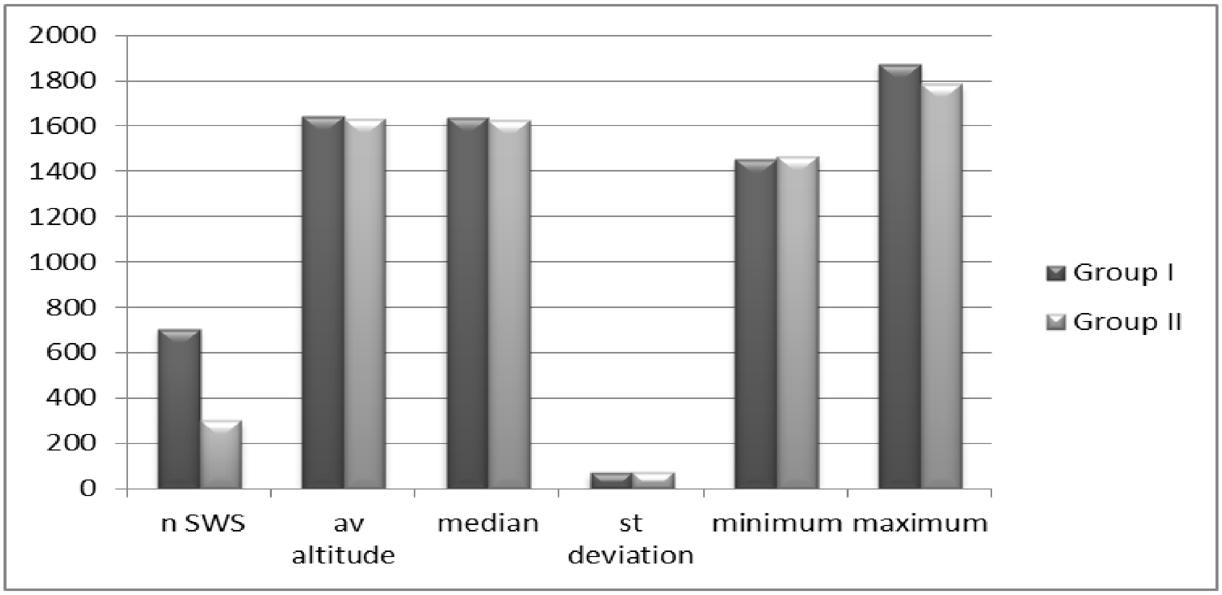

Figure 14. Distribution pattern of SWS in relation to elevation in the research area.

4.3 Clusters

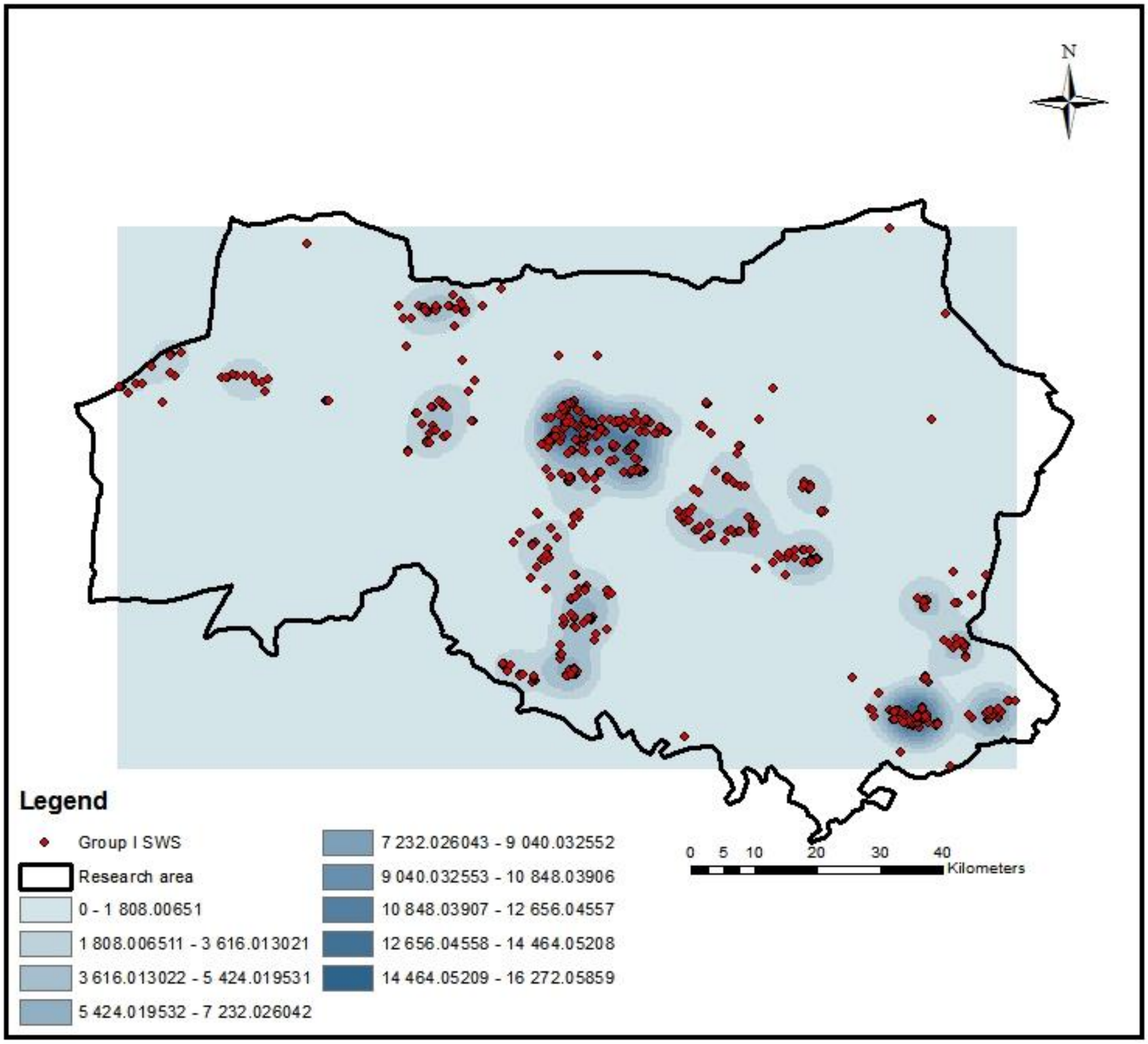

Figure 15. Kernel Density analysis of Group I SWS in the research area. (Measured in km^2)

Site distribution is used to determine whether sites are arranged in a random pattern or in clusters. As mentioned earlier on, Huffman (2007) suggested that Group I SWS were not as clustered as Group II SWS. He explained that the only circumstance when Group I SWS were arranged in a clustered manner meant that it was a chief's place of residence. A Kernel Density analysis was conducted on the research area (**Figure 13 & Figure 14**) to understand the distribution of Group I sites. According to Esri (2016) a Kernel Density analysis measures density of features within a given area and calculates the distance between neighbouring points to establish distribution pattern. The Kernel Density measures the distance between neighbouring points to establish the extent of clustering between a group of points (**Figure 15 & Figure**

16). According to Esri (2016) a kernel density analysis should have a qualitative interpretation rather than a quantitative or literal interpretation. This means that in the resulting maps, darker coloured areas have more points or points are more clustered than in lighter areas. The results showed that in terms of the distance between neighbouring points the range for Group I is higher than that of Group II (**Figure 15 & Figure 16**) meaning to say there was a lot more distance between Group I sites than Group II sites. The results from the Kernel density analysis revealed that, most Group I SWS were organised in smaller clusters compared to Group II sites (**Figure 15**). The Kernel Density analysis also revealed that Group II sites exist in larger clusters (**Figure 16).** Sadr and Rodier (2012) also established the same pattern in Pam1, that Group II sites were more clustered than Group I SWS. This will be revealed in a comparison of the nearest neighbour analysis between Group I and Group II sites.

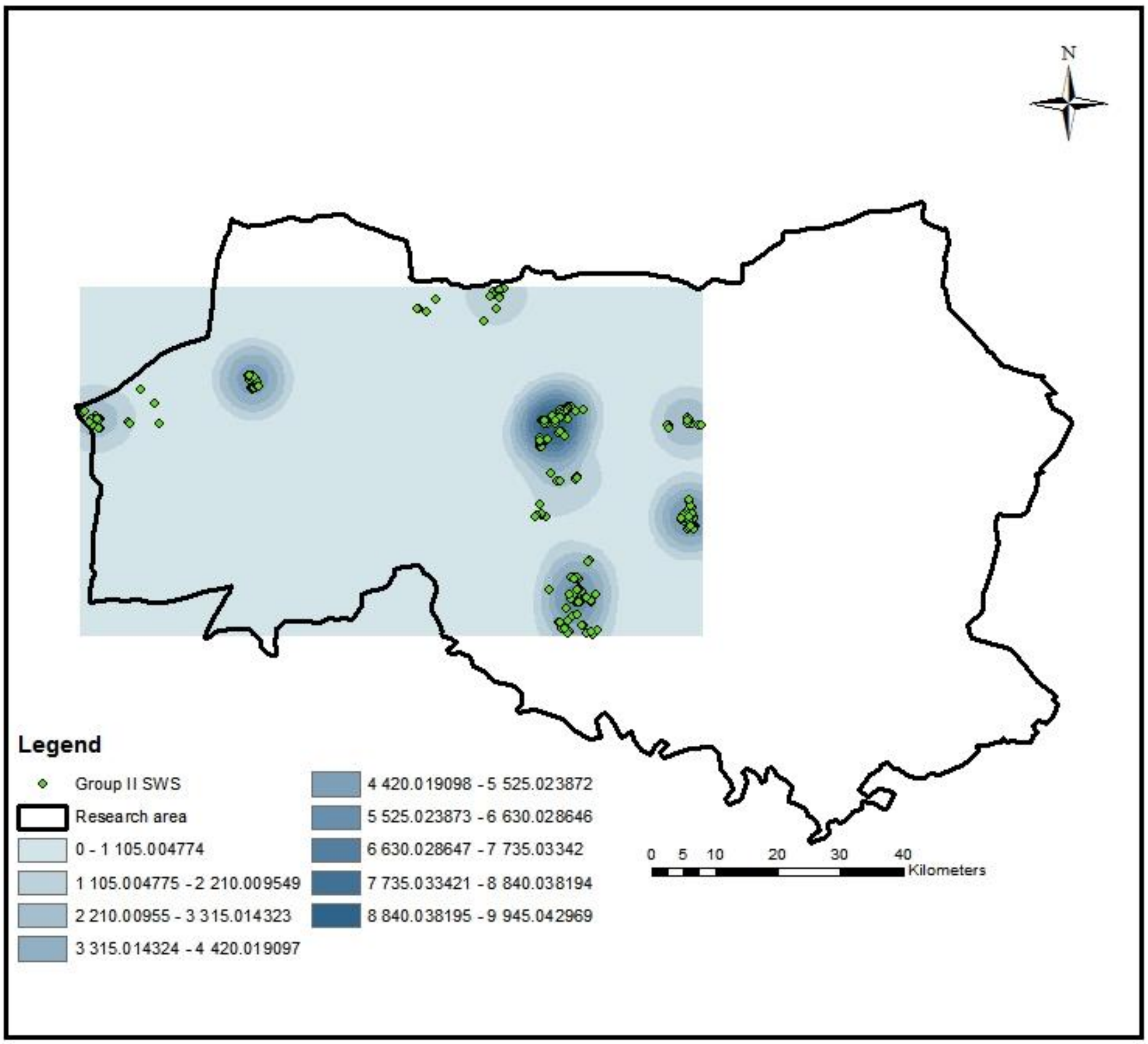

Figure 16.Kernel Density analysis Group II SWS in the research area. (Measured in km^2)

Nearest Neighbour Analysis

Sadr and Rodier (2012) conducted a cluster analysis in Pam 1 and they observed that Group I sites appeared to be more dispersed than Group II sites. Using a more sophisticated method of analysis, the nearest neighbour analysis, they observed that the observed mean distance to the nearest neighbour in Group I sites is 330m while for Group II the Observed Mean Distance (OMD) is 191m **(Table 3)** (Sadr and Rodier 2012:1038) A nearest neighbour analysis was also applied on the research area to obtain more precise results on the distribution patterns of Group I and Group II SWS. A comparison of the Observed mean Distance between results from Pam 1 and the research area shows that in Pam 1 the OMD for Group I sites was higher than (330) than for Group II (191) and for the research area the OMD for Group I (502) was also higher than Group II (276). This means that there was on average a longer distance between neighbouring Group I sites in Pam 1 and in the research area while there was a shorter distance between Group II sites. A 200m buffer was created and dissolved, in both study areas results show that there are more Group II sites per cluster Compared to Group I sites (**Table 4**).

	Group I	Group II
Observed mean distance	330	191
z-score	-10.69	-16.68
n SWS	146	196
n 200 clusters	70	31
n SWS in densest cluster	9	62
% SWS in densest cluster	6.16	31.63
av n SWS/200 cluster	2.13	6.32

Table 3. Comparison of nearest neighbour statistics for Pam 1 (Adopted from Sadr and Rodier, 2012)

	Group I	Group II
Observed mean distance	502	276
z-score	-37.72	-28
n SWS	703	298
Expected Mean Distance	1962	1817
Nearest Neighbour Ratio	0.2563	0.1521
n SWS in densest cluster (200m buffer)	18	25
% SWS in densest cluster	2.56	8.39

Table 4. Comparison of nearest neighbour statistics for the research area.

4.4 Rankings

The size of SWS in the research area can be taken as an indication of the importance of a site, perhaps in terms of population size, power or wealth (Sadr and Rodier, 2012). Boeyens and Plug (2011) further assert that, there is a correlation between settlement size and political superiority in pre-colonial communities. The question now becomes, were the more clustered Group II sites representing one large settlement? Or these were just individual SWS that were located in close proximity to each other. A comparison of results from Pam 1 and the research area reveal that the average area of Group I sites is smaller compared to Group II sites (**Table 5** and **Table 6**). The ranking analysis was achieved through the same procedure that Sadr and Rodier (2012) used. All Group I and Group II sites are enclosed areas hence easily converted into polygons whose areas can be measured. This included the use of a polygon shapefile of the sites available in the SGSWS database where the area of all the SWS are provided. Using the field calculator tool in QGIS the maximum, minimum and average area of the SWS among other calculations were determined. A summary of tables from Pam 1 and the research area show that the area covered by Group II SWS was more than the area occupied by Group I SWS regardless of the fact that there are fewer Group II SWS in the research area (**Table 6**). Rankings results from Pam 1 coincide with results from the research area showing that, basing on the ranked sizes of Group I and Group II SWS, Group I were more egalitarian whereas Group II were more stratified. Basing on Maggs' (1976) definitions, Group II sites had more defined Settlement units compared to Group I sites which mainly comprised of structures.

	Group I	Group II
n SWS	146	196
Average area	2 902	6698
Median area	2 495	4106
St deviation	2 143	7390
minimum	316	407
maximum	17 215	50 443
total	423,758	1,312,852

Table 5. Size comparison of SWS in Pam 1. (Adopted from Sadr and Rodier, 2012)

	Group I	Group II
n SWS	703	298
Average area	2 343m	5785m
St deviation	1 842m	5728m
minimum	63m	539m
maximum	20 074m	64 349m
total	1 647 138m	1 724 077m

Table 6. Size comparison of SWS in the research area.

4.5 Arable lands

Proximity to arable lands was a very important factor to consider in farming communities. They provided fertile soils for crop cultivation. Farming communities exploited resources that were within a 5km distance from their household while hunter gatherers would walk up to 10km a day for supplies (Higgs 1975 & Flannery, 1976). With this in mind a 5km buffer was created around arable soils in the research area (**Figure 17**). Sadr and Rodier (2012) established that more group II SWS (72%) were located within a 5km distance from arable lands while there were fewer Group I SWS (40%) located within a 5km buffer from arable lands (**Table 7)**

	Group I	Group II
SWS within 5km of best arable soil	60	141
n SWS total	149	196
% within 5km	40	72
Total $m^2$of SWS in 5km proximity	168 091	861 528
Total m2 of all SWS	423 758	1 312 852
% m2 of SWS in 5km proximity	39.69	65.62

Table 7. Distribution of SWS relative to best arable soils in Pam 1. (Adopted from Sadr and Rodier, 2012)

Results from the entire research area reveals the same pattern where there are more Group II sites (94%) located within a 5km buffer as compared to Group I sites (78%) (**Table 8**). It is also important to note that the total area in km^2 covered by Group I SWS is less as compared to Group II SWS especially in the research area where there are fewer sites as compared to group I SWS (**Table 7 & Table 8**). This points out to a possibility that perhaps Group I societies, as much there were farming communities in their respect, they were more pastorally oriented. It is possible that they formed that stage of transition when they later evolved into Group II societies which are more defined as farming communities based on their locational preferences relative to arable lands.

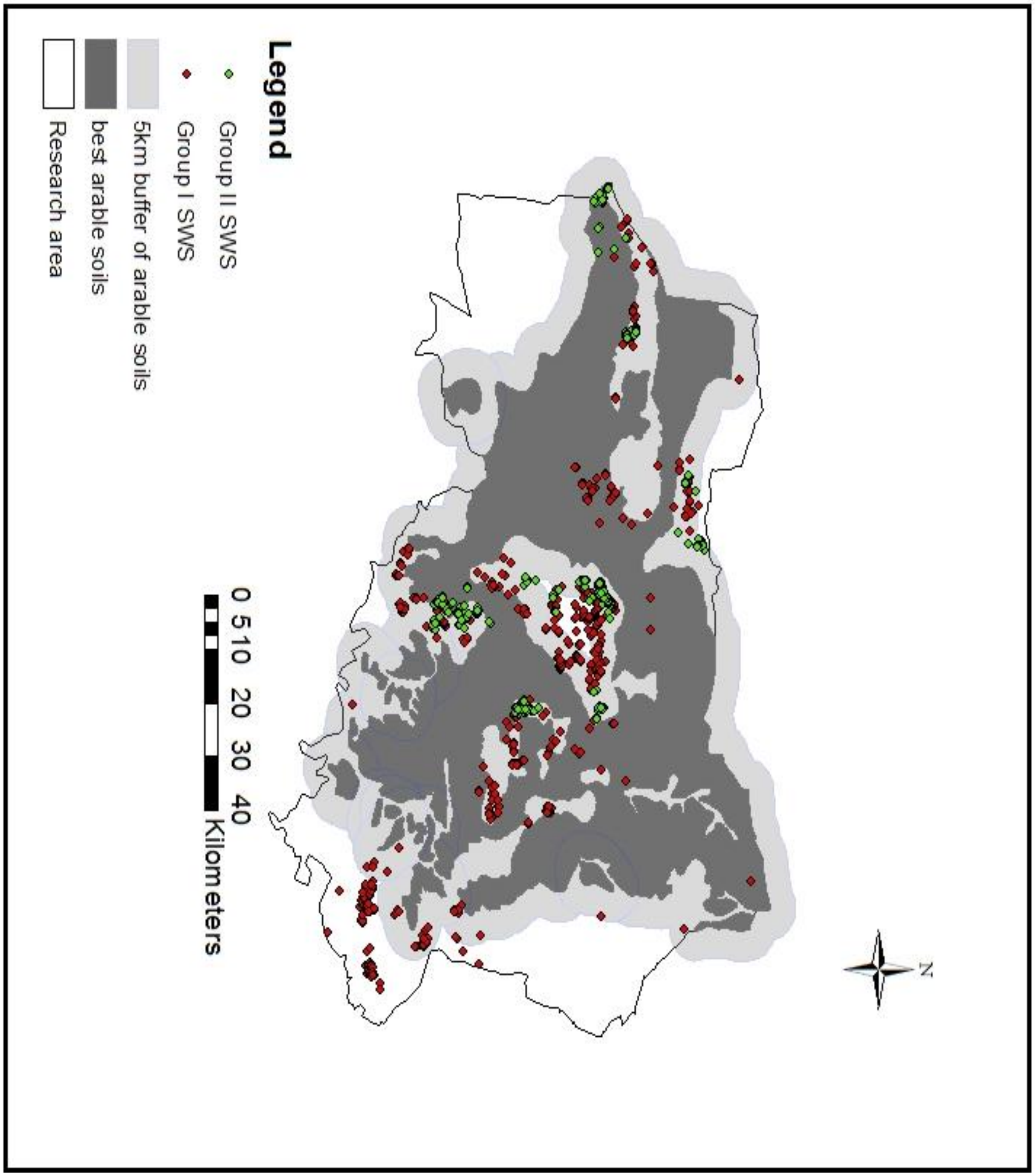

Figure 17. Distribution of SWS relative to best arable soils.

	Group I	Group II
SWS within 5km of best arable soil	554	283
n SWS total	703	298
% within 5km	78.80512	94.96644
Total m2 of SWS in 5km proximity	1 423 207	1 663 159
Total m2 of all SWS	1 647 138	1 724 077
% m2 of SWS in 5km proximity	86.40484	96.46663

Table 8. Distribution of SWS relative to best arable lands in the research area.

4.6 Standard Deviation Ellipse

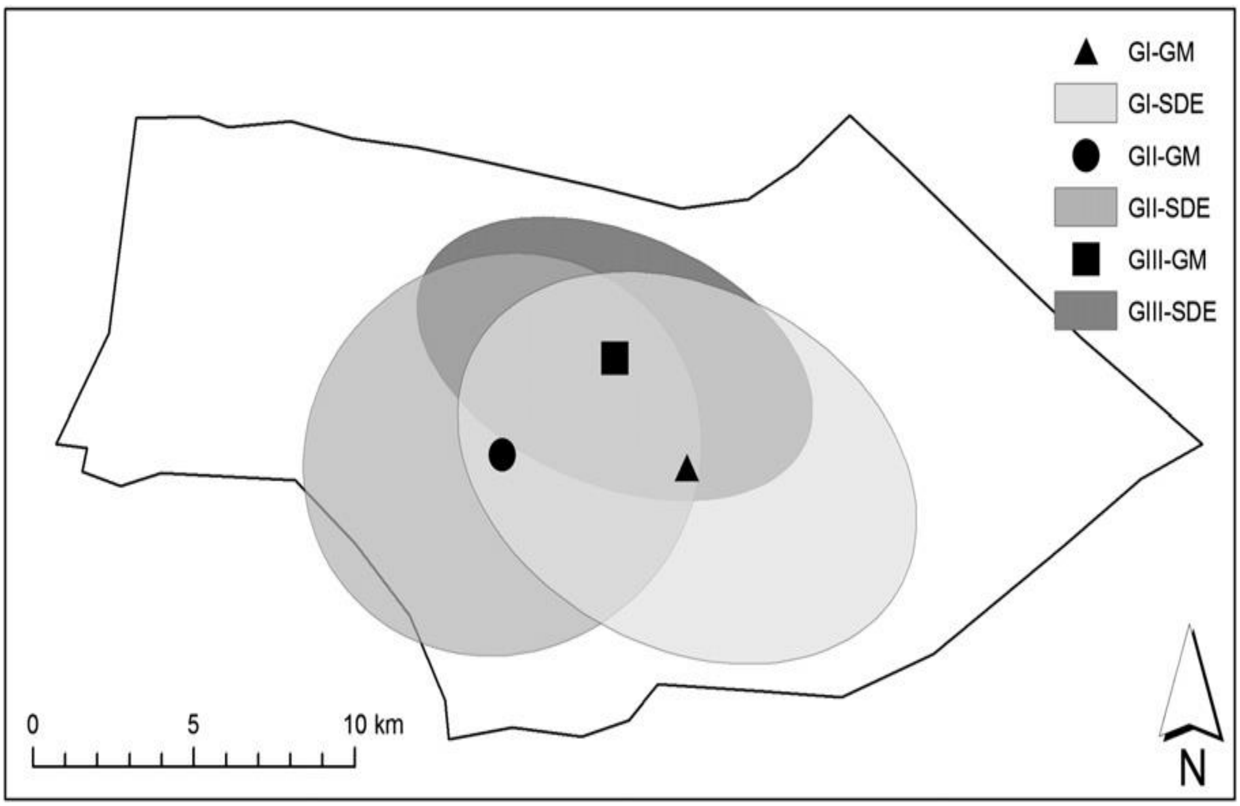

Figure 18. The centroids and one standard deviation ellipse of Group I, II and III SWS. (Adopted from Sadr and Rodier 2012:1041).

According to ESRI (2016) Standard Deviation Ellipse (SDE) is a spatial statistic tool which is used to measure distributions trends. It works by establishing the mean centres of features and calculates the standard distance in the X and Y directions separately. Mitchell (2005) notes that, (SDE) can be used to observe directional trends of different feature groups. Sadr and Rodier (2012) clearly state that, distribution trends in Pam 1 between Group I and Group II suggest that the population moved towards the northwest through time **Figure 18**. In Pam 1 the centroid was located on higher ground suggesting that unlike in other parts of South Africa where Group I sites are located in valley floors and flood plains, in southern Gauteng they were located on higher ground which overlooked the flood plains. A standard deviation ellipse was also calculated for the entire research area and the results profoundly concurred with test results from Sadr and Rodier (2012). **Figure 19** is an SDE which indicates that both Group I and Group II SWS in the research area tend to move towards the north-western direction.

Another observation which can be deduced from both SDEs (from Pam 1 and the research area) is that the size of the SDEs of Group I SWS are bigger as compared to Group II SWS. Generally speaking there are more Group I SWS (703) as compared to Group II SWS (298) in the research area whereas compared to Pam 1 where Group I SWS (149) are fewer as compared to Group II SWS (196). Group II SDEs are smaller in size in both study areas, Sadr and Rodier (2012) explain that Group I sites in Pam 1 represented 'small egalitarian dispersed homesteads' and Group II represented 'more aggregated, larger, ranked settlements overlooking the fertile floodplains' (Sadr and Rodier, 2012: 1041). This means that even though the SDE of Group I is bigger in size, the average area per km^2 of each Group II SWS is bigger than that of the Group I SWS. Meaning to say that instead having a large number of smaller dispersed homesteads, Group II sites evolved into small numbers of larger, clustered homesteads showing a drift from egalitarian societies to more stratified societies

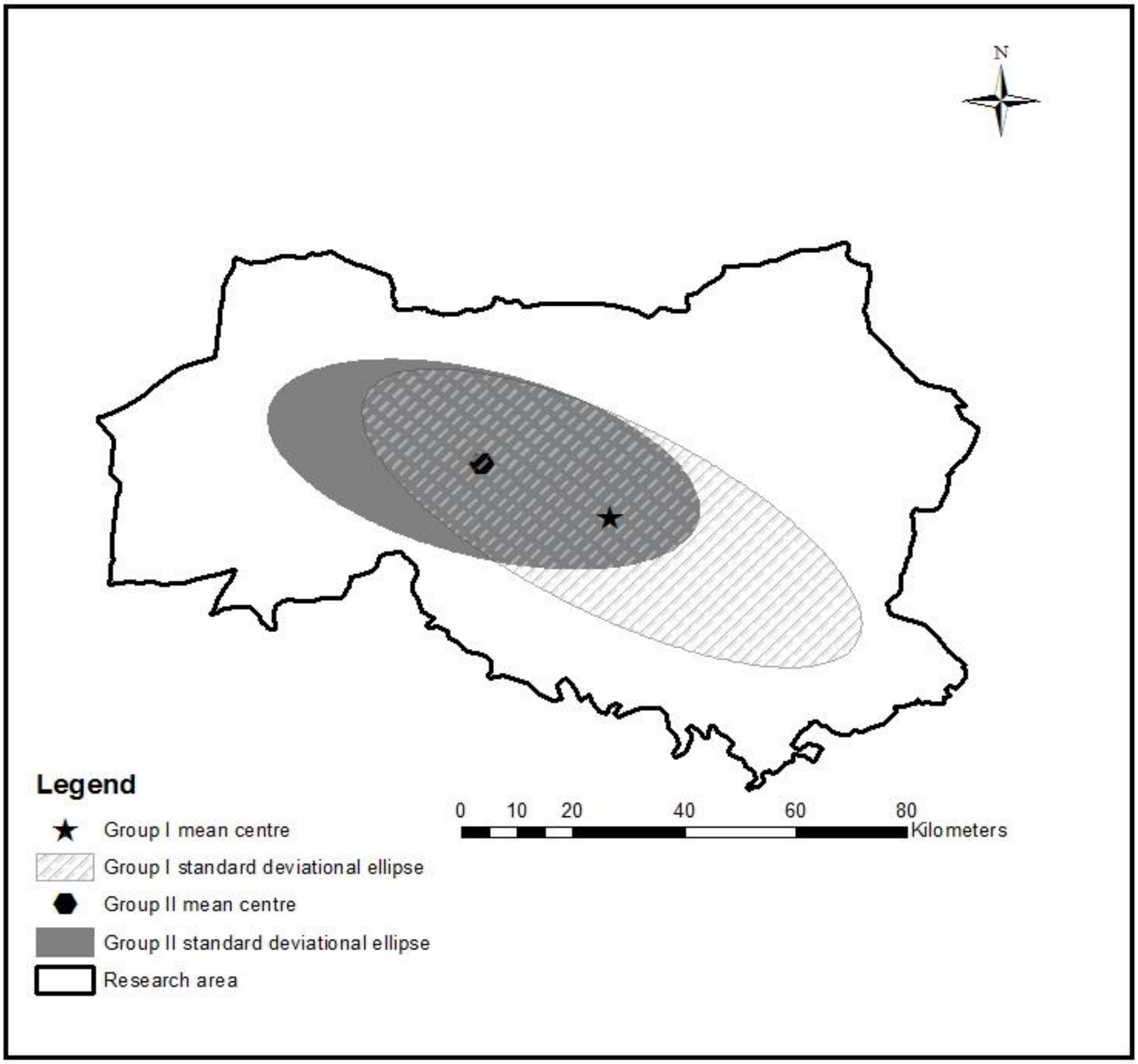

Figure 19. The centroids and one standard deviation ellipse of Group I and Group II SWS in the research area.

Additional analysis

Apart from analysing and comparing the results generated by Sadr and Rodier (2012), the research also considered other environmental parameters that Sadr and Rodier (2012) did not consider. This section focuses on analysing the hydrological system, a detailed approach on elevation and geology. An analysis of the hydrological system will examine the location of Group I and Group II SWS in relation to the drainage system of the research area. Earlier in the chapter elevation was considered; however other parameters such as slope, aspect, hill shade and ruggedness were not considered. Therefore this part of the chapter will focus on how these parameters correlate with site location and distribution. Lastly, this section will also investigate the relationship between the geology of the research area and the location of the SWS. The results will be presented in form of maps, tables and graphs and possible interpretation will also be provided.

4.7 Rivers

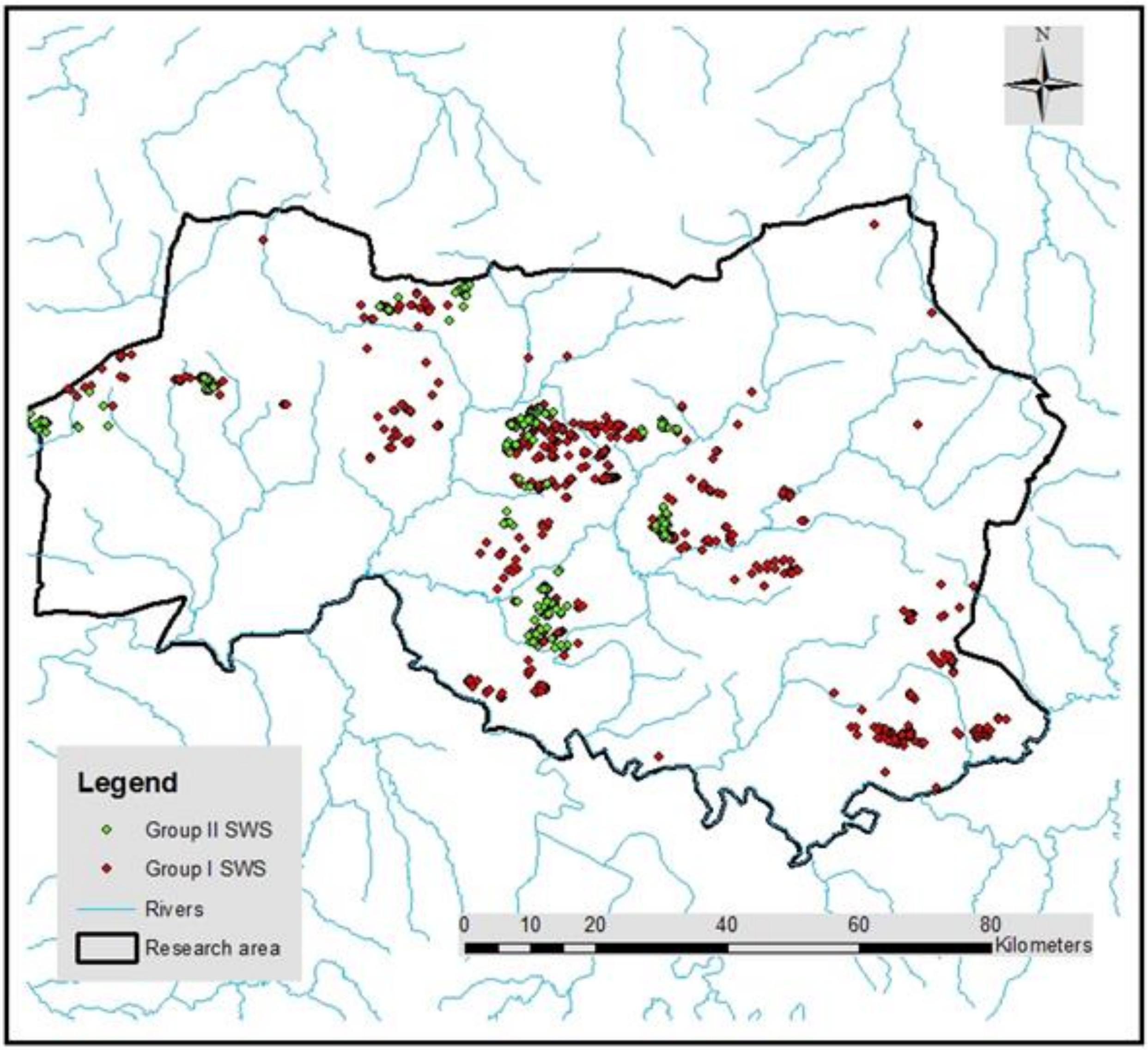

Figure 20. Distribution map showing the location of SWS in relation to the rivers in the research area.

Proximity to reliable water sources played a very significant role in determining the location of prehistoric communities. In Pre-colonial Southern Africa water sources were mostly from rivers. It is important to note that although it has been assumed that pre-historic communities always and directly fetched water from rivers. This is not always the case since wells and springs and some other forms of reservoirs provided the much needed resources to most settlements. Settlements further away from rivers and streams indicated in Figure 20 for example, would suggest reliance on wells, springs and other reservoirs. This calls for ground truthing, to check on these and related features to complement the results found. However this research did not conduct any ground truthing due to limited time and resources. Water was used for domestic purposes which ranged from cooking, washing and drinking. They depended mostly on rain water for their agricultural activities. As a result most of the SWS were located in close proximity to the rivers as evidenced in **Figure 20.** Basing on the data gathered from the research area, a 1km, 2km and a 5km buffer from the rivers was calculated using Esri's ArcGIS 10.3. The resulting map is created **Figure 21** which show the location of Group I and Group II SWS in relation to the different buffers. 14% of SWS in Group I sites and 5% of Group II SWS sites are located within the first kilometre from rivers. It can be observed that more Group I SWS are located in close proximity to rivers as compared to Group II SWS at the same buffer level, except for the 5km buffer where there are more Group II SWS 88% while there are only 79% Group I SWS . There is a fairly small number of SWS out of the 5km buffer in both Group I (16%) and Group II (12%) (**Figure 24**) which demonstrates that even though Group II seem to be further away from the rivers both groups appreciated the value and use of water that they didn't want to stay very far from water sources.(**Figure 22**). An Euclidean distance analysis of the sites to the rivers was also conducted so as to have an appreciation of the location of the sites relative to graduated distance from rivers (**Figure 22 and Figure 23**).

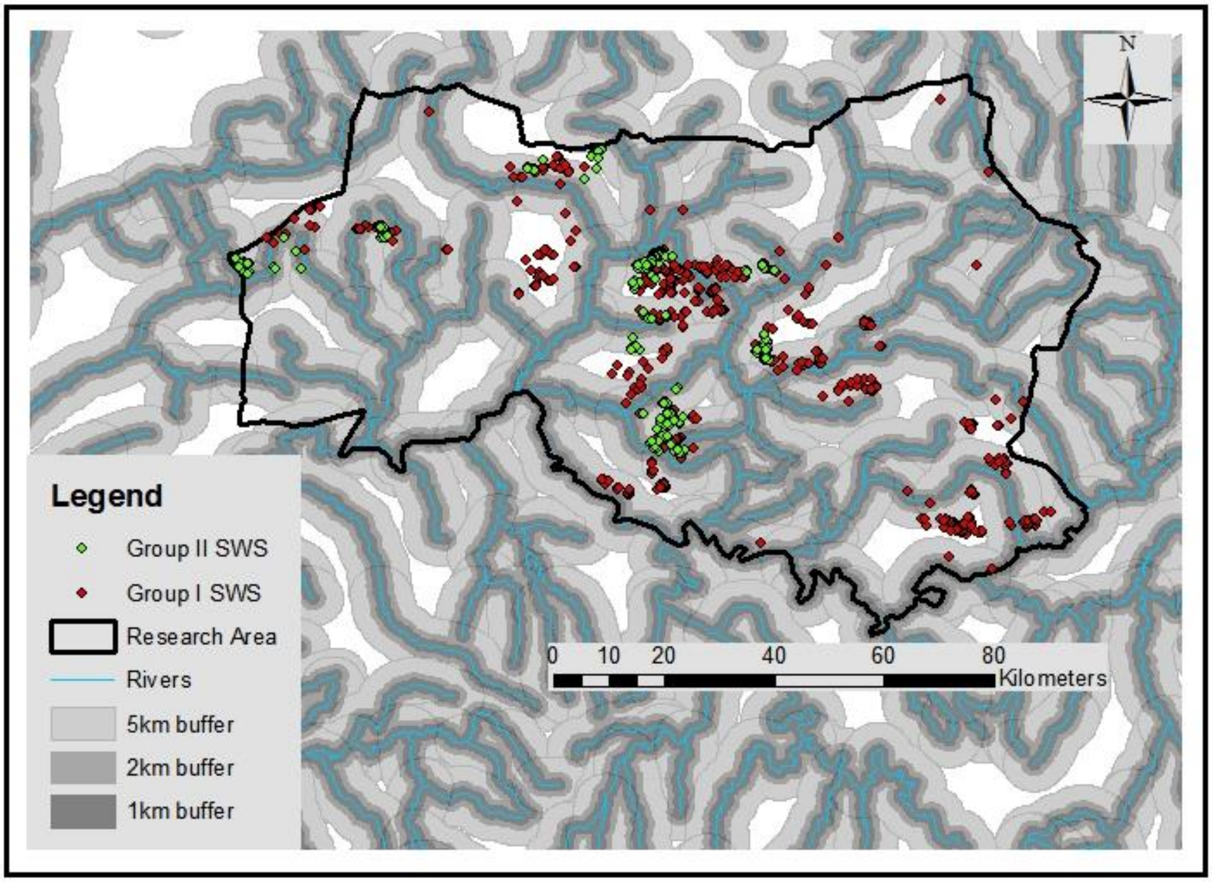

Figure 21. Distribution of SWS in relation to various buffers created around rivers.

	Group I	Group II
n SWS	703	298
n SWS in 1km buffer	95	15
n SWS in 2km buffer	119	52
n SWS between 3-4km buffer	344	196
n SWS within 5km buffer	558	263
n SWS out of 5km buffer	145	35

Table 9. Distribution of SWS in relation to distance from rivers in figures.

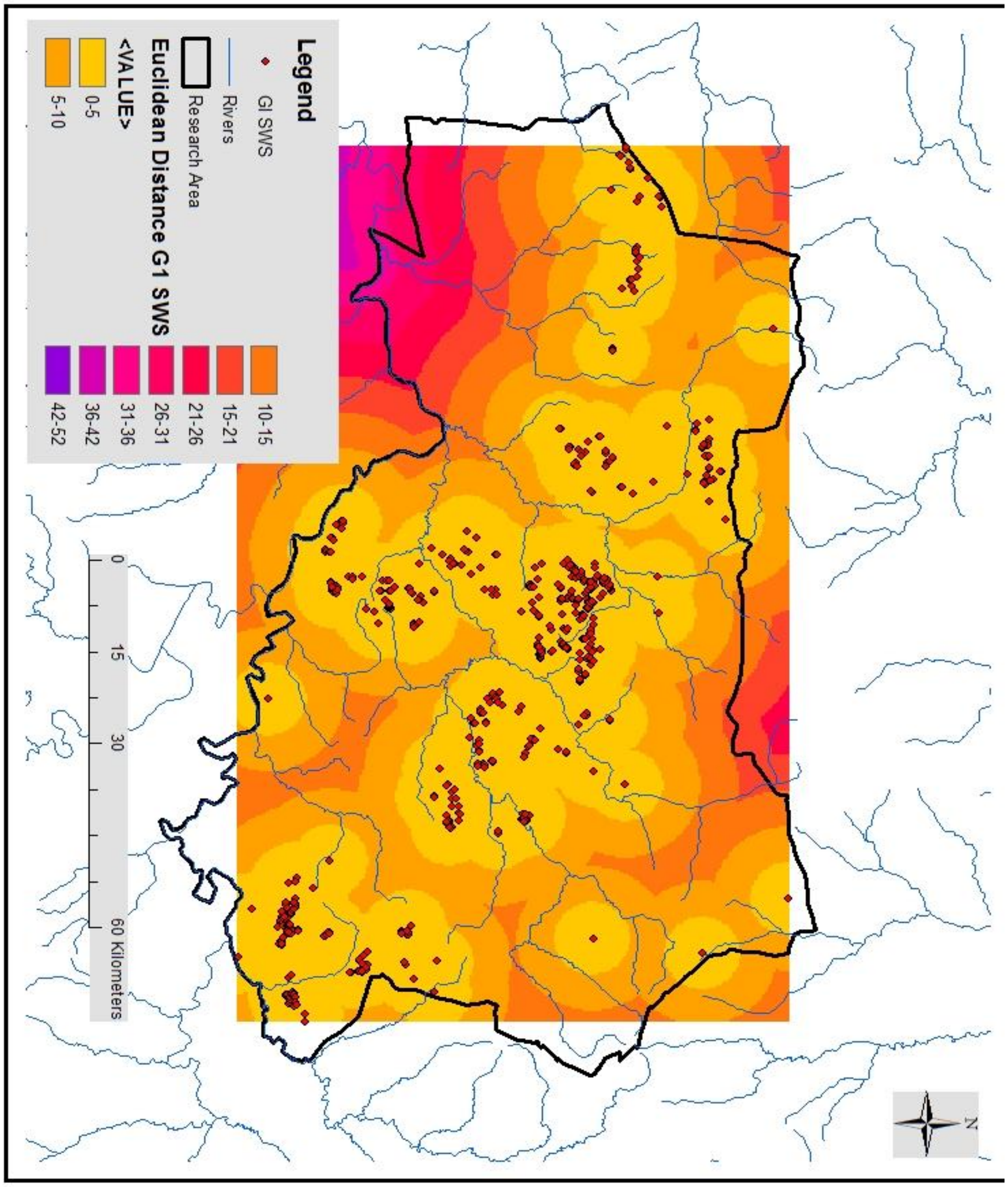

Figure 22. Distribution of Group I SWS relative to Euclidean distance from rivers. (Distance is graduated in km)

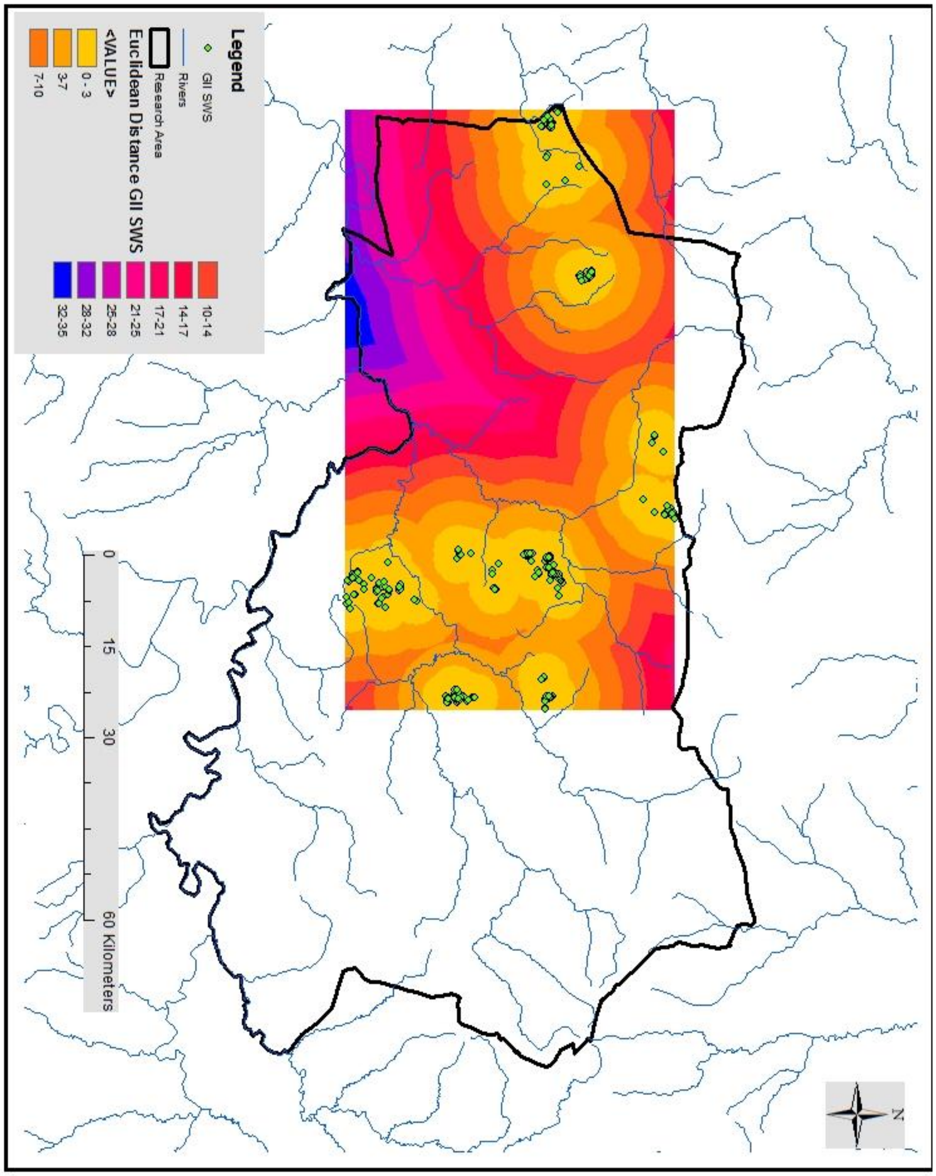

Figure 23.Distribution of GROUP II SWS relative to Euclidean distance from rivers. (Distance is graduated in km)

	Group I	Group II
n SWS	703	298
% within 1km buffer	14%	5%
% within 2km buffer	30%	22%
% between 3-4km buffer	48%	65%
% within 5 km buffer	79%	88%
% out of 5km buffer	16%	12%

Table 10. Distance of SWS in relation to distance from rivers in percentages

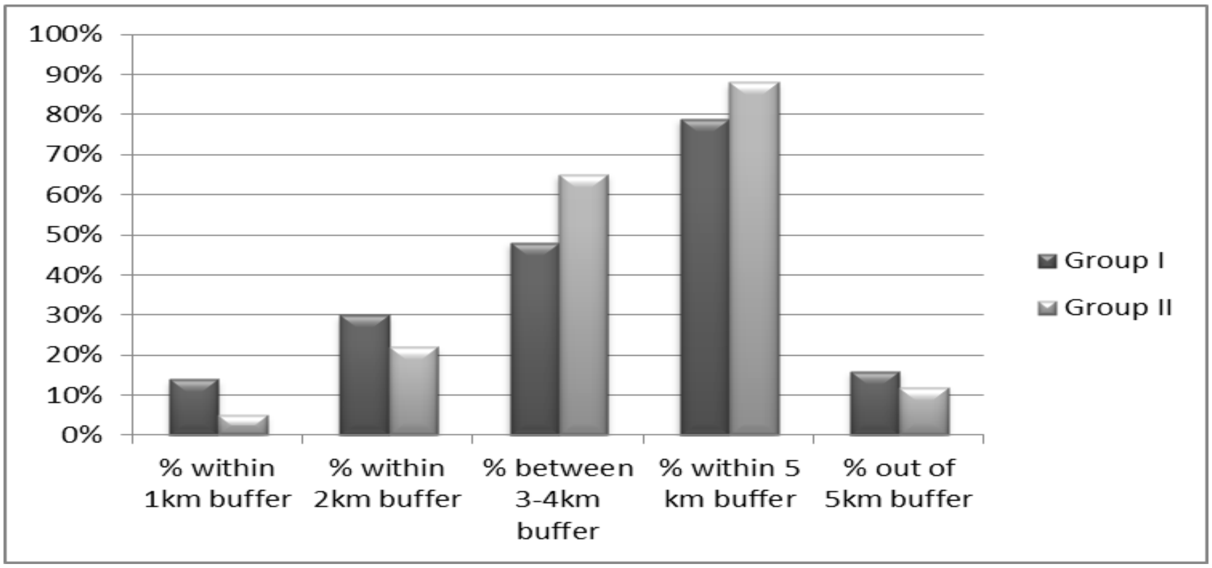

Figure 24. Distribution of SWS relative to distance from rivers.

4.8 Elevation analysis

Aspect

Aspect refers to the orientation of the slope and includes N, NE, E, SE, S, SW, W, NW. According to Wheatley and Gillings (2002) aspect is the direction that a topographic slope faces. Conolly and Lake (2006:190) define aspect as the compass direction of the rate at which elevation changes in the downhill direction. There are more Group II that are facing the south-western direction as compared to any other direction while there are more Group I facing the north-western side **Figure 21.** There are fewer Group II sites that are either facing the north-east, east, or north-west as compared to Group I sites. This shows that while Group I SWS were almost equally distributed in all directions, Group II were located on south-western slopes.

	Group I	Group II

n SWS	703	298
Average	186.2360656	196.9871969
Minimum	1.27303	2.1211
Maximum	360	360
Standard deviation	107.603939337	101.2290853

Table 11. Distribution of Group I and Group II SWS relative to aspect.

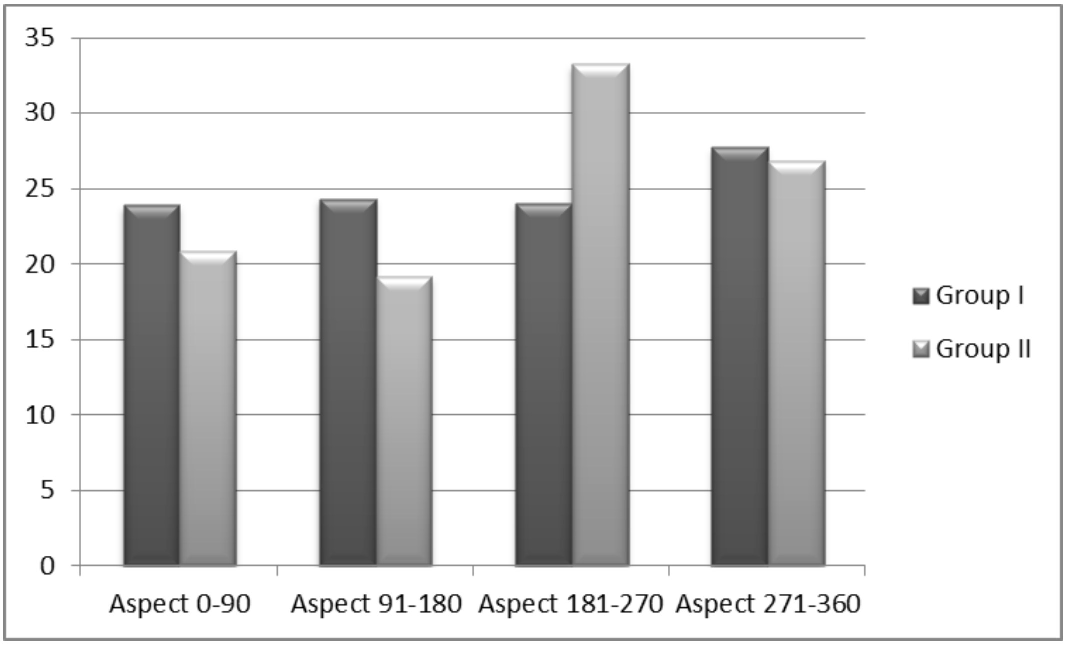

Figure 25. Distribution of Group I and Group II in relation to the directional orientation of the slope.

Terrain Ruggedness

Terrain ruggedness is a measure of how gradually the slope changes between two adjacent cells of a Digital elevation model (Wheatley and Gilling 2002). According to Sadr (In Press) rugged terrain did not promote crop cultivation but it highly encouraged cattle grazing**. Table 13** suggests that, basing on average ruggedness; both groups preferred settling in areas with a smoother terrain. However Group I SWS had the widest range from 0-38, Group II SWS on the other hand were located on less rugged terrain **Figure 25**. This shows that Group II communities gave particular attention to areas with gentle terrain when they were deciding on where to locate their homesteads. The results concur with Sadr's (In Press) observation, that the more pastoral Group I societies settled in areas with a rougher terrain as compared to Group II societies. Group II communities settled in areas with smoother terrain which was more suitable for crop cultivation.

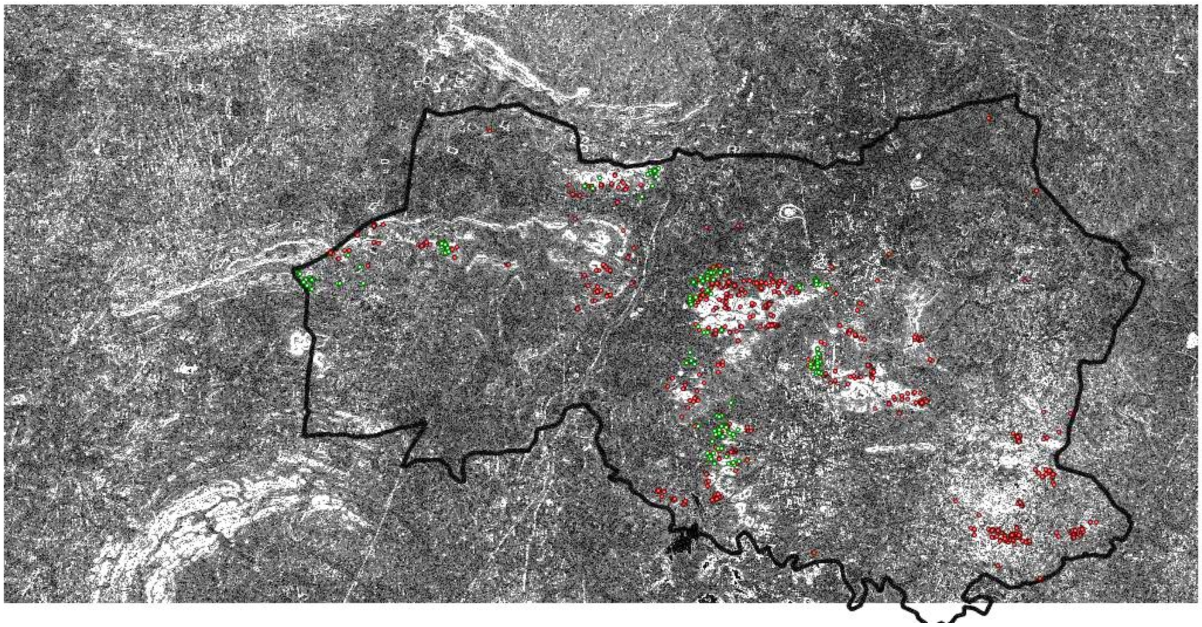

Figure 26. Showing the distribution of SWS in relation to terrain ruggedness. ***(The white areas represent areas with very steep terrain and the grey areas represent areas with gentle terrain. The red dots represent Group I SWS and the green dots represent Group II SWS).***

The white colour represents areas where the terrain was very rugged and probably very steep. The darker grey colour represents areas where the terrain was gentle.

	Group I	Group II
n SWS	703	298
average	9.179621414	6.142732315
minimum	0	1
maximum	37.77565	17.9949
Standard deviation	5.578013694	2.964161683

Table 12. Distribution of Group I and Group II SWS relative to terrain ruggedness.

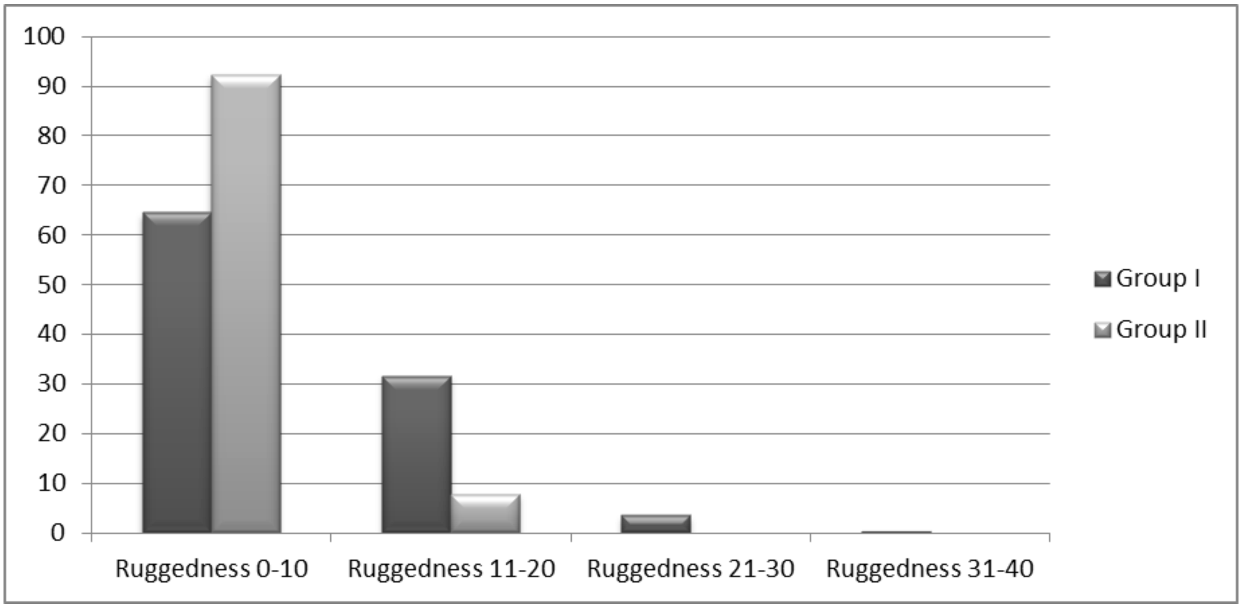

Figure 27. Distribution of Group I and Group II SWS in relation to terrain ruggedness.

4.9 Geology

Availability of rock outcrops played a very significant role in determining site location during pre-colonial times in southern Africa (Mason, 1969). Rock outcrops were used as sources for building material for the SWS; therefore it was important that the sites were located close to raw material such that the people would not have much difficulty in transporting the rocks. The geology also determined the type of soil. This determined the quality of soils suitable for grazing and farming.

An analysis of the relationship between the parent rock and the SWS revealed that, both Group I (62%) and Group II (44%) SWS preferred Ventersdorp formation (**Table 14**). Ventersdorp is a metamorphic rock which according to Van Der Westhuizen, De Bruiyn and Meintjes (1991:83) is divided into three groups the Klipriviersberg sequence , the Platberg sequence and the Pniel Sequence. Winter (1976) notes that the Ventersdorp sequence is located in southern and western Transvaal, Northern Cape and south-eastern Botswana. Of particular interest to this research is the Klipriviersberg sequence located in southern Gauteng which includes our study area.

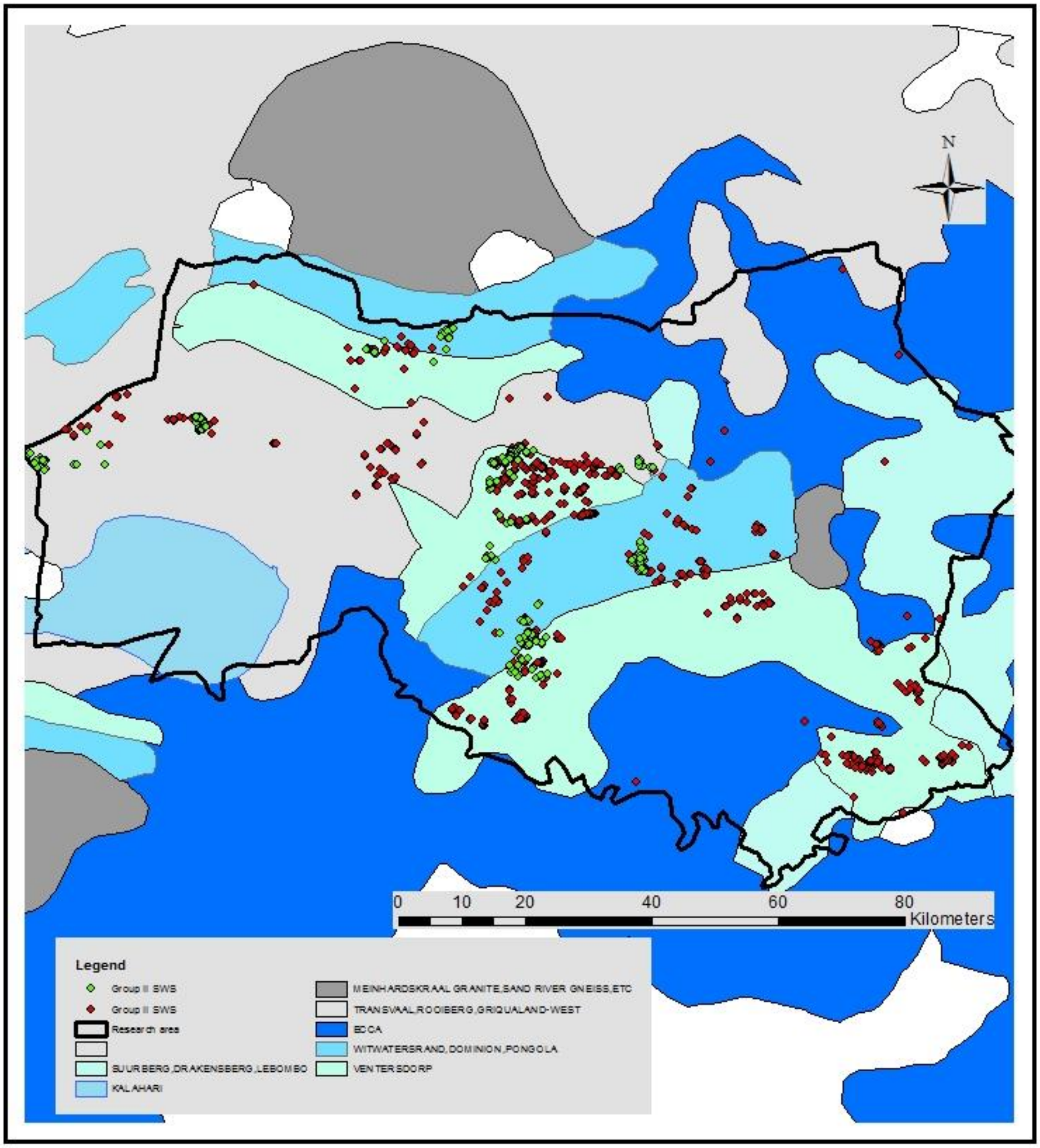

Figure 28. Distribution of SWS relative to geology.

Bredenkamp and Theron (1978) analyzed the vegetation of the Suikerbosrand nature reserve in relation to the Ventersdorp geology. They noted that, Ventersdorp is associated with scatter rock outcrops all over the plateau and soils are characterized with ‘deep, fertile clayey soils of alluvial and colluvial origin’ (Bredenkamp and Theron, 1978:513). Another important characteristic that may have attracted pre-colonial communities to settle in Ventersdorp group is that it is banded with iron formation (Schroder, Lacassie &

Beukes, 2006). This provided a reliable source of raw material for iron products like hoes and spears for everyday use. This provides a possible explanation why a larger percentage of both groups were attracted to this particular geology. The presence of rock outcrops provided an available source of raw material for the construction of the SWS, and fertile soils presented an opportunity for crop cultivation.

	Group I	Group II
n SWS	703	298
Ecca	24	0
Ventersdorp	436	131
Transvaal	100	82
Witwatersrand	135	85
Suurburg	8	0

Table 13. Distribution of SWS relative to the geology of the study area.

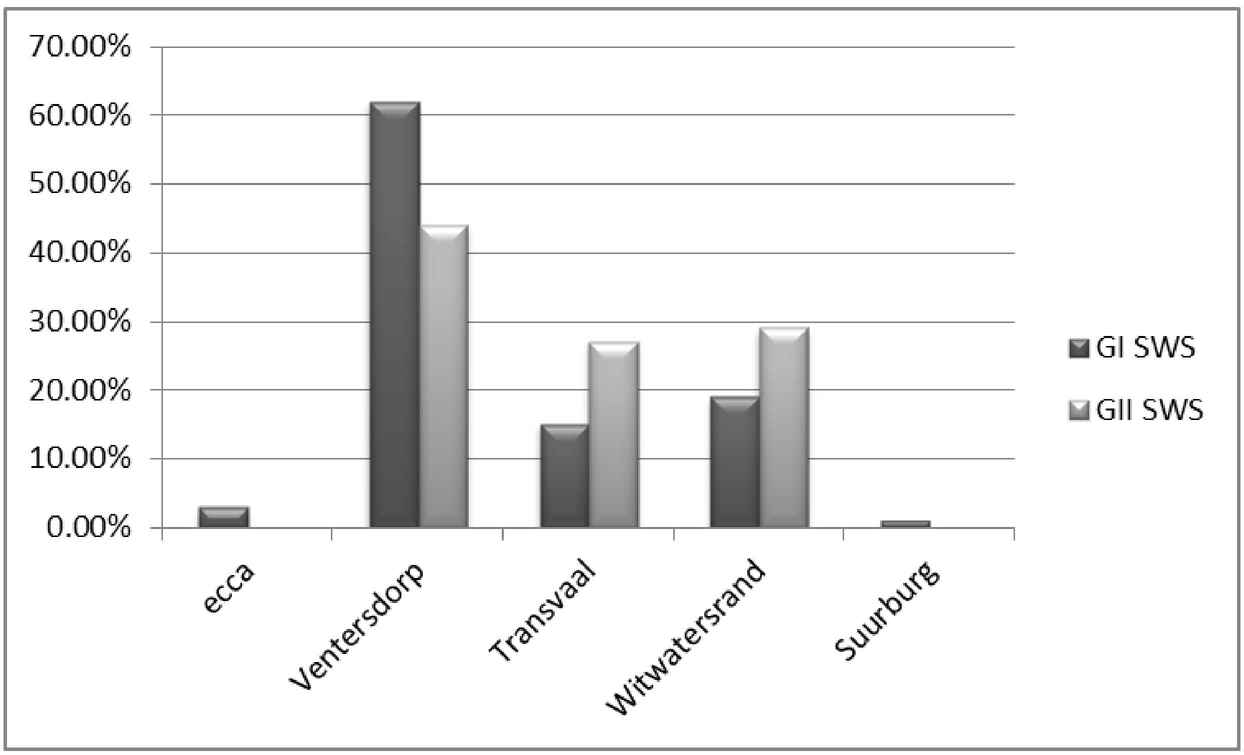

Figure 29. Distribution of Group I and Group II SWS in relation to the geology of the research area in percentages

There are more Group II SWS located within the Witwatersrand and the Transvaal geology groups as compared to the Group I SWS (**Figure 29**). The Witwatersrand group is characterized with quartzite and banded iron (McCarthy and Rubridge, 2005). They note that the Witwatersrand group is mainly found deep underground but it surfaces in Gauteng and the Free State. These surfaced outcrops might have also presented an opportunity for raw materials extraction hence the reason why a fairly reasonable number of Group II settled close to this super group. Another important observation is that there are no Group II SWS located within Ecca and Suurburg geology. Ecca is characterised with sandstone, shale and mudstone. This makes it hard to find outcrops let alone raw materials for constructing SWS. This lights to a possibility that, there was no point for the Group II communities to settle near Ecca as there was nothing much to benefit from it. Transvaal Super group consists of granites, gneisses and green stones and this presents a reliable source of building raw material. This might explain why a fairly significant number of Group II SWS (28%) (**Figure 29**) were located within the Transvaal super group. Group I (14%) are less. Within the Witwatersrand super group there are more Group II SWS (29%) compared to Group I SWS (19%).

4.1.0 Urban Sprawl

The city of Johannesburg was formed as a result of the 1886 Witwatersrand gold rush. Before the era of the gold rush there were a few farmer settlements scattered all over the region (Petermann, 1868 and Merensky, 1875). During the pre-colonial era, the Sotho-Tswana used to inhabit this region. (Mason 1962, 1986; Maggs, 1976; Taylor, 1979) who left remarkable architecture of stone walled structures. Recent studies have revealed that, the southward expansion of the city of Johannesburg has destroyed about 20% of the SWS in the region (Sadr in press). According to Sadr (in press) about 850-1350 SWS between the Witwatersrand ridge and the Vaal River have been destroyed due to the industrialization of the region. Infrastructural developments which include the construction of transport systems, residential and commercial activities in this area in this have led to the destruction of SWS (**Figure 30 and Figure 31**). As a result this has affected the distribution of SWS as some sites are no longer present where they used to be (**Figure 32 and Figure 33)**

The current state of SWS in southern Gauteng does not represent the entire picture of precolonial SWS in southern Gauteng. **Figure 31** indicates that the effects of urban sprawl are more towards the northern part of the research towards Johannesburg. According to Sadr (In press) the rate of destruction is at 5 SWS for every 10 km^2 of urban sprawl. He acknowledges that infrastructural development is important; however there is need to maintain balance between modern cultural developments and archaeological material. It therefore becomes important to acknowledge that the SWS that remain in southern Gauteng do not represent what was there during the precolonial era. This presents room for error but, we just had to deal with the information that was available. This also presents opportunities for further research where one could model and predict the actual number of sites that were lost and the exact location they used to be before the expansion of Johannesburg.

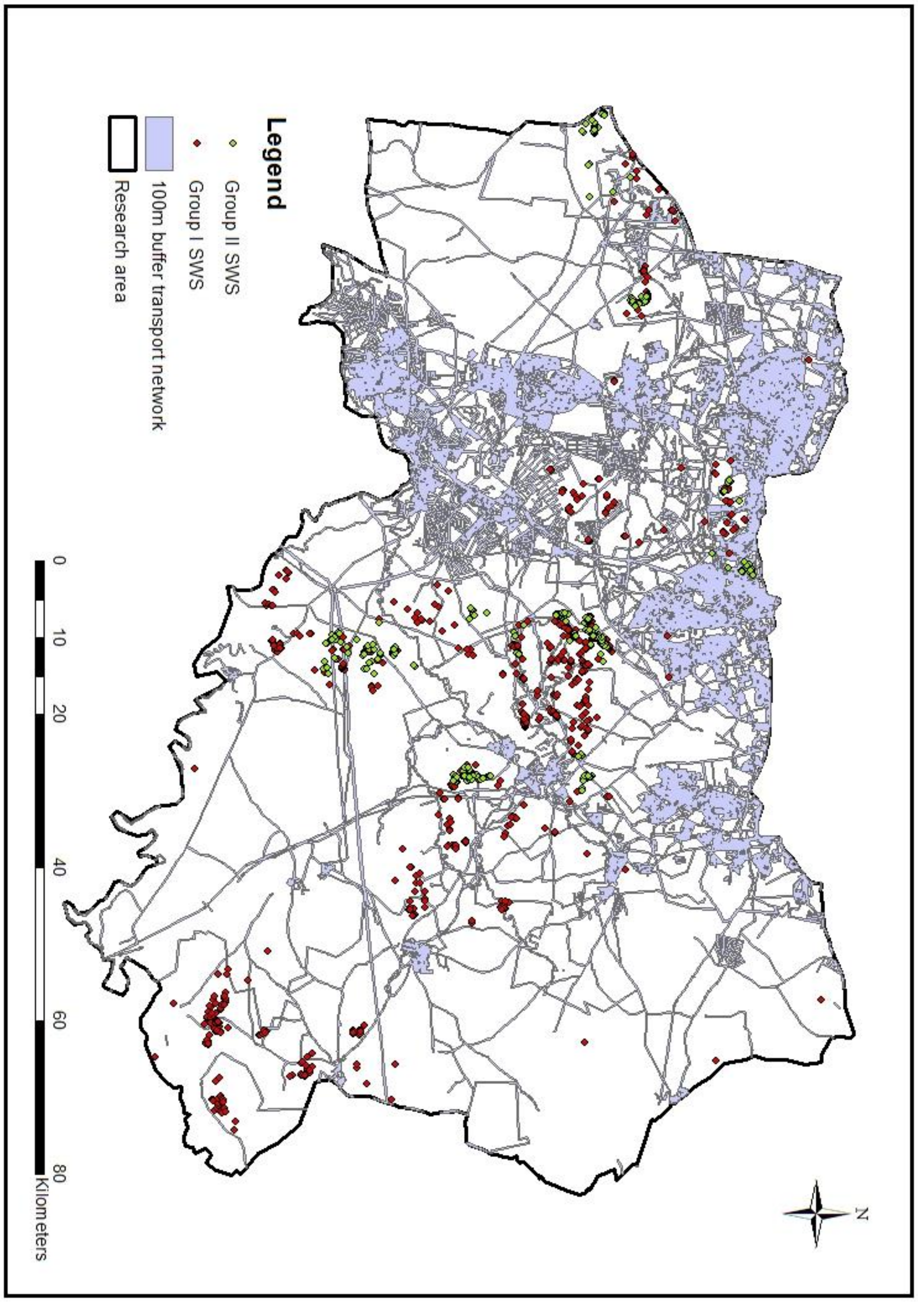

Figure 30. Distribution of SWS in relation to a 100m buffer around transport networks in southern Gauteng.

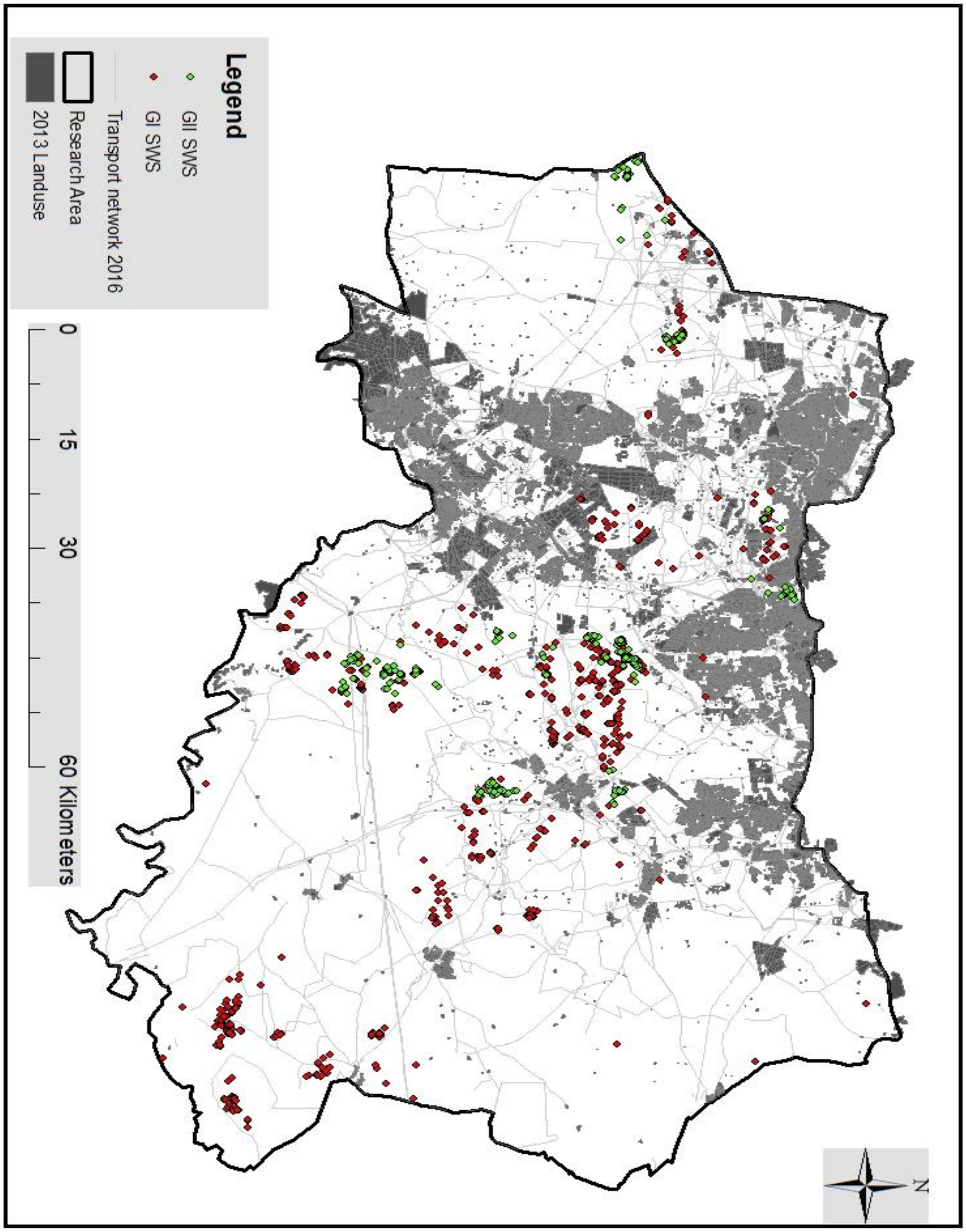

Figure 31. Showing the distribution of SWS relative to infrastructural developments in the research area.

Figure 32. Google Earth image taken in 2012 before the construction of the Mall of the South.

A good example can be noted from **Figure 32** where some SWS were visible on a Google Earth image before the construction of the Mall of the South in southern Gauteng. **Figure 32** was taken in February 2012 and one can observe that there are a number of SWS surrounding the mountain feature. In September 2016 **Figure 33** was captured for the same area using Google earth, the more recent image was taken a year after the opening of the mall of the south. With an area of 65 000m2 the mall of the south destroyed some of the SWS and this will definitely affect the distribution of the SWS in southern Gauteng.

Figure 33. Google Earth image taken in 2016 after the construction of the Mall of the South.

4.1.1 Statistical analysis

Statistical analysis in archaeology is important because it reduces errors associated with human interpretations (Binford 1989). The first part of this chapter, compared spatial data using exploratory approaches and similar conclusions that were reached by Sadr and Rodier (2012) were also achieved in this research. Results from Pam 1 and the research area suggests that Group I evolved from egalitarian pastoral societies to Group II which were more stratified farming communities. This final part of the chapter will establish if the differences that were observed during the exploratory analysis can be statistically significant. Two tests were carried out, the Kolmogorov-Smirnov (K-S) test and the Mann-Whitney test to determine if the two groups represent two separate populations. Any value between 0-0.05 (<0.05) is regarded as a small p value therefore the null hypothesis is rejected meaning to say that there is a significant difference between the two groups and they probably came from two different populations (Rumsey 2010). A p-value more than 0.05 (>0.05) suggest that there is no significant statistical difference and gives no reason to reject the null hypothesis therefore meaning the two samples probably came from the same population.

Arable lands analysis

An exploratory analysis of Group I and Group II SWS from the research area highlighted that there were more Group II sites (94%) located within a 5km buffer as compared to Group I sites (78%). Sadr and Rodier (2012) also established the same results, that there were more Group II SWS (72%) located within the 5km buffer from arable lands as compared to Group I SWS (40%). These results show that in both Pam 1 and the Research area there is a 16% (Pam 1) and a 32% (research area) difference in the number of SWS within 5km buffer from arable lands between Group I and Group II SWS. From an exploratory point of view there is a significant difference (more than 15%) between the location of sites in relation to Group I and two in both study areas. A statistical analysis of the same data showed that there was no significant difference between the two distributions (**Table 14**). Both the K-S test and the Mann-Whitney test had p-values of 0.333 which suggest there is no significant statistical difference in the distribution of SWS between Group I and Group II SWS in the research area relative to arable lands. Therefore according to the K-S test and the Mann Whitney test the two group have similar distribution tendencies. This suggests that they probably originate from the same population. In archaeological terms, this suggest that the changes that occur with the distribution of Group I and Group II are not statistically significant to argue that there were any significant cultural changes that occurred between Group I and Group II SWS. However an exploratory analysis of the tables and graphs generated from the arable lands data suggests different settlement traits between Group I and Group II sites. According to the exploratory analysis conduct there is a significant difference between settlements traits shown in Group I and Group II SWS. These differences as Sadr and Rodier (2012) suggests might be attributed to culture evolution within a particular community as to the introduction of a completely different settlement pattern by a different cultural group.

Rivers Analysis

An empirical analysis of the relationship between Group I and Group II SWS and distance to rivers revealed that although both groups are generally located in close proximity to rivers, there are more Group II sites (88%) within the 5km buffer as compared to Group I SWS (79%). It is also important to note that within the first kilometre buffer from river there are generally more Group I sites (14%) compared to Group II sites (5%). Basing on these results there is almost a 10% or more difference which can be said to be a significant difference when using an exploratory analysis. However two tests of significance, the K-S test and the Mann-Whitney suggested that there was no statistical differences between the distribution tendencies between Group I and Group II SWS relative to distance from rivers. Both the Kolmogorov-Smirnov test and the Mann-Whitney test computed a p-value of 0.3333 which proved to be not significant

(**Table 14).** Basically the people who constructed the Group I SWS are the same with the people that constructed Group II SWS and there is no evidence of major cultural changes.

	Kolmogorov-Smirnov Test	Mann-Whitney Test
Arable lands Analysis	0.3333	0.3333
River Analysis	0.3333	0.3333
Elevation Analysis	1	0.6667
Nearest Neighbour Analysis	0.3333	0.3333

Table 14. Showing the results of the K-S and the Mann-Whitney tests conducted on SWS.

Elevation Analysis

An analysis of the distribution of SWS in relation to elevation revealed that Group I SWS are located on higher ground as compared to Group II sites. These results are very different to what has been normally accepted as the distribution of SWS in relation to elevation. This is to say that Group II sites are locate on higher ground as compared to Group I sites (Mason, 1968; Taylor, 1979; Boeyens, 2003). Elevation results from this study are similar to Sadr and Rodier's (2012) results where they observed that Group I SWS have a wider range in the research area, the minimum elevation of Group I sites is 1450 which is a bit lower than that of Group II sites (1466). However the median (1638m) and maximum (1871) altitude for Group I sites is higher than Group II sites (1621m) and (1783m) respectively. Statistical tests revealed that even though the probability that these two samples (Group I and Group II SWS) come from two different groups is higher compared to the rivers and arable lands analysis, the results showed there was no significant statistical differences in the distribution tenancies of the two groups (**Table 14**).

Nearest neighbour analysis

A nearest neighbour analysis was applied on the research area to obtain more precise results on the distribution patterns of Group I and Group II SWS. This was done to determine if the SWS in the research area were organised in clusters or if they were dispersed. A comparison of the Observed Mean Distance between results from Pam 1 and the research area shows that in Pam 1 the OMD for Group I sites was higher than (330) than for group II (191) and for the research area the OMD for Group I (502) was also higher than group II (276). This means that there was a longer distance between neighbouring Group I sites in Pam 1 and in the research area while there was a shorter distance between Group II sites. The question now, was to determine if that difference between the distribution of Group I and Group II sites in relation to their nearest neighbour is significant enough to suggest cultural evolution. A Kolmogorov- Smirnov test and a Mann-Whitney test was conducted and both tests generated a p-value of 0.3333 (**Table 14**). A p-value of 0.3333 suggests that the probability of Group I and Group II sites are from two different groups is low at just one third, therefore , the opposite is true, that, Group I and Group II SWS are from the same population.

CHAPTER FIVE
DISCUSSION AND CONCLUSION

Introduction

A comparative analysis of the results generated from the Sadr and Rodier (2012) article and results generated from the research area show that, the same conclusions made by Sadr and Rodier (2012) can be applied to the rest of the research area. Based on the survey and settlement pattern analysis of a 350 sq km focus area within this larger research area, Sadr and Rodier (2012) suggested that in the last 500 years the Late Iron Age SWS here show a sequence of cultural evolution from relatively egalitarian, dispersed, mainly pastoral socio-economic system to a proto-urban, hierarchical and intensively agricultural one just before the colonial era. Sadr and Rodier (2012) analysed distribution patterns of SWS using a combination of analysis which combined the use of arable lands, elevation, average kraal index among other things to establish the distribution tendencies of the SWS in relation to their size, architectural skills and the surrounding environment.

The current research observed that the distribution of Group I and Group II SWS relative to best arable lands was in such a way that Group II were in closer proximity to arable lands than Group I sites. In terms of area coverage, Group II sites occupied more land compared to Group I even though there were many Group I sites. The results from the cluster analysis of study area show that Group I settlements occurred in small dispersed group concurring with Boeyens' (2000) observation that Group I sites are not as clustered as Group II sites. However results from the elevation analysis revealed that Group I sites were not limited to valley floors and flood plains. The results from Pam 1 located southern Gauteng (Sadr and Rodier, 2012) revealed that, Group I sites had the widest range in terms of elevation. Results from the research area also in southern Gauteng showed that Group I sites were located on elevated ground as compared to Group II sites.

Recently, Sadr (2012) through the Klip River Kraals (KRK) project observed that instead of two different groups building the SWS, spatial studies on the distribution of the SWS in the area suggests that the different SWS were constructed by the same group of people. However because of some differences that can be deduced from an exploratory analysis of the data, this cultural evolution is evident in their change in architectural styles, increase area size per SWS, more clustering of SWS, change in perception towards distance to arable lands, rivers and geology. The change in distribution tendencies from Group I to Group II SWS may not be statistically significant but the difference in percentages observed from the exploratory analysis is substantial enough to notice that there was a cultural evolution within the same population.

Discussion

As highlighted earlier on (Chapter 2) cultural ecology is the study of the relationship between human behaviour and ecology (Steward, 1955). Human behaviour can be expressed in settlement patterns which Wiley (1953) defines as a demonstration of how human behaviour is displayed in a given landscape. According to Connah (1987) when studying settlement patterns in prehistoric and historic communities, it is very important to pay attention to the physical environment surrounding the archaeological sites. He explains that emphasis should be given to the soil type, water sources, the geology of the area, vegetation cover, rainfall and temperature characteristics among other things. This research analysed the relationship between SWS in southern Gauteng, South Africa relative to arable lands, geology, rivers and elevation. The research also analysed the relationship between the sites in relation to the location of other sites within the same research area. The results generated from this research demonstrated that there is a correlation between SWS and their surrounding areas. Regardless of minor differences in settlement tendencies in Group I and Group II SWS both groups are relatively located in close proximity to resources such as water and raw materials for example rock outcrops which provided building materials for the construction of SWS and iron which was used for tool manufacturing.

According to Ericson and Balée (2006) historical ecology is the analysis of the complex historical relationship between human beings and the physical environment. Balée (1998) notes that historical ecology is based on the premise that instead of evolutionary events, historical events have shaped relationships between human societies and their surrounding environments. It works under the premise that historical events directly influence biocultural developments (Balée, 1998). Unlike cultural ecology, environmental determinism and cultural materialism which focuses on the adaptation of humans to the physical environment, historical ecology focuses on the interpenetration of culture and the environment rather than the adaptation of human beings to the environment (Balée, 1998). Lindholm et al (2015) concur noting that landscapes are influenced by the complex relationship between human behaviour which include experience, knowledge, and practice of individuals and social groups. Landscapes are spatial and temporal manifestations of these interactions between humans and their environment (Lindholm et al, 2015). According to Ingerson (1994) the relationship between culture and the physical environment is mutual, more of a dialogue than a dichotomy.

In his article, Human Responses and Contributions to Environmental Change in Africa, Sinclair (1997) focuses on the relationship between the physical environment and settlement patterns, environmental changes through space and time and the effects of culture on the environment. He notes that, a fundamental aspect to be considered in spatial analysis studies is the environmental scale. He notes that the environmental scale determines the outcome of different settlement patterns. According to Sinclair (1987) basing on his spatial analysis in Zimbabwe settlement clusters correspond to the macro scale of the environmental units at a macro level, however, this is not the case when dealing with spatio-temporal analysis at a micro-level as the location of settlements are affected directly by the location of the chief's residence or the central authority (Sinclair 1987). This means that when dealing with larger areas possibly with different micro-climates settlement patterns are shaped by the nature of the physical environment. Whereas when dealing with geographically smaller areas settlement patterns are directly influenced by the location of a figure in authority. Due to the nature and amount of data that is required in spatio-temporal analyses there is need to select an adequate methodology to deal with such kind of data. A key methodology is integrated landscape analysis and GIS which allows researchers to test ideas, interpretations and combine experimental and deductive lines of reasoning of the natural sciences with the holistic critical perspective of the humanities and social sciences Lindholm et al (2015). According to Lindholm et al (2015) spatial analysis and modelling in archaeology is not feasible without the use of GIS. However it is also important to compliment results from GIS, remote sensing and spatial statistics with historic evidence, ethnography and physical surveys.

Other models of settlement patterns in southern Africa have been suggested by Huffman (2007) who suggest the Zimbabwe pattern walling and the Central Cattle Pattern (CCP). According to Huffman (2007) the settlement pattern represented by the Zimbabwe pattern walling was influenced more by culture than by the physical environment settlement patterns were influenced by social stratification and the need for ritual seclusion for the sacred leader (Huffman 2007). It is however important to note that environment played a significant role in this cultural consideration because elevated areas were reserved for the elite and low lying areas were reserved for the commoners. This model of settlement pattern is demonstrated at Mapungumbwe, Great Zimbabwe and Khami. Huffman also suggests the CCP were he argues that, stone walled settlement were constructed reflecting the importance of cattle in these communities. This settlement pattern is very common in Mpumalanga Province, where stone walled structures were used to funnel cattle along certain routes and for agricultural terracing (Delius & Schoeman, 2008). Another model which shows the influence of the environment on settlement patterns was suggested by Kritzinger (2010) who suggests that the terraced stone walls located the eastern highlands of Zimbabwe were strongly influenced by the extraction and processing of gold in the area. All these models highlight the importance of the relationship between culture and the environment. It is clear that the relationship as suggested in historical ecology is two way meaning, the culture shapes the environment as much as the environment shapes culture. This model concurs to the results that were generated in this research with specific reference to the southern Gauteng.

These results supports Mason's (1968) observation that SWS were in most cases located on elevated ground and near rock outcrops. From his explanation he hypothesized that SWS were located in areas with high elevation and preferably near rock outcrops. This was supported by the results from the study area which shows that SWS from both groups were generally located on elevated area. However a comparison of the location of Group I and Group II SWS in the research area and other areas suggests a different conclusion. In the research area Group I SWS are located on more elevated areas compared to Group II SWS. Boeyens (2003) notes archaeological evidence suggests that by the 15th century these people lived in small groups in valley floors and plains. However, there was a change in settlement location around the 17th century, from valley floors to hilltop settlements. The results from the study area suggests that the inhabitants initial settled on higher ground and as time went by they settled on lower ground. Boeyens' research in the Northwest province suggests that initially (Group I) settlements were located in low lying areas but eventually moved to higher ground in the 17th century (Boeyens, 2003). Therefore there is need for further research to determine if this variation in settlement tendencies between Group I and Group II SWS in different areas can be traced in other areas or if it is just between Gauteng and the Northwest provinces.

A settlement pattern analysis in the research area revealed changes in the social organisation of the research area between the 15th and 19th century. The results concur with Sadr and Rodier's (2012) conclusion which shows a sequence from more egalitarian and pastoral settlements and social organization in the earliest part of the sequence (Group I) to hierarchical, densely nucleated agricultural towns (Group II). A nearest neighbour analysis of the research area showed that group I sites were not as densely clustered as Group II settlements. Further analysis of the research area indicated that the settlement size also increased in Group II sites compared to Group I sites. It is important to note that the results from the exploratory analysis of the results suggest a significant change in settlement patterns between Group I and Group II SWS. As highlighted earlier on, changes in the clustering of sites and area size per site suggests changes in the social organisation of these communities. These differences as Sadr and Rodier (2012) suggests might be attributed to culture evolution within a particular community as to the introduction of a completely different settlement pattern by a different cultural group. This is supported by the statistical tests of significance conducted on the two samples, Group I and Group II. The statistical tests suggest that these two samples probably originate from the same population. In archaeological terms, this suggest that the changes that occur with the distribution of Group I and Group II are not statistically significant to argue that there were any significant cultural changes which might have resulted from the influence of a different population.

Bevan and Conolly (2006) indicated that, the use of statistics in archaeology enables archaeologists to understand the correlation between sites within a particular settlement (intra-site). The use of statistics also enables archaeologists to understand spatial relationships between two or more settlements (inter-sites). A synthesis of the results from the environmental parameters under investigation revealed that Group I SWS were generally located in areas with lower agricultural potential and on higher ground with a more rugged terrain. Most of them were located close to rock out crops and rich iron deposits and were generally located close to rivers. This description suggests a community that was more oriented towards herding compared to extensive agricultural activities. Areas with lower agricultural potential provided better grazing lands for their animals. Studies by different scholars (Mason, 1968; Maggs, 1976; Taylor, 1979) suggests that Group I inhabitants focused more on cattle compared to smaller livestock. Group II settlements were located in close proximity to arable lands and on lower ground with a more gentle terrain. They were located closer to rivers and rock outcrops and potential iron deposits. However, It is important to note that as much as the exploratory analysis indicate changes in the settlement traits of the two groups, statistical analysis indicate that there was no statistically significant changes between these two groups. This means that, there were changes in the settlement patterns between Group I and Group II communities but these changes are not statistically significant enough to conclude that these two settlements traits were produced by two different cultural groups. Instead a combination of the exploratory analysis and the statistical analysis points out to a possibility of these structures being constructed by the same group of people (the Tswana) as early as the 15^{th} century. However with time there was change in ideology within these same people such that they started to appreciate accumulation of wealth, become more agriculturally oriented and observed social stratification.

Conclusion

The main aim of the research was to conduct locational analyses on the Group I and Group II ruins in the entire study area which is just under $9000km^2$ to test the conclusions reached by Sadr and Rodier (2012) in their smaller sample. This was achieved through a series of objectives which started with mapping the spatial distribution of a host of relevant physical environmental as well as modern cultural features (such as best arable soils, urban developments which might affect distribution of ruins, etc.) in the southern Gauteng. Modern cultural features refers to all infrastructural and land developments in the contemporary society. The second step was to map the distribution of all Group I and Group II SWS in the study area. The third step was to analyse the nature and the extent of the relationship between the distribution of SWS and the physical environmental and modern cultural features. The fourth step was to conduct appropriate statistical tests to determine the significance of any relationships observed in the third objective. The last step was to test Sadr and Rodier's (2012) conclusions by comparing settlement patterns of Group I and Group II SWS from across the entire study area to their sample.

Based on the results generated from the study using both an exploratory analysis and a statistical analysis the results that were obtained from the study area concur with the results from Sadr and Rodier (2012). Basing on a 350 sq km area, Sadr and Rodier (2012) concluded that the SWS in Pam 1 show a sequence of cultural evolution from relatively egalitarian, dispersed, mainly pastoral socio-economic system to a proto-urban, hierarchical and intensively agricultural one just before the colonial era. The distribution of Group I and Group II SWS in the research area in relation to physical parameters such as arable lands, altitude, distance from rivers, and geology and cultural parameters like nearest neighbour analysis and hierarchical rankings based on the size of the SWS revealed the same pattern of cultural evolution. It is important to conduct future research which focuses on a statistical analysis of data from Pam 1 and also a comparison of the distribution patterns to a randomly generated series of points and perhaps compare the results to other SWS settlement patterns in South Africa.

Limitations and challenges.

The research was carried out using data from two phases (based on architectural styles) of SWS, Groups I and II. Sadr (2016) explains the issue of inter-analyst variability in the classification of SWS and suggest that one can achieve reliable results by using the intersection of the classification by two different analysts. Using this approach, Group I and II SWS have been thinned to reduce inter-analyst variability. The sample was created by two analysts, K and S who used an intersection of three views (aerial photographs, google earth imagery and Lidar imagery) to establish the k & t sample (Sadr 2016).The three-way classification test for Group III SWS has not yet been carried out and they are left out of my study. This is not a problem as Groups I and II define the extremes of the continuum in settlement patterns from egalitarian, pastoral and dispersed to proto-urban, hierarchic and agricultural, as described by Sadr and Rodier (2012). Group III is the transitional phase. Another limitation to this research is the inability to conduct physical surveys of the research area to validate some of the statistical findings. It therefore creates opportunities for future research to conduct physical surveys and ground truthing of the research area to validate some of the statistical findings of the research.

I used the modern environment as proxy for past environments. There was certainly considerable climate change over the last 500 years with the Little Ice Age peaking around AD 1700 (e.g., Woodborne et al. 2015). However, it is assumed that the physical parameters of geology, soil, hydrology and terrain have remained stable over this time frame. This implies that using modern environments as a proxy for past environment will not be much of a problem. Another limitation to the study is the fact that some analyses especially the ones that included distance did not account for changes in elevation. With this in mind there was need to develop a mobility cost surface which would calculate the shortest distance to resources which required the least energy. However because of limited time, this could become a potential focus area for future research and could help us understand better how societies interacted and exploited elevation.

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http://support.esri.com/en/knowledgebase/GISDictionary/browse/k

https://sites.google.com/site/southerngautengsws/home

http://www.agis.agric.za/agisweb/agis.html

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http://edndoc.esri.com/arcobjects/9.2/net/shared/geoprocessing/spatial_statistics_tools/average_nearest_neighbor_spatial_statistics_.htm

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http://www.esri.com/news/arcnews/spring06articles/protecting-archaeological.html

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http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/hillshade-function.htm

http://support.esri.com/other-resources/gis-dictionary/term/hillshading

APPENDIX

Author	**Settlement type**	**Characteristics of classification (architecture)**	**Climate and vegetation**	**Landscape**
Maggs 1976	Type V	-Primary enclosures are grouped in a ring. -Can be linked together by a secondary wall. -Free standing huts around the periphery built of stone. -Corbelled stone huts present but not diagnostic. -Just like type V, primary enclosures are grouped. -However different in the sense that each settlement unit is surrounded by a wall. -Detached huts made of reeds and grass occurs between the secondary wall and the central structures.	-Rainfall 600-800mm. -Grassveld Cymbopogon – Themeda,	-1450-2000m (above sea level). -Favour spurs and isolated hills. - Did not consider aspect. -Clusters around rivers and watersheds. -Prefer areas with marked relief e.g

	Type N	-large number of primary enclosures in globular clusters. -Unitary pattern within these structures but poorly developed. -Primary enclosues are large and are located in the center. -Smaller primary enclosures located on the periphery. -central enclosures range from 21-70m in diameter and the smaller ones are 14m.	-Rainfall 200-800mm. -Highveld grass Cymbogon-themeda.	valleys and hill tops.
	Type Z		-Rainfall 550-600mm relatively dry.	-Lower relief, flat uplands gentle slopes.

				-avoided river banks.
	Type R		-Drier climate. -400mm rainfall. -Drought incidents. -Sweet grass veld and Karoo. -Higher temperatures.	-Notes that settlements are geographically and environmental different from the other groups -Landscape is flat studded with rocky dolerite hills. -Roughly located 3km from rivers
Taylor (1979)	Group I	-Comprised of a wall elliptical in shape which surrounded a group of smaller primary walls in the centre.	-Taylor gives a general background on the climatic and vegetation characteristics of all the SWS irrespective of	-Located on quartzite hills. -Located on high terrain. -Northerly aspect.

			their classification. - He explains that the area has light sandy soils that promote the growth of Acacia Karoo, Acacia Caffra and Protea Caffra. -Rainfall is generally between 570-650mm. -Winter frost can be sever but summer temperatures can reach 30 degrees.	
	Group II	-the secondary was discontinuous in nature and was made from a series of semi-circles that faced the primary enclosures.		-Located below 1500m (above sea level).
	Group III	-A cluster of smaller primary enclosures which have secondary wall of different lengths and shapes to mark their limits.		Located below 1450m (above sea level). -Associated with large alluvial deposits.

				- located on the foot scarp of north east facing slopes (aspect).

Table 15. Showing summaries of Maggs' (1976) and Taylor's (1979) classification of SWS with architectural, climatic, vegetation and landscape characteristics.

Input data	Data layer	Source
Geology	Simplified geology	AGIS (Agricultural Geo-Referenced Information System).
Soils	-Structurally favourable soils -General soils -Water holding capacity	AGIS.
Land use	-Infrastructural developments i.e. buildings and farms	GCRO (Gauteng City-Region Observatory).
Arable Lands	-Best arable lands -Semi Arable lands	GCRO
Terrain/Elevation	-DEM	Consortium for Spatial Information (CGIAR; CSI) but originally sourced from NASA'S Shuttle Radar Topographic mission (SRTM)
SWS	-Group I -Group II	SGSWS database (sample from intersecting polygons)

Table 16.Showing the input data which was used in the research and the sources they were acquired from.

Category	**Shapefile name**	**Source**	**Time period of content**	**Scale**	**Data type and Format**	**Data projection**
Geology	Simplified geology	AGIS	1997	1cm:149 km	Vector digital data and shapefile	Geographic
Land Use	Transport network Land Use	GCRO GCRO	2016 2013	1cm:149 km 1cm:149 km	Vector digital data and shapefile	Geographic
Hydrology	-Rivers -Tertiary catchment areas	AGIS AGIS	1998 unknown	1:500000 1:50 000	Vector digital data and shapefile SDE Feature Class	Geographic

Arable Lands	Best arable lands. Semi-arable lands	AGIS	1997	1cm:149km	Vector digital data and shapefile	Geographic
Elevation	DEM	CSI	2015	90M	Rasta digital data	Geographic

Table 17. Showing the maps obtained from AGIS and GCRO.

	2km buffer	5km buffer	K-S test	Mann-Whitney test
Group I	318	554	1	0.667
Group II	166	283		

	Within Arable lands	2km buffer	K-S test	Mann-Whitney test
Group I	58	318	0.3333	0.3333
Group II	23	166		

	Within Arable lands	5km buffer	K-S test	Mann-Whitney test
Group I	58	554	0.3333	0.3333
Group II	23	283		

Table 18. Showing the statistical results of the K-S test and the Mann-Whitney test on arable lands.

Rivers analysis

	Within 2km from rivers	Within 5km from rivers	K-S test	Mann-Whitney test
Group I	214	589	0.3333	0.3333
Group II	67	263		

	Within 2km from rivers %	Within 5km from rivers %	K-S test	Mann-Whitney test
Group I	30	83	0.3333	0.3333
Group II	22	88		

Table 19. Showing the statistical results of the K-S test and the Mann- Whitney test on rivers analysis

	Above 1600m	Below 1600m	K-S test	Mann-Whitney test
Group I	528	175	0.3333	0.3333
Group II	186	122		

	1600m	1500m	K-S test	Mann-Whitney
Group I	387	187	1	0.6667
Group II	119	116		

Table 20. Showing the statistical results of the K-S test and the Mann- Whitney test relative to elevation

	Nearest neighbour index	z-scores	K-S Test	Mann-Whitney test
Group I	0.255665707	-37.78561198	0.3333	0.3333
Group II	0.136867161	-28.50471184		

Table 21. showing the statistical results of the K-S test and the Mann-Whitney test relative to nearest neighbour analysis.