

https://dspace.org/

Locating the rock art of the Maloti-Drakensberg: identifying areas of higher likelihood using remote sensing

Pugin, James Malcolm

2016

http://hdl.handle.net/10539/21686

Pugin, James Malcolm (2016) Locating the rock art of the Maloti-Drakensberg: identifying areas of higher likelihood using remote sensing, University of Witwatersrand, Johannesburg, <http://wiredspace.wits.ac.za/handle/10539/21686>

Downloaded from a DSpace repository. https://dspace.org/

Locating the rock art of the Maloti-Drakensberg:

Identifying areas of higher likelihood using Remote Sensing

A Dissertation submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science

James Pugin

374962

Johannesburg, February 2016

Supervisors: Dr Sam Challis and Dr Clement Adjorlolo



Declaration

I hereby declare that this is dissertation is my own, original work, except where otherwise acknowledged. It is being submitted for the degree MSc to the University of the Witwatersrand, Johannesburg. I have not submitted it previously, for the purpose of obtaining any degree, qualification at this, or any other, university.



15 / August / 2016

James Pugin Date

Acknowledgements

Usually acknowledgements given to supervisors are to recognise their continuous and unwavering support throughout the research, however, in this case it does not suffice. Both Dr Sam Challis and Dr Clement Adjorlolo were always readily available to assist with any queries and problems encountered throughout this research, for your help I am truly grateful.

To Nicoletta Maraschin, your assistance, support and motivation throughout this research has been a constant force that has enabled me to continue when at times I thought I would never finish. Thank you for everything, I would not be here if were not for you.

Furthermore this research would not have been possible if it were not for the generous funding provided by the National Research Fund (Innovation Masters and Doctoral Scholarships for 2013-14) and the Archaeological Society of South Africa (ArcSoc Student Equipment Grant).

To the Ministry of Tourism, Environment and Culture of the Kingdom of Lesotho for affording this research an opportunity to test its effectiveness.

To the Mehloding Community Trust, the researchers are grateful for access into this amazing area to conduct this research.

To those that assisted with the arduous task of proof reading your help is much appreciated:

Nicoletta Maraschin
Dr Barbara Duigan
Michael Cadmen
Alison Zeelie

To all that assisted with surveying and recording sites under the auspices of the MARA programme in Matatiele and Sehlabathebe:

Puseletso Lecheko
Joseph Ralimpe
Rethabile Mokhachane
Hugo Pinto
Dr Sam Challis
Mncedisi Siteleki
Ntabiseng Mokeona
Lineo Mothopeng
Dr Mark McGranaghan
Pulane Nthunya
Andrew Pugin
Alice Mullen

To all at the University of the Witwatersrand that assisted with guidance and offered support:

Prof Karim Sadr	Dr Elhadi Adam	Dr Rachel King
Prof Fethi Ahmed	Dr Cornelia Kleinitz	Azizo de Fonseca
Prof Stefan Grab	Dr Stefania Merlo	Dr Barend Erasmus
Janista Daya	Dr Mark McGranaghan	

To all those at SANSA that assisted me with obtaining and processing data for this research:

Dr Clement Adjorlolo	Dr Jane Olwoch
Nosiseko Mashiyi	Nomnikelo Bongoza

Abstract

This dissertation examines the role of remote sensing on rock art survey and is motivated by two key objectives: to determine if remote sensing has any value to rock art survey, furthermore if remote sensing is successful to determine if these individual remote sensing components can contribute to a predictive (site locating) model for rock art survey. Previous research effectively applied remote sensing techniques to alternate environmental studies which could be replicated in such a study. The successful application of google earth imagery to rock art survey (Pugin 2012) demonstrated the potential for a more expansive automated procedure and this dissertation looks to build on that success. The key objectives were tested using three different research areas to determine remote sensing potential across different terrain.

Owing to the nature of the study, the initial predictions were formulated using the MARA database – a database of known rock art sites in the surrounds of Matatiele, Eastern Cape – and were then applied to surrounding areas to expand this database further. Upon adding more sites to this database, the predictions were applied to Sehlabathebe National Park, Lesotho and then 31 rock art sites in the areas adjacent to Underberg. The findings of this research support the use of predictive models provided that the predictive model is formulated and tested using a substantial dataset. In conclusion, remote sensing is capable of contributing to rock art surveys and to the production of successful predictive models for rock art survey or alternate archaeological procedures focusing on specific environmental features.

Table of Contents

Declaration ii

Acknowledgements iii

Abstract v

Table of Contents vi

List of Figures x

List of Tables xi

List of Photos xii

List of Equations xii

List of Rock Art Sites xii

Glossary xiii

Chapter 1: Introduction 1

1.1 Rock Art Survey Past and Present 1

1.2 The Study Area and MARA Research Area 3

1.3 Rock Art Deterioration, a motivating factor for predictive modelling 4

1.4 Remote Sensing applications to rock art research 7

1.5 Aims and Objectives 9

1.6 Chapter Breakdown 10

Chapter 2: Background and History of Matatiele and Sehlabathebe 12

2.1 Research Area 12

2.2 Climatic Conditions 15

2.3 Geological Formations 17

2.3.1 Drakensberg Basalt Formation 17

2.3.2 Clarens Sandstone Formation or Cave Sandstone Stage 18

2.3.3 Molteno Formation 18

2.3.4 Elliot Formation or Red Beds Stage 19

2.3.5 Burgersdorp Formation 19

2.4 Vegetation of the research areas 19

2.5 Elevation Sub Regions 20

2.6 The History of the Area 21

2.7 The Archaeology of the Matatiele Region 23

2.8 Rock Art Research to date in the Matatiele Region 25
2.9 Brief History, Archaeology and Rock Art Research of Sehlabathebe 26
2.9.1 Archaeological research 27
2.9.2 History of Sehlabathebe 28
Chapter 3: Literature review 29
3.1 Rock Art Surveying 29
3.1.1 Hunter Gatherer Rock Art Site Selection 31
3.1.2 Rock Art and Environmental Determinism 36
3.1.3 Other Applicable Biases 36
3.2 Literature Supporting Methodology 37
3.2.1 Introduction 37
3.2.2 Case studies implementing similar techniques 38
Chapter 4: Methods 60
4.1 Introduction 60
4.2 Data Acquisition 60
4.3 Processes 63
4.4 Components used for predictive modelling 64
4.4.1 Normalized Vegetation Difference Index 65
4.4.2 MARA database and Site Record Sheets 66
4.4.3 Hill/Relief Shading 67
4.4.4 Slope 67
4.4.5 Predictive Modelling 68
4.4.6 Applying Predictive Models to Alternate Areas 69
4.4.7 Weightings 70
4.5 How the models were applied? 75
4.6 Comments on the initial models 76
4.7 Fieldwork 77
4.8 Conclusion 78
Chapter 5: Results 79
5.1 The Individual Thresholds 80
5.1.1 MARA Database 80
5.1.2 Slope 80
5.1.3 Shaded Relief 82
5.1.4 NDVI 83
5.1.5 Aspect 85

5.2 The Predictive Model based on MARA 2012 dataset 86
5.3 Predictive model vs SNP 95
5.3.1 Slope 99
5.3.2 Shaded Relief 100
5.3.3 NDVI 100
5.3.4 Aspect 100
5.4 Predictive model vs random SARADA Rock Art Sites 101
5.5 Conclusion 106
Chapter 6: Discussion 107
6.1 Components that were tested but excluded 107
6.1.1 Aspect 107
6.1.2 Supervised and Unsupervised Classification 108
6.1.3 Geological Map 108
6.2 The different predictive models 108
6.2.1 MARA Models 109
6.2.2 SNP Models 111
6.2.3 Test Models 112
6.3 Was the research a success? 113
6.4 What the results mean 114
6.5 Limitations 115
6.5.1 Data resolution 115
6.5.2 Site characteristics 115
6.5.3 Remote Sensing Thresholds 115
6.5.4 Site Database 116
6.6 How can the results be improved? 116
6.7 Were the aims achieved? 117
6.8 Recommendations for future research 117
6.9 Remote sensing components and exclusions 118
Chapter 7: Conclusion 119
7.1 Achievement of aims 119
7.1.1 Test methods/components that had been effectively applied elsewhere 119
7.1.2 Test whether predictive models had any value to rock art surveys 120
7.2 Implications to rock art research 121
7.3 Future Work 122

Chapter 8: References 123

Chapter 9: Appendix 138

9.1 Tables 138

9.2 Data Used 152

9.3 Figures 153

9.4 Site List 172

9.5 Site usage 173

9.5.1 Aspect 173

9.5.2 Environmental Determinism 173

9.6 Case Studies 174

9.6.1 Phuting Valley Case Study 175

9.6.2 Mofoqoi Valley Case Study 175

9.7 Predictive Modelling Process 176

9.8 Rock Art Sites 177

List of Figures

Figure 1.1: MARA survey tracks with known site locations, showing the extent of the unsurveyed region. 5
Figure 2.1: Locating map of both research areas. 14
Figure 2.2: Suspected site locations in the areas surrounding Matatiele (Derricourt 1976, see also van Riet Lowe 1956; Vinnicombe 1976)..... 24
Figure 3.1: Image taken from Smits (1983: 62) depicting the ARAL survey areas. Research areas include Phutiatsana (top), Qhoqhoane (left), Sebapala (bottom), Sehlabathebe (right). 33
Figure 4.1: Methodological Process..... 62
Figure 5.1: Model Output 1 with near equal value weightings and individual remote sensing components background data negated, white background reflects areas with null values..... 87
Figure 5.2: Model output 2 with doubled slope thresholds and individual remote sensing components background data negated, showing so called 'blanket coverage', white background reflects areas with null values. 89
Figure 5.3: Model Output 3 with the 1.5x threshold for slope, individual remote sensing components background data negated, white background reflects areas with null values..... 91
Figure 5.4: Model Output 7 with expanded slope and NDVI thresholds, white background reflects areas with null values..... 92
Figure 5.5: SNP Model Output 1, white background reflects areas with null values. 96
Figure 5.6: SNP Model Output 2, white background reflects areas with null values. 97
Figure 5.7: SNP Model Output 3. 98
Figure 5.8: Further test 1, white background reflects areas with null values. 103
Figure 5.9: Further test 2, white background reflects areas with null values. 104
Figure 5.10: Further test 3..... 105
Figure 9.1: MARA survey tracks, areas without tracks depict areas where tracks were overwritten. 153
Figure 9.2: Painted Relief for the Alfred Nzo and Joe Gqabi Districts with MARA Sites as of 2012. 154
Figure 9.3: Slope slice for the Alfred Nzo and Joe Gqabi Districts, white background reflects areas with null values. 155
Figure 9.4: 150% extension of the slope slice, white background reflects areas with null values. Large white area depicts the alluvium as discussed earlier..... 156
Figure 9.5: MARA shaded relief, white background reflects areas with null values. 157
Figure 9.6: MARA NDVI, white background reflects areas with null values. 158
Figure 9.7: MARA NDVI with thresholds expanded by 150%, white background reflects areas with null values. 159
Figure 9.8: MARA aspect slice, derived from SRTM, white background reflects areas with null values..... 160
Figure 9.9: Model Output 4, white background reflects areas with null values..... 161
Figure 9.10: Model Output 5, white background reflects areas with null values..... 162
Figure 9.11: Model Output 6, white background reflects areas with null values..... 163
Figure 9.12: Model Output 8, white background reflects areas with null values..... 164
Figure 9.13: Model Output 9..... 165

Figure 9.14: Slope slice for the Alfred Nzo and Joe Gqabi Districts, white background reflects areas with null values. *166*
Figure 9.15: 150% extension of the slope slice, white background reflects areas with null values. Large white area depicts the alluvial plain discussed earlier. *167*
Figure 9.16: MARA shaded relief, white background reflects areas with null values. *168*
Figure 9.17: MARA NDVI, white background reflects areas with null values. *169*
Figure 9.18: MARA NDVI with thresholds expanded by 150%, white background reflects areas with null values. *170*
Figure 9.19: MARA aspect slice, derived from SRTM, white background reflects areas with null values. Red and purple depicts areas that are preferential based on the mean aspect. *171*

List of Tables

Table 3.1: Geological breakdown for sites located by ARAL (Smits 1983: 68-69) *32*
Table 3.2: Exposure for sites located by ARAL (Smits 1983: 69) *33*
Table 3.3: Location/Feature types for sites located by ARAL (Smits 1983: 70) *34*
Table 3.4: Aspects of Sites located by ARAL (Smits 1983: 70) *34*
Table 4.1: Geological Breakdown for MARA Rock Art sites *71*
Table 4.2: Breakdown of slope for MARA sites *72*
Table 4.3: Breakdown of MARA sites against Aspect *73*
Table 4.4: Breakdown of MARA sites against NDVI *74*
Table 4.5: Breakdown of MARA database against shaded relief *75*
Table 5.1: Slope values for the MARA research areas. *81*
Table 5.2: Shaded relief values for the MARA research areas. *83*
Table 5.3: NDVI values for the MARA research areas. *84*
Table 5.4: Aspect values for the MARA research areas. *85*
Table 5.5: Breakdown of the initial output models. *94*
Table 5.6: Comparison of test models *101*
Table 9.1: SNP Database *138*
Table 9.2: MARA Database *144*
Table 9.3: List of known sites in the surrounding areas of Matatiele. Abbreviations included for Natal Museum Records (NMR), East London Museum Records (ELMR), Archaeological Data Recording Centre (ADRC), and Van Riet Lowe (VRL) *172*

List of Photos

Photo 1.1: Displaying the severity of the terrain with Three Sisters Mountains in the background Photo: James Pugin 2013. ..... *2*
Photo 1.2: Image of Kinira Poort 3 showing the extent of paint removed to date. Photo: Dr Sam Challis 2010 ..... *6*
Photo 1.3: Image of Phepela 1 showing extensive paint removal. Photo: Puseletso Lecheko 2014 ..... *7*
Photo 2.1: James Pugin recording of site E01, Sehlabathebe National Park. Photo: Dr Sam Challis 2015 .. *28*
Photo 5.1: Image showing nature of terrain northeast of the old lodge, Sehlabathebe. Photo: James Pugin 2015..... *99*
Photo 7.1: An example of sudden drop that is unlikely to be present in poorer resolution data. Photo: Dr Sam Challis 2012..... *121*

List of Equations

Equation 4.1 Calculation for the threshold maximum *65*
Equation 4.2: Calculation for the threshold minimum *65*
Equation 4.3: Formula to calculate NDVI (Campbell 2008, Lasaponara and Masini 2012: 27) *66*

List of Rock Art Sites

Rock Art Site 1: Dipaki 2 ..... *177*
Rock Art Site 2: Ha Phiri 1..... *178*
Rock Art Site 3: Hekeng Ya Tshepe 1 ..... *179*
Rock Art Site 4: Malithethana Source 6 ..... *180*
Rock Art Site 5: Mambhele 1..... *181*
Rock Art Site 6: Phuting 5 ..... *182*
Rock Art Site 7: Phuting 6 ..... *183*
Rock Art Site 8: Phuting 8 ..... *184*
Rock Art Site 9: Phuting 11 ..... *185*
Rock Art Site 10: Phuting 15 ..... *186*

Glossary

A.D.: *Anno Domine*
ARAL: Analysis of Rock Art in Lesotho Project
ARCGIS: Aeronautical Reconnaissance Coverage Geographic Information System
ASAPA: Association of Southern African Professional Archaeologists
ASTER: Advanced Spaceborne Thermal Emission and Reflection
c.: *circa* – approximate date, around
COMRASA: Conservation and Management of Rock Art Sites in Southern Africa
DEM: Digital Elevation Model
DTM: Digital Terrain Model
ENVI: Environment for Visualizing Images
ERDAS: Earth Resources Data Analysis System
EROS: Earth Resource Observation Services
ETM: Enhanced Thematic Mapper
GIS: Geographical Information System
GMTED: Global Multi Resolution Terrain Elevation Data
IR: Infrared
ISODATA Iterative Self Organizing Data
km: Kilometres
LAMAP: Locally Adaptive Model Of Archaeological Potential
Landsat ERTS: Earth Resource Technology Satellite
MYA: Million Years Ago
MAP Maximum A Prior Probability
MARA: Matatiele Archaeology and Rock Art
m: metres
MK: *Umkhonto we Sizwe*
ML: Maximum Likelihood
NDVI: Normalized Difference Vegetation Index
NIR: Near Infrared
R: Red
RARI: Rock Art Research Institute
SANSA: South African National Space Agency
SARADA: South Africa Rock Art Digital Archive
SNP: Sehlabathebe National Park
SPOT: Satellite Pour l'Observation de la Terre
SRTM: Shuttle Radar Topography Mission
UKZN: University of KwaZulu Natal
UNESCO: United Nations Educational Scientific and Cultural Organisation
WOE: Weight of evidence

Chapter 1: Introduction

1.1 Rock Art Survey Past and Present

Most archaeologists and rock art researchers are required to survey as part of their research, nevertheless, the majority neglect to publish their methodological processes along with their findings. A limited number of researchers have contributed to South African rock art survey methodology (Mazel 1982, 1984: 348; Challis & Laue 2003; see also Smits 1983; Pugin 2012). Furthermore, there has been very little published on the topic internationally. Even research handbooks are noticeably quiet on the subject (e.g. Whitley 2005).

The Maloti-Drakensberg form the south eastern part of the greater Drakensberg Mountain range which is located on and constitutes the border between South Africa and Lesotho. This vast mountain range is discussed further in Chapter 2: 12.

Large sections of the better-known regions of the Maloti-Drakensberg have been surveyed, piecemeal, by researchers over the years such as Maggs (1967), Smits (1971, 1983), Lewis-Williams (1972), Vinnicombe (1976), Parkington (1979), Mazel (1983), Blundell (2004), Challis (2008) and Pearce (2002). Large tracts remain un-surveyed, however, and Challis (2008: 55) describes the Matatiele area as poorly documented and in need of a systematic survey between the towns of Qacha's Nek and Mount Fletcher.

Aspects of this unsurveyed region have been researched in recent years under the auspices of the MARA[1] (Matatiele Archaeology Rock Art) programme (Challis 2008; Pugin 2012; Regensberg 2012), but there is still much to do. The MARA survey has surveyed this region since its establishment in 2011 (Challis 2011). Rock art surveying will be discussed in greater detail in subsequent chapters.

Surveying areas of the Maloti-Drakensberg (Photo 1.1: 2) is a time-consuming task (Pugin 2012), owing particularly to the steep and mountainous terrain and the vast areas that require searching when conducting a survey in a systematic manner.

[1] www.marasurvey.com



Photo 1.1: Displaying the severity of the terrain with Three Sisters Mountains in the background Photo: James Pugin 2013.

Previous inquiry found that there is limited recorded methodology describing how to survey and locate rock art sites (Pugin 2012). The records to date showing explicit survey methods are limited to Mazel (1983) and a COMRASA report (Challis & Laue 2003). With such limited written accounts on how to survey, any methodological developments that will aid in reducing this knowledge gap are vital. Describing the survey methods used by the MARA programme, and then developing techniques for their improvement can be seen as the two primary contributions of this research project.

This research project looked into different experimental methods that could enable the recognition of regions likely to contain rock art sites based on environmental characteristics observed at previously discovered rock art sites. The remote sensing predictive model described in this thesis is the result of a combination of key factors that, among others, were tested and found most relevant: slope, NDVI (Normalized Difference Vegetation Index) and shaded relief. As we shall see, the specifics of selecting the appropriate components, and

testing them in a variety of landscapes, form the main body of this text. Subsequent to the completion of this research a similar predictive model was found to be successful in the locating of sandstone outcrops in India (Banerjee & Srivastava 2014).

1.2 The Study Area and MARA Research Area

The Matatiele region falls into the Alfred Nzo District and is adjacent to the Joe Gqabi district to the southwest. The Transkei region was proclaimed as a homeland or 'Bantustan' during the Apartheid regime (Mauder 1982: 573; Douek 2013: 207). Related histories provide insight into why this area was neglected by researchers. However, this does not explain the lack of research attention succeeding the decline of the Apartheid era.

The MARA survey is aimed at redressing the lack of historical record in the Matatiele region (Challis 2011). The project set out by Challis initiated a systematic survey of the region, which to date has discovered more than 200 previously unknown archaeological sites. Since the MARA survey has had limited time, and funds, to achieve its aims, the methods outlined in this dissertation will assist in achieving this goal.

The research area for this project extends from the Qacha's Nek Border Post towards the Ongeluks Nek Border Post, which falls within the MARA survey area. Figure 1.1: 5 shows the research area set out by the MARA survey together with the sites that had been located by the MARA survey. Figure 1.1: 5 also illustrates the current extent of the MARA survey tracks prior to the commencing of this research project. Despite the MARA successes, a substantial amount of surveying is still required between the Qacha's Nek border post and Mount Fletcher in order to establish the presence of other sites. Due to the unsurveyed areas surrounding Matatiele, there are concerns about the condition of possible rock art sites because many sites located to date are in close proximity to local villages[2].

During the writing of this thesis, the opportunity arose to test the model in Lesotho's Sehlabathebe National Park (SNP) as part of the UNESCO (United Nations Educational Scientific and Cultural Organisation) World Heritage Survey. The survey was required to map out the park for rock art site locations. This then considerably expanded the dataset by

[2] Throughout this research when referring to potential rock art sites, the following are grouped into one label: shelters, overhangs, kranslines, and boulders

introducing a new site database and survey data for a separate area to the initial model that could be used for testing purposes.

The final aspect of the research presented in this thesis tests the output models against a further 31 rock art sites in the surrounding areas of Sehlabathebe which include some areas above and below the escarpment.

1.3 Rock Art Deterioration, a motivating factor for predictive modelling

Rock art deteriorates due to many different factors, some of which are natural such as flaking, exfoliation, water seepage; others are anthropogenic, like vandalism, graffiti, fires and damage caused by the kraaling of domestic animals (Ward 1996; Meiklejohn *et al.* 2009). Limiting the damage to the rock art is dependent on identifying the forces that are damaging the rock art. The concern related to the rock art in the MARA survey area is locating the sites in order to record and then identify the possible threats to the rock art in an expedient manner.

The deterioration of rock art sites is discussed in great depth by Ward (1996) and Meiklejohn *et al.* (2009). Ward used historical sketches by Taylor from 1896 to try and assess the deterioration of rock art in the Giants Castle Game Reserve. One of the initial causes of degradation in the 1890s was vandalism and it is seen to be a recurring trend (Ward 1996). Ward discussed four types of deterioration that she found and they seem to be common trends in rock art studies to date. These deterioration types include the exfoliation of the rock face, fading of the paintings, complete deterioration of the art and finally vandalism. Meiklejohn *et al.* (2009) support the claims of Ward (1996) and go on to discuss how rock art is being damaged by both natural and anthropogenic forces.

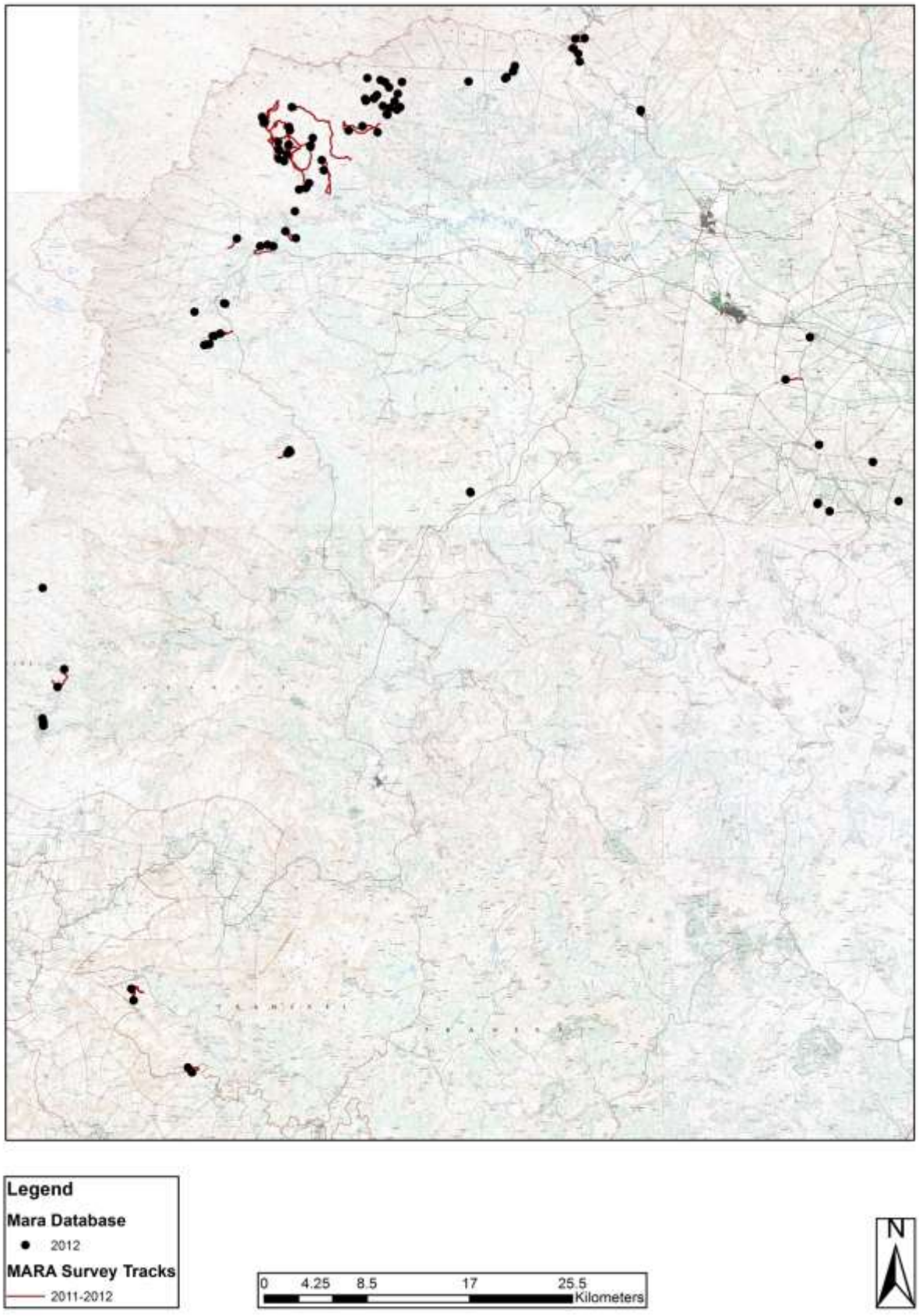


Figure 1.1: MARA survey tracks with known site locations, showing the extent of the unsurveyed region.



Photo 1.2: Image of Kinira Poort 3 showing the extent of paint removed to date. Photo: Dr Sam Challis 2010

Listing the forces of deterioration is relevant because similar trends have been documented by Challis and displayed by Regensberg (2013). Although the records of the paintings span about five years, the damage to the sites is still significant enough to be noticeable. In the case of the rock art in the MARA survey area, it is been observed that this damage is mostly due to anthropogenic forces such as vandalism and graffiti (James Pugin 2013 *pers. obs.*). One key factor that affects the rock art which may not be termed as vandalism is the removal of paint for the use in the preparation of traditional medicines and may represent one of the last remaining links between current occupants of the land and their San ancestors (Regensberg 2013; Dr Sam Challis 2013 *pers. comm.*). Limiting the effect of anthropogenic forces relies on education about the rock art and its historical cultural importance. The MARA survey has since used community involvement to promote a sense of ownership and heritage management in an attempt to limit the damage to the rock art (Mokoena 2015).

Consideration of the threats to the rock art of the MARA survey region was the main contributor towards the use of expedited methods of surveying.



Photo 1.3: Image of Phepela 1 showing extensive paint removal. Photo: MARA, Puseletso Lecheko 2014

1.4 Remote Sensing applications to rock art research

Testing the applicability of remote sensing methods in rock art surveying, if successful, will provide a method for identifying areas that are most likely for rock art to occur. Remote sensing provides the researcher with accurate tools to determine areas of interest. Current research methods lack this aspect and would benefit from such an approach.

This research, if successful or not, is necessary because it will determine whether remote sensing techniques are a viable method for locating rock art sites. The success of the model will either encourage further research into the applications of remote sensing to rock art

surveys or guide further research in a different direction. A model that incorporates geology, terrain modelling, with all other aspects that are relevant to rock art survey should contribute to the improvement of archaeology and rock art surveying techniques.

Previous studies have revealed that GIS (Geographic Information Systems) and RS (Remote Sensing) are applicable tools for rock art research (Russell 2012: 37; Pugin 2012). The research method employed by Pugin (2012) involved an analysis of aerial photographs and utilised Google Earth in an attempt to visually identify possible sandstone rock feature locations (i.e. shelters, boulders, and cliff faces/kranslines) in the hope that these features may contain rock art sites (Pugin 2012: 19). The advantage of this method is the ability to remotely locate rock features of relevance for rock art sites on a larger scale than previous methods like Google Earth. Pugin (2012), however, barely scratched the surface of a complex process. The limitation of the technique used in the 2012 method was the lack of capacity to use three-dimensional images to locate these rock features. The two-dimensional aerial photographs and Google Earth imagery lacked the vertical depth/dimension that are seen in a three-dimensional representation. The problem with trying to identify rock features on a two-dimensional image is that some features appear flat when they are in fact three-dimensional (Pugin 2012: 12).

At the very least, previous research (Pugin 2012) revealed the potential for a basic remote sensing process to be used for rock art surveys. The use of Google Earth imagery and aerial photographs showed that areas of interest for rock shelters could be identified remotely. Although it was stated that satellite imagery was not used owing to its cost and lack of resolution, with the availability of new satellite imagery it has become feasible to test whether remote sensing procedures can aid in locating rock art shelters.

There is a need for a method or model that can identify areas likely to contain sites, thereby reducing the time spent surveying unlikely areas. Remote sensing was seen as a possible method that could assist with discovering the rock art of the Alfred Nzo district quickly. The remote sensing approach accounts for different landscape conditions and then provides an output map showing the areas that have the potential for containing rock art. This thesis set out to test the effectiveness of remote sensing-based surveys by identifying the sandstone rock features that are likely to contain rock art. It does not ‘find’ rock art sites by itself, rather it puts the researcher in areas more likely to contain rock art.

The remote sensing method incorporates vegetation analysis and DEM (Digital Elevation Model) by-products such as relief shading analysis, slope and aspect to derive a predictive model for locating rock art sites.

The use of specific remote sensing methods aids in identifying site-specific attributes and allow for future identifications of such features. Remote sensing will aid in identifying the features that are synonymous with rock shelters and related features that are known to contain rock art sites. Therefore, as long as these diagnostic features are replicated elsewhere in the world this method is effective at locating rock shelters not just in the Matatiele Drakensberg, or the Maloti-Drakensberg in general but, conceivably in any similar setting. A secondary application of this method is to check whether other known site locations correspond to the features identified. Finally, the method can also be used to check supposed areas that have been extensively surveyed to see if there were any sites that were not found in the areas of most potential.

1.5 Aims and Objectives

It is important to note that this research, as much as trying to locate the rock art of the Maloti-Drakensberg, is in actual fact aimed at identifying the likely environmental conditions where these sites occur. Potential site locations are rock features such as rock shelters, overhangs, boulders, and cliff faces/kranslines. The model is judged on its effectiveness at locating these geomorphological features not the presence of rock art. The placement of rock images is a human choice and this exercise does not attempt to model for the human agency. Therefore, any viable surface that is considered a potential site will be recorded as well as any rock art sites encountered.

The remote sensing method analyses NDVI (Normalized Vegetation Difference Index), geology, shaded relief, slope and aspect as well as other applicable procedures. The combined effect of these processes tests the effectiveness of remote sensing based surveys by identifying the sandstone rock features that are most likely to contain the locations that house the rock art. These processes look to emphasise and reinforce an aspect already known to many rock art researchers, which is that rock art occurs in mountainous regions that have outcropping sandstone or other rock faces that provide shelter, with a suitable canvas for rock art.

Remote sensing identifies such outcrops and puts researchers in survey areas with the greatest potential. The objective of the research was to test whether the application of spectral and three-dimensional remote sensing methods could enhance the identification of areas that may contain rock art and then identify the likely locations for rock art sites to occur within these areas. This research tests whether remote sensing is applicable in identifying features of relevance for rock art site locations: that is, the shelters and boulders themselves. Remote sensing methods were applied in conjunction with field surveys and was utilised in two areas to test their effectiveness and tested against a computer database for another area.

A breakdown of the remote sensing based processes that were applied includes a number of techniques that identify specific features of the landscape that are to be associated with the presence of rock art, namely analysing NDVI, slope, shaded relief and lastly aspect against the known site locations of the MARA database (Table 9.2: 144).

Some processes did not produce the desired result and were therefore discarded. Furthermore, this research assesses the credibility of the different environmental characteristics and determines which of these has the biggest impact on the location of areas that contain rock art (i.e. boulders, shelters, overhangs, cliffs).

There are numerous methods of modelling that are considered and these are discussed in the latter sections of this research (3.2.2.6: 44). Modelling for rock art is different to other predictive models due to the nature of where rock art sites are found. Most predictive models are reliant on replicating specific conditions of known site characteristics that vary from site to site whereas, in the case of a rock art specific model, these sites are found in somewhat more consistent locations. These sites are specifically found in sandstone formations because of the nature of features found within these geological formations, however, the other characteristics are more varied.

1.6 Chapter Breakdown

Chapter 1 outlines the motivation and importance of this research. The objectives, limitations and rationale are described in regards to how this research can benefit rock art research and assist in more rapid discovery of previously unrecorded heritage sites.

The justification as to why the research is necessary for this area is explained further (1.3: 4). By assessing the history of the MARA and SNP research areas. Assessing the history of the Alfred Nzo and Joe Gqabi districts, it is possible to understand why this research area was neglected for large parts of the 20th century. The chapter also focuses on Sehlabathebe by providing a brief outline of the area in terms of archaeology, vegetation, geology, and history.

By assessing the available literature in Chapter 3: 29, methods that have been applied successfully in other research areas are discussed with relevance to how this research can be applied effectively. The methods discussed here provide the groundwork on how to set out the remote sensing components for the modelling procedure to be effective.

The application of remote sensing methods discussed in Chapter 3 is further developed in Chapter 4: 60 with regard to how they will be implemented and what these methods contribute towards creating a predictive model. This chapter sets out to explain this research so that it can be replicated in future.

The results of the different processes and the predictive model, Chapter 5: 79, look at the overall success of the predictive model and then focus in on the individual remote sensing outputs compared to the different test areas. This dataset is then expanded to include the newly discovered sites and the thresholds determined from the collective MARA database will be used to model the areas of likelihood within Sehlabathebe National Park.

A discussion in Chapter 6: 107 reviews the model's success and discusses how it can be improved with relevance to how the results were calculated, how they may contribute towards future modelling parameters and, whilst noting limitations experienced throughout the research, how these were overcome. The discussion focuses on key archaeological topics such as environmental determinism, seasonal site usage and site preference.

Finally, Chapter 7: 119 draws conclusions about how the model performed in regard to its results, how it may be improved in the future, what implications it may have for rock art research and whether or not it is an acceptable tool to complement or advise rock art survey.

Chapter 2: Background and History of Matatiele and Sehlabathebe

As the research takes place within South Africa and Lesotho, the background chapter will first assess and describe the conditions of the landscape of South Africa and then turn its focus to the Sehlabathebe National Park, Lesotho. While the predictive model used the data from the Matatiele area to identify the thresholds of the different characteristics, it is important to make the reader aware of how the landscape differs between the two research areas. A further aspect to note is that the geological formations are the same for Sehlabathebe as Matatiele, as well as a few of the vegetation groups. These similarities in vegetation and geology should improve the success of a model based on environmental features.

2.1 Research Area

This thesis is concerned with the un-surveyed areas of the former Transkei Maloti-Drakensberg Mountains of the Eastern Cape[3] (Displayed previously in Figure 1.1: 5). The Drakensberg Mountains have been surveyed piecemeal, with certain areas receiving more research attention than others. This region (or parts of it) have at times been referred to as Nomansland, East Griqualand, and from 1976 to 1994, the Transkei. The area is now referred to as the Eastern Cape Province, and subdivisions are known as districts. The region encompassing the Alfred Nzo and Joe Gqabi districts cover most of the mountainous geology that contains rock shelters in this academically neglected region (Challis 2008: 305). Challis (2008) identified the region between Qacha's Nek and the town of Mount Fletcher because it had not been systematically surveyed and was in an area that possibly had a high rock art density. It is here that the MARA programme has set up its parameters for survey (MARA 2011). Because of the large size of this research area identified by Challis (2008), the area from Qacha's Nek towards Ongeluks Nek was identified as a more suitable target survey sample area.

The MARA survey was started in 2011 to redress the history of the misunderstood former 'Transkei' and to document the archaeology of the region (Challis 2011). The aim of the MARA survey is to locate as much archaeology as possible (especially rock art because it is exposed) which will enable it to be conserved and understood. Since the MARA survey

[3] Also known as the Ukhahlamba Drakensberg in Kwa-Zulu Natal (Wright & Mazel 2007, 2012)

has limited time to achieve its aims, the methods of this dissertation will assist in achieving this goal.

Subsequent to the commencement of the systematic survey, the MARA survey had surveyed a substantial portion of its research area in an attempt to document the archaeology of the region. To date, track logs show that surveyors have covered at least 500 km[4]. However, despite the MARA successes, a large amount of surveying is still required between the Qacha's Nek border post and Mount Fletcher in order to establish the presence of other sites. Figure 9.1: 153 shows the research area set out by the MARA survey and displays the sites that have been located and the current extent of the MARA survey tracks.

[4] This is the total distance of the survey tracks combined.

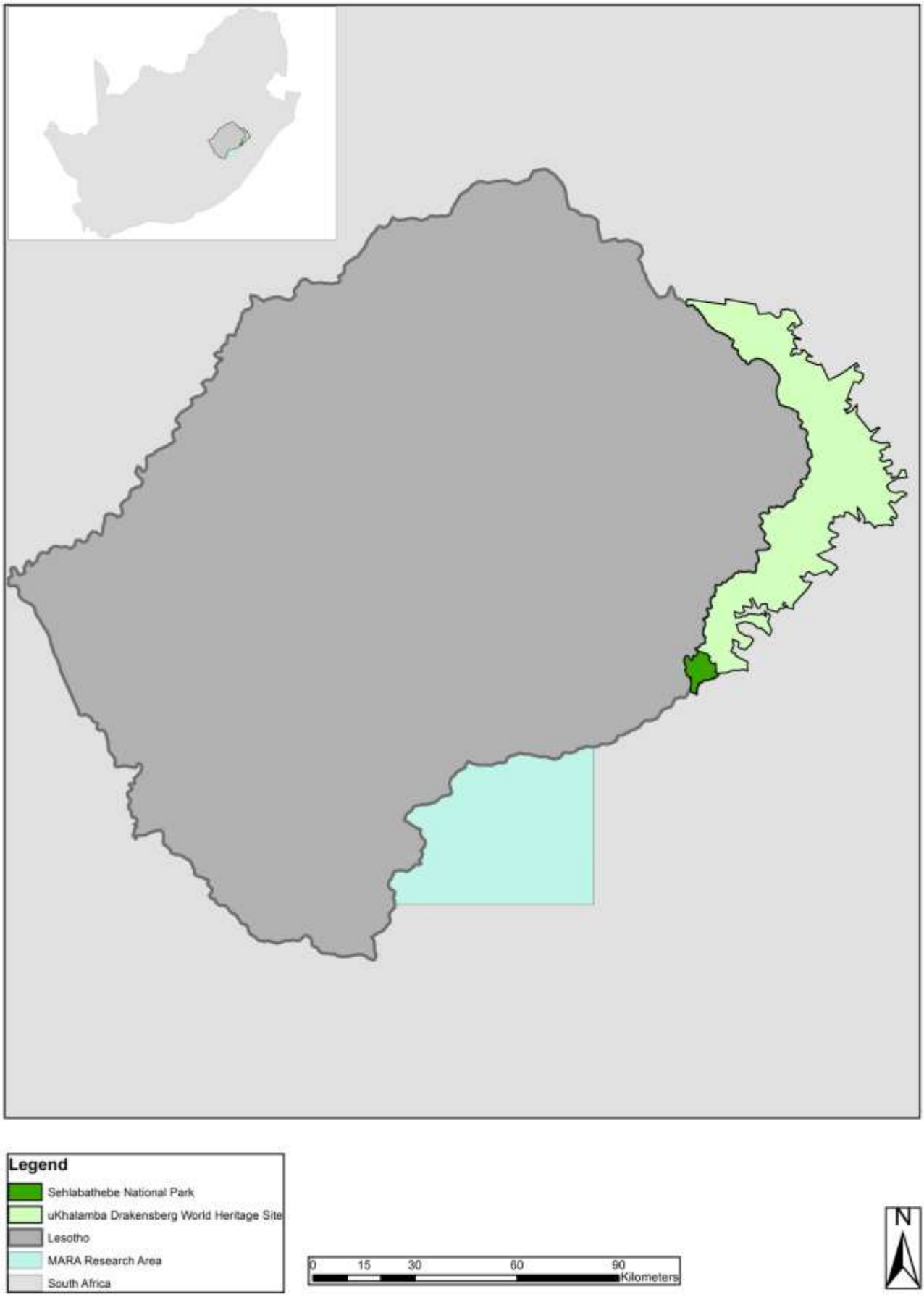


Figure 2.1: Locating map of both research areas.

2.2 Climatic Conditions

The Maloti-Drakensberg mountain range has the largest influence on the climate of Lesotho, south Natal and the north Eastern Cape and acts as a climatic divide, which splits the east and west of Southern Africa.

Roe (2005: 646) describes the effect a mountain range can have on rainfall in the mid-latitudes as follows “The classic picture of orographic rainfall is of a mountain range in the mid-latitudes whose axis lies perpendicular to the prevailing wind direction. In the climatological average, the windward flank of the mountain range receives much more precipitation than the leeward flank, resulting in the well-known rain shadow that is reflected in sharp transitions in climate, flora, and fauna across the divide.”

The Maloti-Drakensberg acts as a drainage divide, which causes areas on the leeward side of the mountains (Lesotho above the escarpment) to fall into the rain shadow, and the windward side (Eastern Cape below the escarpment) to receive more rainfall. The precipitation is due to relief/orographic rainfall (Roe 2005), whereby warm moist air is forced up the leeward side of the mountain by the prevailing wind and the air column is cooled, which in turn results in condensation and precipitation (Tyson *et al.* 1976; Smith *et al*. 2003; Tyson & Preston-Whyte 2004; Roe 2005: 656). An additional feature that contributes to the difference in temperature is the difference in altitude between the coastal regions and the Highveld interior.

The Maloti-Drakensberg mountains are unsurprisingly identified as having a mountain climate, i.e. having lower temperatures than surrounding areas of lower altitude (Van Zyl 2003: 50). The area is synonymous with winter, and occasional summer, snowfall at higher altitudes. The region relies on heavy thunderstorms for the summer rainfall (Van Zyl 2003). The major determinant affecting the climate and weather of the Drakensberg region is the effect of altitude which impacts directly on the temperature and rainfall patterns. Rainfall generally occurs in two forms; deluges and drizzle (Irwin *et al.* 1980: 49). The weather can be unpredictable in the summer months as conditions can worsen in a short period of time.

Winter conditions in the Maloti-Drakensberg are generally dry and have predominant westerly winds that can exceed 60kmph. The area benefits from a high-pressure system when there are clear skies. However, the appearance of Cirrus clouds is a good indicator for inclement weather which is associated with frontal systems moving across southern

Africa. The poor weather conditions are often associated with precipitation and snow fall which occurs between 6 and 12 times a year (Irwin *et al.* 1980: 49) although farmers in the Matatiele district also rely on the infrequent snowfalls to water the soil for crops.

The topological difference between the two areas of Matatiele and Qacha's Nek is as follows: Qacha's Nek is situated on a pass of the Maloti-Drakensberg at an altitude of 1950m. This is compared to the town of Matatiele which is situated below the escarpment at an altitude of approximately 1460m above sea level. Van Zyl (2003) shows how areas at higher altitudes have lower temperatures than surrounding areas at lower altitudes. This trend can be identified by consideration of the temperature data for the region of Matatiele and comparing the towns of Qacha's Nek and Matatiele (Tyson *et al*. 1976: 35).

The temperature and precipitation for both Matatiele and Qacha's Nek are described by Tyson *et al.* (1976). The towns of Qacha's Nek and Matatiele are separated by 27 kilometres yet differentiated by 500 metres in altitude and show a difference in rainfall of 242 mm. The two areas have been portrayed in graphs where similar trends are depicted (Tyson *et al*. 1976: 35). The daily average temperature at Qacha's Nek for summer is 18^0C and decreases to 10^0C in the winter months, whereas Matatiele has a daily average temperature of 22^0C in summer and 12^0C in winter (Tyson *et al*. 1976: 35). The two areas have similar climatic conditions because of their proximity. The main observable differences are that can be seen is the Qacha's Nek weather station is situated on the escarpment, which shows lower temperature averages and increased annual rainfall.

Although Van Zyl (2003) describes the effect that altitude has on temperature, there is a similar effect with regard to the precipitation. The Qacha's Nek area receives a higher amount of annual rainfall (928mm) and has a higher number of days with precipitation (97 days). The Matatiele area, however, receives a lower yearly total (686 mm) of rain and has fewer days of precipitation (78 days). By comparing the monthly rainfall, the Qacha's Nek area receives more rainfall in the summer months (928mm compared with 686mm) (Tyson *et al*. 1976: 54). Therefore, the higher area of Qacha's Nek receives more rainfall compared to Matatiele due to orographic rainfall. However, the Lesotho District of Qacha's Nek, immediately behind the escarpment and encompassing Sehlabathebe, falls within the Drakensberg rain shadow.

Both areas receive annual snowfall but the records are limited to newspaper articles. The Maloti-Drakensberg has on average 8 days with snow (Tyson *et al*. 1976: 60). Resident Ntate Puseletso Lecheko has reported that there has been at least one snowfall in recent years about 1m deep in the Machekong village at an altitude of 1630m above sea level (Puseletso Lecheko *pers. comm.* 2012).

2.3 Geological Formations

The geology of the Matatiele and the Maloti-Drakensberg falls into what is commonly known as the Karoo System/Supergroup, which covers much of Lesotho and the surrounding areas. As mentioned earlier, much of the geology of the two research areas are identical. The Stormberg series exists as a component of the Karoo system and is comprised of the following geological groups Clarens (Cave) Sandstone Formation, the Molteno or Red Beds Formation and Elliot Formation (Hamilton & Cooke 1960; Visser 1989; Johnson *et al.* 2006). The layers are listed based on the order in which they appear from the areas of higher altitude to the lower altitudes. This geological sequence is capped with the extensive Drakensberg Basalt sheets (Haughton 1969). The Cave sandstone band of the Lower Jurassic period has been eroded into numerous rock shelters which provided the ideal canvas for rock paintings (Du Toit 1966). The layer that is of most interest with regard to rock art and archaeological research is the Clarens Formation or Cave sandstone band.

2.3.1 Drakensberg Basalt Formation

The Drakensberg Basalt Formation covers most Lesotho and the surrounding highland areas (Haughton 1969: 154) and was formed approximately ±187 MYA, during the Early Jurassic (Visser 1989: 155). The Drakensberg Basaltic Formation was formed by stacked lava flows, fissure eruptions, and volcanic lava that comprise the upper part of the Maloti-Drakensberg escarpment. This layer is also known as the Drakensberg Volcanic stage (Visser 1989: 154). This upper portion forms the border between Lesotho, the South African provinces of the Eastern Cape and KwaZulu-Natal. This layer is dark grey to black and once weathered appears brown to purple (Haughton 1969: 154). The basalt caps the Sandstone in many places and erodes slowly, which prevents the breakdown of the sandstone layers below (Hamilton & Cooke 1960: 368). Shelters containing rock art have been found in

basaltic formations but only within Lesotho, around the Mokhotlong area (Pinto 2014). So far no such shelters have been seen in the basalt on the escarpment and, therefore, this geology was excluded from the model.

2.3.2 Clarens Sandstone Formation or Cave Sandstone Stage

The Clarens Formation was formed predominantly by fine-grained Aeolian sand during the Late Triassic/Early Jurassic (Visser 1989: 153; Johnson *et al.* 2006: 482). This layer is uniform and consists of white, cream or pinkish coloured sandstones (Visser 1989: 154). In parts, basalt is incorporated into the layers because of the increase in volcanic activity during its creation (Hamilton & Cooke 1960: 368). The Clarens Sandstone layer was initially referred to as the cave sandstone stage and is known for the weathered overhangs and caves, which are known to contain San rock art (Hamilton & Cooke 1960: 265).

The rock overhangs of the Clarens sandstone Formation of the Maloti-Drakensberg were once inhabited by the San, in a similar fashion to the way in which the current Basotho herd boys use the shelters today (Vinnicombe 1976: 2). The majority of paintings occur in the yellow sandstone of the Clarens/Cave sandstone Formation, with a few found on Clarens Sandstone boulders or rocks (Irwin *et al.* 1980: 43).

2.3.3 Molteno Formation

The Late Triassic Molteno Formation encircles Lesotho and is comprised of medium to coarse-grained sandstones and grey mudstones, shales and infrequent conglomerates (Beukes 1969: 366; Visser 1989: 151). The sandstones and mudstones present in the Molteno Formation may contain glittering quartz particles (Haughton 1969: 365). The layer also contains sandy shale that weathers (Visser 1989: 151). This layer has some rock art sites present.

2.3.4 Elliot Formation or Red Beds Stage

The Elliot Formation was formed during the Late Triassic and is comprised of mudrock and fine to medium grained sandstones, red to purple shales. The Elliot is a further sandstone Formation known for containing rock art sites. The felspathic sandstones exist in yellow or white with red mudstones (Hamilton & Cooke 1960). The Elliot formation is typically caused by flash flood depositions and the sandstones are due to the deposition of fine sheet sand (Visser 1989: 152).

2.3.5 Burgersdorp Formation

The Burgersdorp Formation exists below the Molteno Formation in the geological strata but as part of the Beaufort group. The formation exists mainly with sandstones occurring in red and maroon, whilst interspersed with grey-white sandstones (Schlüter 2008: 140).

2.4 Vegetation of the research areas

In a similar manner to the geology, certain vegetation groups are present within both research areas. The vegetation groups that are present will be discussed briefly to show the similarities between the two research areas.

Owing to the diverse characteristics of the rock art sites encountered to date, vegetation was seen as a possible indicator of where rock art sites may occur. Due to the relationship that exists between NDVI and the rock art sites of the MARA database, it is important to list the different vegetation types in the instance that there is a higher correlation to one such vegetation subgroup. Vegetation is described in detail because of the correlation with the NDVI. By defining the different vegetation groups within this study it is therefore possible to determine correlations with these smaller vegetation units.

Cowling *et al.* (2004) note that there are extensive grasslands located throughout the Maloti-Drakensberg Mountains. Both research areas fall into the broader grassland biome and contain different subgroups of this biome (Mucina & Rutherford 2004). The vegetation units included the following: Southern Drakensberg Highland Grassland, Drakensberg Foothill

Moist Grassland, Lesotho Highland Basalt Grassland, Lesotho Mires, Eastern Temperate Freshwater Wetlands, Southern Mistbelt Forest, Mabela Sandy Grassland, East Griqualand Grassland, Drakensberg Wetlands, and Drakensberg Afroalpine Heathland (Mucina & Rutherford 2004).

The Matatiele region appears in the grassland biome. The vegetation units are the Southern Drakensberg Highland Grassland and the Drakensberg Foothill Moist Grassland (Mucina & Rutherford 2004: 366, 423).

The prominent grasses found within the subalpine belt are the *Themeda triandra* and the *Festuca* species of grasses. The *Themeda triandra* occurs throughout the subalpine belt, whereas, the *Festuca* appears in the upper portion of the belt (Killick 1963; Irwin *et al.* 1980: 77-80). The specific bioregions are described further by Mucina and Rutherford (2006).

2.5 Elevation Sub Regions

There are varying accounts as to the exact names of regions based on elevation. Three regions have been identified by Bester (1998) namely: the Alpine belt (>2850m above sea level), the Sub-alpine belt (1830-2850m above sea level) and the Montane belt (1280-1850m above sea level).

Conversely, Irwin *et al.* (1980) describe the Montane regions as everything exceeding 2000m and classify areas below 2000m as highland to sub-montane. The sub-montane region is recognised as having forest, sub-forest, grasslands with proteas and riverine scrub, whilst the montane region has a variety of Drakensberg fynbos, and stunted forest (Irwin *et al.* 1980: 47).

The shrub species listed by Bester (1998: 6) occurring in the sub-alpine belt includes: *Cliffortia linearifolia, Leucosidia sericea, Buddleja salviflora.* However, the Montane grasses include the: *Themeda triandra, Hyparrhenia, Miscantidum-Cymbopogon.*

The presence of two invasive Australian Wattle species (*Acacia mearnsii* and *Acacia dealbata*) has been identified within the research area (de Neergaard *et al.* 2005). The researchers were able to identify that these invasive Wattle species have grown in coverage in two aerial photographs of Madlangala since 1953. It was identified that the Wattle

coverage increased in the two plots from 7% to 48% and 20% to 58% (de Neergaard *et al.* 2005: 216, 230).

A further study completed by Poona and Shezi (2010) assessed invasive alien plants across KwaZulu-Natal. Poona and Shezi (2010) employed plant mapping methods using SPOT 5 multispectral imagery with both supervised and unsupervised classifications. This research identified that using the Maximum Likelihood and Mahalanobis classification algorithms were the most successful in identifying and delineating areas covered by these plants.

Identifying the coverage of Wattle species is relevant to rock art research as these species have increased in coverage since the 20th century. Rock art sites can easily be concealed by Wattle forests. These species are seen to flourish in areas where rock art exists (Pugin 2012: 21). Therefore, in many cases, it is pertinent to identify areas that have Wattle species as areas that require surveying.

2.6 The History of the Area

Owing to the space constraints and focus of this project, a brief overview of the history of the area is provided.

Hunter-gatherers have occupied the Maloti-Drakensberg for the last 100 000 years and are known to be have been home to the San hunter-gatherers (Wright & Mazel 2007: 1). Approximately 8 000 years ago, groups of hunter-gatherers started living in the Maloti-Drakensberg Mountains for longer periods of time. These hunter-gatherers are believed to be the ancestors of the San people (Wright & Mazel 2012: 6). An absence of hunter-gather presence in the Drakensberg has been noted later than 25 000 years ago (Wright & Mazel 2007: 29, 2012).

Using this analysis (Wright & Mazel 2007: 25), the last glacial maximum provides a reason for the absence of hunter-gatherers during the period between 25 000 to 10 000 years ago. During the glacial maximum, temperatures are believed to have been 5ºC colder than current day temperatures. There is a presence of hunter-gatherers across Lesotho for this time period in shelters such as Sehonghong cave, Lesotho (Wright & Mazel 2007: 25; Carter *et al.* 1988; Mitchell 1996).

The San hunter-gatherers existed for millennia without interaction from outsiders until the emergence of pastoralists and arrival of agriculturalist groups. The San are believed to have had interactions with Khoekheon pastoralists around 300 AD in the southern and western Cape (Schweitzer & Scott 1973: 547; Vinnicombe 1976: 9). In the last 1 000 years, the emergence of African Iron Age farmers is noted (Vinnicombe 1976; Mazel 1989, 1993, 1997; Mitchell 1996: 22, 2002: 294). Early Iron Age farmers populated the shoreline and hinterland of the south-eastern Cape in the firth millennium AD (Feely 1987) However, it is noted that the arrival of the Iron Age farmers, most notably the Cape Nguni and Sotho in the Matatiele regions of the Maloti-Drakensberg, occurred at approximately 1800 AD (Huffman 1996: 55; Mitchell 2009: 18; Regensberg 2011: 4), after political instability and an inability for crops such as millet and sorghum, to possibly grow in the area.

Wright and Mazel (2012) have noted that the San hunter-gatherers moved into the Thukela basin for increased interactions with farming communities (Mazel 1996a *cf;* Mazel 1996b *cf*). Around 700 years ago, groups of African farmers started settling at the base of the foothills of the Maloti-Drakensberg (Wright & Mazel 2007: 23). Eventually, the farmers encroached into the higher lying grasslands the San were forced to retreat further into the mountains (Thorpe 1997; Wright & Mazel 2012: 27). By the 19th century, the San were confined to the mountainous regions of the Maloti-Drakensberg.

During the mid-19th century, the European colonists started taking control of the area. White farmers gradually hunted out most of the game that the San subsisted on, which in turn forced the San communities to raid the farmers' cattle. The San cattle raids continued as a form of subsistence until the colonial powers declared all such activities illegal – essentially reducing the San to the status of vermin. Upon this declaration, hunting parties were set up to exterminate the San people residing in the Maloti-Drakensberg. San communities existed until the close of the 19th century. By the 1890s, San communities, through expansion of neighbouring groups, had ceased to exist. Many of the San were exterminated, however, many were incorporated or absorbed into other cultural groups (Mitchell 1996: 22, 2009: 18-9; Mazel 2007: 119; Challis 2008: 4; Mitchell *et al. 2008*: 5).

2.7 The Archaeology of the Matatiele Region

Until recently, the archaeology of the Matatiele area has not received sufficient research attention. There have been few archaeological studies that were undertaken in the area (Farnden 1966; Derricourt 1977; Feely 1987; Challis, 2008, 2009, 2012; Pugin 2012; Regensberg 2012). Accounting for this research, there is still a substantial amount of surveying required in the area to locate more undocumented rock art, and archaeological, sites. Accounts by Vinnicombe (1976) and Derricourt (1977) provide details of some site locations in the East Griqualand area. The site lists (tables. 2 & 3) of Derricourt (1977: 253-258) include numerous sites that the MARA survey has been able to locate and record. However, the survey will cover these areas timeously as the systematic survey continues.

Derricourt (1977) listed the sites that form part of his research area in the Transkei and Ciskei of which he included 42 sites that are within the MARA survey area, the sites listed are largely based on Van Riet Lowe's (1956) archaeological survey. However, Derricourt's site list has six sites that were documented and Pigeon Rocks was the only site to have been excavated (Derricourt 1977). The extent of the Derricourt sites (Figure 2.2: 24) shows the likely distribution of rock art sites across the Matatiele area.

With this expansive area displaying potential for high site density, there is a definite need for research. The presence of sites outside of areas described by Derricourt indicates a possible high density for rock art to occur throughout the region (Derricourt 1976: 257-258).

The lack of documented sites shows the knowledge gap that prevails in the Matatiele region, whereby sites are known to be in the vicinity of named farms instead of exact locations. Subsequent to recent consultation with Derricourt, it was uncovered that he had limited knowledge of the exact site locations for most of the sites listed in the Matatiele area. The sites in the area of which he was aware, are based on locations provided by others. Vinnicombe (1976) and Carter both have listed some site locations in the area of Matatiele which are listed in the appendices (Table 9.3: 172)

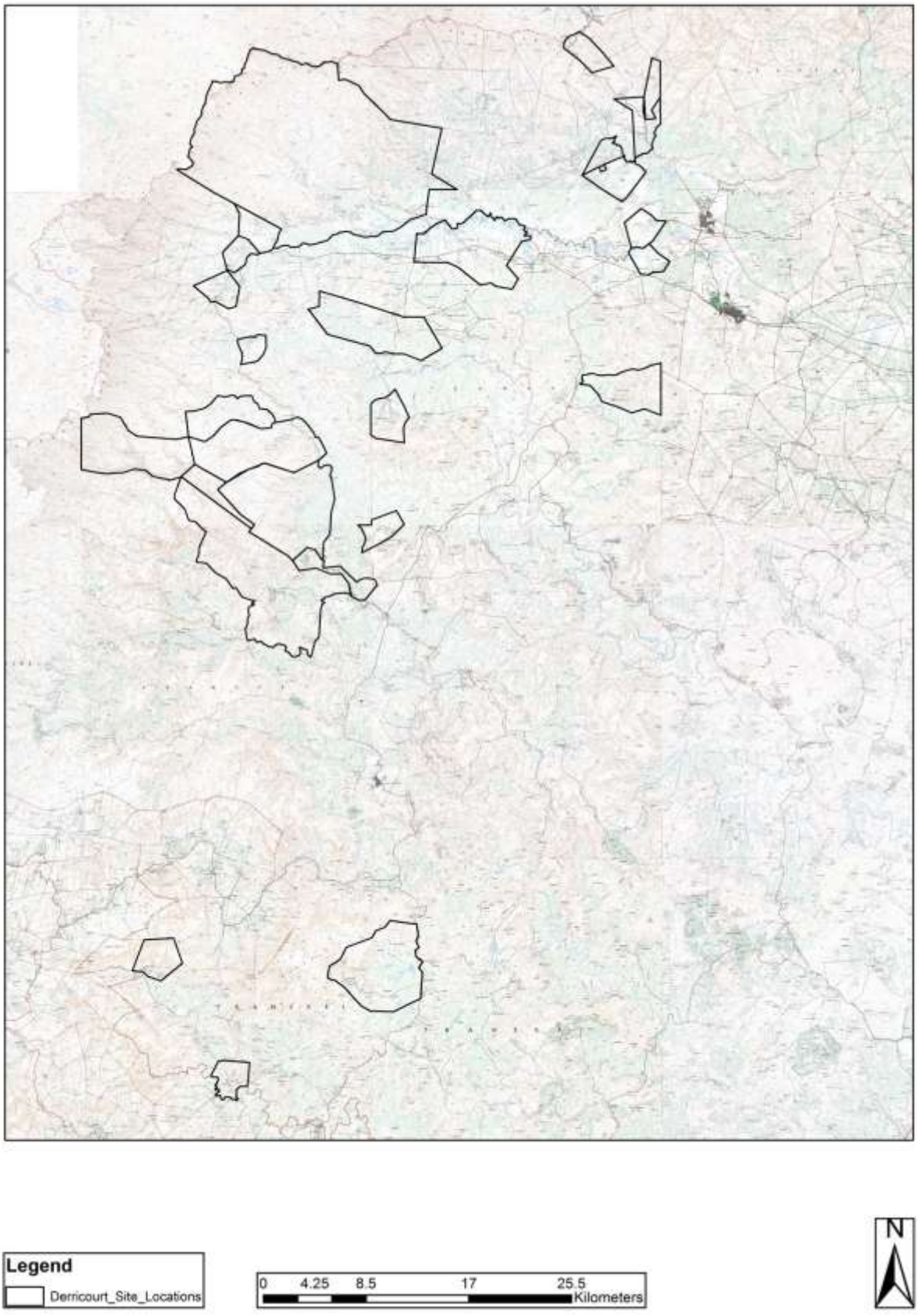


Figure 2.2: Suspected site locations in the areas surrounding Matatiele (Derricourt 1976, see also van Riet Lowe 1956; Vinnicombe 1976)

2.8 Rock Art Research to date in the Matatiele Region

Rock art from the greater Matatiele area has been included sporadically in numerous publications (Batiss 1948; Willcox 1956; 1963: 32-33; Malan 1955; Cook 1969; Vinnicombe 1976; Derricourt 1977), however, there was little research prior to the involvement of the MARA survey. Patricia Vinnicombe visited a number of sites[5] in the surrounds of Matatiele, some of which are included in the *People of the Eland* (Vinnicombe 1976). Further research was limited to Patricia Vinnicombe's tracing of the New Amalfi Rock Shelter (Farnden 1966) and the recordings of around 42 possible site locations (Table 9.3: 172) in the MARA survey area, of which only the Pigeon Rocks site was excavated (Derricourt 1977: 257). Subsequent to the MARA survey, there has been unpublished honours research completed by Regensberg (2012) and Pugin (2012), and the MARA excavation results are forthcoming (Pinto *et al.* in prep).

The MARA survey has completed two excavations in the Matatiele region where the first excavation occurred at the Mafusing 1 shelter and the second excavation at Gladstone 1 shelter. The excavation at Mafusing was used to understand the social narrative of the rock shelter (Regensberg 2012). The comparison of the rock art and the material culture from the excavation of the Mafusing rock shelter contributed towards the construction of this social narrative. Regensberg (2012) was able to relate the different stratigraphic layers to different occupation periods where hunter-gatherers and farming communities had utilised the rock shelter (Regensburg 2012: 49).

The second research component of the MARA survey was the completion of an honours dissertation (Pugin 2012). Pugin (2012) employed the use of a Google Earth-based survey to identify areas with possible rock art sites (Pugin 2012). The researcher focused on identifying areas with exposed Clarens Sandstone features in Google Earth/Aerial Photographs and then digitised these likely points for future surveys. These digitised points were then surveyed to see if the method was effective at identifying possible rock art site locations. One remit of this research was not to look for rock art, but rather to look for areas that had site types that corresponded with known rock art sites such as rock shelters, overhangs, kranslines and boulders. It must also be noted that the research was at no stage

[5] Site list in appendix

looking for the rock art, instead looking to identify geomorphological features that had a possibility of containing rock art.

The method proved successful because it identified areas where rock art sites existed, however, in many cases there were points that didn't contain any rock art sites (Pugin 2012). The research identified areas with rock shelters, overhangs, kranslines and boulders that could contain rock art sites in the vicinity to these digitised points. The method analysed shaded areas in the imagery to see if there was a link to possible rock shelters. The method proved successful in identifying areas of interest for containing possible rock art sites. This was a success insofar as it was more concerned with locating likely features that resembled rock art sites (i.e. rock shelters, boulder and kranslines). In the process these results allowed for user-based discrimination of survey areas, thereby allowing the researcher to choose areas based on potential and exclude improbable areas.

The method was effective in placing the researcher in the place within the field and provided a reasonable chance of locating rock art. However, this research had its drawbacks, namely the time-consuming nature of processing aerial photographs in order to identify areas that could be of interest. Secondly, the inability to process multiple areas at a time slowed the procedure down. A further drawback experienced was linked to the use of Google Earth imagery, which in some cases areas appear as though they are flat when in fact these areas are steep and had some large overhangs.

2.9 Brief History, Archaeology and Rock Art Research of Sehlabathebe

Owing to the space constraints and focus of this project, a brief overview of the history of the area and archaeology is given. Importantly, the recent UNESCO survey conducted by members of the MARA team has added significantly to the data for the Sehlabathebe National Park (Challis *et al.* 2015)

2.9.1 Archaeological research

Archaeological research throughout Lesotho was limited prior to gaining independence in 1996 (Mitchell 1992: 3-34). Prior to this research was limited to Carter (1969, 1978; Carter *et al.* 1988), Vinnicombe (1976), Smits (1983), Mitchell (1995, 1996, Mitchell & Plug 2008), and Arthur (*cf* Mitchell 2009).

Research that has been undertaken in the vicinity to the Sehlabathebe includes Carters' excavation of Ha Moshebi and Ha Soloja, and the initial survey of Sehlabathebe National park by Lucas Smits in the late 1970s and early 1980s (Smits 1983). The ARAL (Analysis of Rock Art in Lesotho Project) record compiled by Smits consisted of field notes and photographs which are curated by the Rock Art Research Institute at the University of the Witwatersrand.

2.9.1.1 UNESCO World Heritage Survey 2015

Subsequent to the inclusion of Sehlabathebe National Park into the Ukhahlamba Drakensberg World Heritage Site, a baseline survey of the park was required as a record of the archaeological sites within the park was limited to a few none sites. This UNESCO World Heritage survey of Sehlabathebe National Park, Qacha's Nek, Lesotho was undertaken and performed by a team of trained field technicians with the assistance of the MARA/RARI team of researchers.

Owing the transformation process that the MARA project has in place, the majority of the team are field technicians with professional experience in either Lesotho or South Africa. The field survey was directed by BoNtate Rethabile Mokhachane and Puseletso Lecheko. This team of researchers surveyed the park in three months with the assistance of the MARA/RARI researchers.



Photo 2.1: James Pugin recording of site E01, Sehlabathebe National Park. Photo: Dr Sam Challis 2015

The UNESCO survey of Sehlabathebe was the first baseline survey of the national park and aimed to locate and record the rock art and archaeology of the national park. The ARAL survey during the late 1970's located 85 rock art sites, however, the UNESCO survey located a further 20 rock art sites and numerous other archaeological sites within the park.

2.9.2 History of Sehlabathebe

Records of a San presence, in or around the Sehlabathebe National Park, first come encountered around 1850 AD. Although there are records' supporting the presence of the San throughout the parts of Lesotho for the past 8 000 years is discussed previously by Wright and Mazel (2012: 6). Owing to increased livestock numbers in areas that the San relied upon for hunting, game numbers diminished correspondingly. As a result, the hunter gatherer lifestyle was compromised by 200 years of colonial expansion and 1 500 years of contact with Nguni speakers. This forced the San to depend on stock theft to survive (Wright 1971; Challis 2012; Challis *et al.* 2015).

Chapter 3: Literature review

The need for advanced methods of survey in rock art can perhaps only be comprehended after one has seen the effort and difficulty associated with such surveys. Finding rock art and archaeological sites in the mountains of Southern Africa can be a costly and time-consuming exercise. Numerous rock art researchers have painstakingly surveyed the Maloti-Drakensberg Mountains by foot to some avail. However, locating rock art is especially reliant on good survey planning, knowledge of the research area and understanding the types of features where the rock art is usually painted, and most importantly the existence of rock art within a possible site. One problem associated with rock art surveying is the very few published accounts of survey methodology (Mazel 1983; Challis & Laue 2003). In an attempt to rectify this lack of survey methodology, this research expands on the path set out by Pugin (2012) and incorporate further remote sensing techniques to best assist in surveying for rock art sites. Therefore, any advances made in remote sensing that can be made applicable to rock art surveying is beneficial.

3.1 Rock Art Surveying

Assessing the available rock art survey literature provides little evidence for how to actually locate rock art sites. The few examples that discuss the actual methodology of rock art research predominantly discuss the recording process that ensues after locating a rock art site (e.g. Loendorf 2001; Whitley 2005; Sharpe & Barnett 2008). The lack of published methodology on how to locate rock art sites is problematic, not because researchers have limited knowledge on how to locate rock art sites, but rather because only two accounts of distinct methods have been published (Mazel 1983; Challis & Laue 2003).

Research by Mazel (1984: 349) is the first published example that includes a portion on termed ‘rock art searching strategy’. In this short paragraph, the method of survey and the way it was implemented was discussed during the survey undertaken in the Royal Natal National Park and surrounding areas. Mazel discussed two different methods that were implemented depending on the features that he was surveying. Simply put, Mazel (1984) surveyed the areas most likely to contain rock art by walking along the valleys that had exposed sandstone outcrops.

With the intention of checking the area's most likely to contain rock art (e.g. valleys with exposed sandstone outcrops) Mazel (1984) was able to survey the area effectively. Mazel (1984) accounts for the occurrence of rock shelters that are likely to contain rock art in various sandstone bands, namely Clarens, Molteno, Elliot and Upper Tarkastad. According to (Mazel 1984: 348) there was no record of rock art sites occurring in the Drakensberg Basalt Formation, however, prior to this Vinnicombe (1976: Map 5, 2009: 357) located a site 'X1' within the Drakensberg Basalt Formation (Pinto 2014: 5, 6, 37, 113).

Rock art research requires a standardised method of survey that can be used to survey areas for rock art. Although there is methodology associated with rock art surveying it is rarely discussed or published. In an attempt to rectify this methodological void, a method that incorporated aerial photographs, Google Earth imagery, survey planning and survey tactics was instituted as part of the MARA survey (Pugin 2012). The survey used aerial photographs and google earth to determine the likely locations of exposed sandstone outcrops (Pugin 2012). The next stage was to digitise areas that indicated that they may contain shelters or overhangs. After digitising these locations, they are surveyed along with any adjacent areas that looked promising. The survey method used was the uncontrolled exclusive survey (White & King 2007: 85). The aim of this survey was to exclude the areas that did not contain any sandstone, whilst providing the surveyor with the freedom to deviate from the course if there was a likely rock art site that was not located within the original survey location.

The research was successful in identifying areas that looked promising to contain rock art by identifying areas with outcropping sandstone. The research was successful because it was able to place the researcher in areas that contained rock art. Through the application of these techniques, the MARA survey was able to utilise this methodology to locate other undiscovered rock art sites.

Research has shown that GIS and remote sensing can be applicable to archaeology (Parcak 2009; Lasaponara & Masini 2011) and to rock art (Pugin 2012; Russell 2012), and this was seen as an ideal opportunity to incorporate techniques and processes into this survey methodology.

A secondary aspect to consider when assessing rock art surveying is the need for an understanding of how sites were selected in the past because it provides an insight into

what a researcher is required to look for in the field. The section on site selection is valuable as a guideline to make researchers aware of the likely features that could have been painted on and to be able to identify any likely site locations.

3.1.1 Hunter Gatherer Rock Art Site Selection

It is important to consider that rock art sites were possibly chosen based on characteristics that are largely unknown to researchers today. Therefore, any environmental proxies could assist researchers identifying a trend. Insights into these environmental proxies, are discussed in depth for sites distributed across Southern Africa (Mazel 1984: 67-75) and are compared to the distribution of sites for the Matatiele region. This breakdown of sites is valuable for consideration when assigning values to the different factors that affect a predictive model.

The evaluation of rock art site conditions (altitude, aspect, geology, distance to water, etc.) was completed as part of the Analysis Rock Art Lesotho (ARAL) research (Smits 1983). The ARAL survey included the Sehlabathebe National Park, which is the second area that this method is applied to (Figure 3.1: 33). The publication has listed breakdowns of the sites against different characteristics.

A valuable aspect included in Smits' (1983) ARAL survey of Lesotho is the presence of a breakdown of sites against different feature types, geological formations, and aspect. This breakdown of sites showed how site distribution can differ in alternate areas across Lesotho and provided an insight into possible site distribution types and trends.

The inclusion of the different factors affecting the distribution of sites for the multiple areas across Lesotho and South Africa is a valuable aspect to take into consideration when assigning values to different components that will be used to assign weights to a model. It is useful to use existing data from previous surveys. However, as this type of data is seldom available, the availability of the ARAL data for predictive models is an advantage.

It is of interest to note how the differences in landscape and site conditions affect the distribution and density of sites within a specific area. Site distributions that are of interest are listed below, and discussed to show their relevance and how these distributions were taken into consideration in regards to how they affect or impact on future models weighting.

The different factors are discussed as listed in Smits (1983). It is of interest to test other areas that are not expected to contain rock art such as Polihali (Mokhotlong) in Lesotho (Pinto 2014).

The first aspect discussed takes into consideration the changes and variations within the different areas, and how the rock art sites are distributed amongst different geological formations. The second aspect taken into consideration is site exposure and how this varies across the different research areas listed. The final characteristics discussed by Smuts (1983) are site type, which shows the distribution of sites per site type for the different research areas and finally, how aspect varies across the multiple research areas.

These distributions show how sites are not necessarily dependent on geology as can be seen in Table 3.1: 32. Phutiatsana is an area where sites are located within all the geological formations including the basalt, whereas Sebapala and Sehlabathebe contain sites located within only the Clarens and Elliot formations. The results listed by Smits (1983: 68-69) are misleading because the presence of sandstone lenses within the basalt refer to sites that are located within the basalt Formation where in fact these sites could be painted on sandstone.

Table 3.1: Geological breakdown for sites located by ARAL (Smits 1983: 68-69) [6]

Geology	Phuthiatsana	Qhoqhoane	Sebapala	Sehlabathebe
Basalt*	28(11%)	0	0	0
Clarens	190(73%)	21(22%)	33(44%)	53(82%)
Elliot	12(5%)	18(19%)	42(56%)	12(18%)
Molteno	28(11%)	47(50%)	0	0
Burgersdorp	1(%)	8(9%)	0	0

Exposure is one characteristic that does not seem to vary as much as aspect or geology. As listed the Table 3.2: 33, displays the majority of sites that occur within overhangs with a few outliers occurring in caves and even less that are exposed.

[6] Smits discusses sandstone lenses within the Lesotho Basalt formation. There are however sites located within the basalt around the Mokhotlong region of Lesotho as evidenced in Vinnicombe's X1 site (Vinnicombe 1976: Map 5, 2009: 357) and Pinto's survey of the Polihali Dam Survey (Pinto 2013)

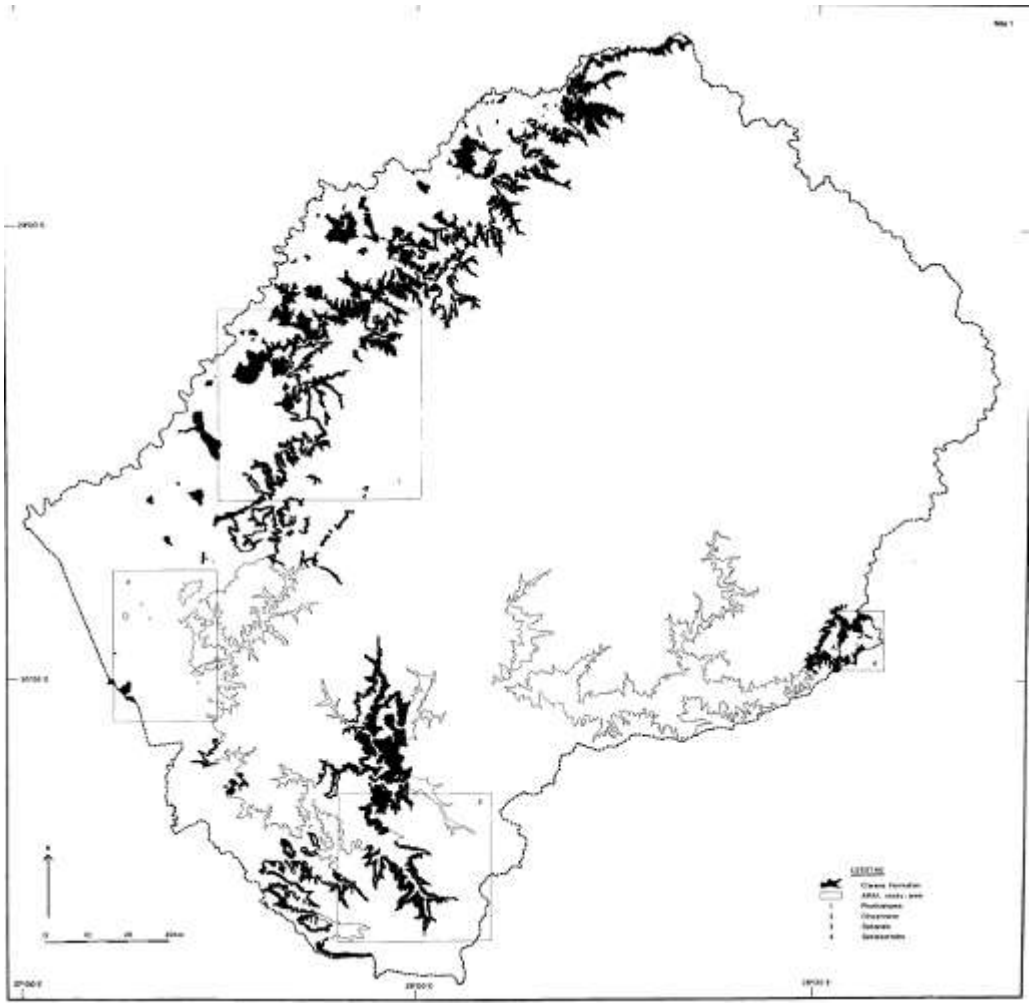


Figure 3.1: Image taken from Smits (1983: 62) depicting the ARAL survey areas. Research areas include Phutiatsana (top), Qhoqhoane (left), Sebapala (bottom), Sehlabathebe (right).

Table 3.2: Exposure for sites located by ARAL (Smits 1983: 69)

Exposure	Phuthiatsana	Qhoqhoane	Sebapala	Sehlabathebe
Exposed	4%	2%	3%	0%
Overhang	93%	97%	88%	97%
Cave	3%	1%	9%	3%

Location is a characteristic that does fluctuate between the different areas. As Smits (1983) has shown that certain areas have features that are more popular and likely to contain rock art than others. The distribution of sites across the range of features might be an indication of the broader landscape of the area but this is a more accurate display of the feature preferences per research area.

Table 3.3: Location/Feature types for sites located by ARAL (Smits 1983: 70)

Location	Phuthiatsana	Qhoqhoane	Sebapala	Sehlabathebe
Boulder	11%	21%	4%	5%
Outcrop	42%	55%	41%	71%
Cliff	47%	23%	55%	25%

Aspect is one of the most varied components and this is due to the varied environments across Lesotho. The majority of sites from Lesotho occur in a range of aspects whereas the aspects of sites within South Africa occur in a more varied range of aspects from North West to East, with fewer occurring elsewhere.

The variations in aspect could suggest multiple possibilities from seasonal site usage (I.e. North facing sites used in winter due to greater heat within these shelters, whereas south facing sites in summer due to cooler temperatures), variations in drainage patterns, the availability of sites in a specific direction, preferences for painted sites to occupational sites. All these are possibilities that could affect distribution of rock art sites.

Table 3.4: Aspects of Sites located by ARAL (Smits 1983: 70)

Aspect	Phuthiatsana	Qhoqhoane	Sebapala	Sehlabathebe	Ndedema Gorge	Giants Castle	Barkley East	Olifants River Valley
N	18	11	27	11	17	42	11	16
NE	14	7	12	26	24	15	18	13
E	17	13	9	28	21	29	34	21
SE	15	12	7	6	5	7	0	9
S	9	26	15	6	0	0	0	15
SW	6	14	9	14	0	2	3	7
W	9	15	11	2	7	4	8	14
NW	13	3	11	8	26	21	26	5

The ARAL research comprised a list of data that is shown in Table 3.4: 34 that displays the differences in distribution compared to the ARAL study areas within Lesotho and others mentioned within the Maloti-Drakensberg.

Many of these proxies are identified as possible indicators for this research. Whilst considering the differences in environments there are many similarities (Refer to Predictive Modelling) in conditions such as geology and geomorphological features. However, aspect and exposure would differ firstly due to the position of the areas and secondly, the nature of the drainage system that affects the Matatiele area as opposed to elsewhere in the Maloti-Drakensberg.

However, this research (Smits 1983: 70) concluded that the physical site characteristics/location had little effect on site choice and distribution but rather the most crucial aspect affecting the presence of a rock art site was the availability of a suitable rock surface to paint. This is an important point to consider in regard to this research because the objective of this research is to locate areas with suitable rock faces to facilitate rock art. These areas occur at the juncture of sandstone outcrops and specific geomorphological process that form these sites.

Although the ARAL team's research (Smits 1983) does not include any relevant survey methodology, it does uncover some valuable factors that affect rock art site selection. These aspects could enable researchers to focus on identifying the most likely aspects of San hunter gatherer site choice. Although hunter gatherer site selection is a delicate topic of discussion, in many cases rock art sites can be identified by the availability of a shelter/overhang and the presence of a rock face. Understanding the exact attributes or characteristics of a site may never be fully known to researchers but the requirement for shelter and rock face provide researchers with an important starting point to identify further locations (Smits 1983; Mazel 1984).

Although there are few cases of rock art occurring within the basalt, these cases are few and far between (Vinnicombe 1976; Smits 1983, Mazel 1984). Subsequent to the Polihali Dam survey (Pinto 2014) discovered numerous sites within the basalt. With the discovery of rock art within the basalt formation, there could be rock art present in areas that were once neglected due to geological formation.

These findings could indicate that in the case where no suitable shelters exist, the basalt may be used as a substitute. That is to say, the necessity to paint prevailed over the choice of substrate.

3.1.2 Rock Art and Environmental Determinism

Considering methods that are dependent on site-specific characteristics requires an understanding of the limitations of taking an environmentally deterministic approach. This research may be seen as environmentally deterministic because it employs geomorphological proxies and vegetation data in an attempt to locate rock art sites. However, the only proxies that are known to researchers are based on physical environmental characteristics. An experienced researcher's view may and often does contain an environmental consideration because many of these sites may not have been selected based on geomorphological proxies but the presence of the rock art sites is dependent on the presence of specific geomorphological features. In fact, there are problems in trying to predict human choices and behaviour. However, identifying sites in using an environmental consideration is less problematic because the locations of painted rock art sites seem to be in similar features (shelters, overhangs, cliff faces). The parameters that can be identified, however, are largely environmental (specific features include geology, aspect, landscape features, surrounding vegetation, nearby water sources etc.). Other than these physical features, rock art sites were chosen with parameters that are largely unknown to us (Ouzman 2001: 252). "In Smits opinion (1983: 63), the best indication was a suitable surface on which to paint. This, of course means that rock art occurs in rock shelters and this, we knew. Whether that shelter contains a suitable canvas one can only discover by visiting the site, which necessitates systematic survey. Since we must do this anyway the criteria are not so useful. Ouzman observes that beyond the parameters of physical geography (rock shelter), the reasons for site choice are largely unknown."

3.1.3 Other Applicable Biases

Most predictive model based surveys will create a field survey bias that will prioritise areas that correspond with known site based thresholds. This bias will enable the surveys to be expedient and make best use of time and resources, whilst locating as many sites as possible. In a method that looks to be expedient, there will be areas that are discarded at the time of the initial survey, however, they are not excluded from future research. Although researchers have funding grants and research time frames, applying biases that will encourage the locating of archaeological sites in an expedient manner will maximise the time and funding of the researcher and increase future funding opportunities owing to the

discoveries made. Survey methodology has an inherent problem with the statement “100 % survey or fully extensive survey” namely because of the risk of missing any potential archaeological evidence is high (Renfrew & Bahn 2004; White & King 2007).

3.2 Literature Supporting Methodology

3.2.1 Introduction

Geographic Information Systems (GIS) have been used effectively in archaeological research for some time (Lock & Stancic 1995; Westcott & Brandon 2003; Parcak 2009). Yet although the applications of GIS systems have been used extensively in archaeology (Scollar *et al.* 1990; Lock & Stancic 1995; Conolly & Lake 2006; Wiseman & El-Baz 2007), they have rarely been applied to rock art studies (Pugin 2012).

Remote sensing is seen as the best way to assist in locating areas of interest prior to stepping into the field. The applications of remote sensing are vast and can be seen throughout archaeological practice, however, in regards to rock art surveying these techniques are limited to Pugin (2012).

Remote sensing techniques have been used to identify archaeological sites through the successful application and incorporation of aspects such as Normalized vegetation difference indices, DEM and related elevation derivatives (aspect, slope, shaded relief/hill shading) and predictive modelling. Owing to theoretical and methodological shortfalls, predictive models are known to be contentious in Europe and North America (van Leusen 2009). Van Leusen identified six areas of concern for predictive models that have contributed to the possible shortcomings of predictive models. The concerns listed include:

- are the quality of the archaeological data acceptable and are there enough data
- are the environmental data relevant
- the need for more social and cultural data
- limited use of temporal or spatial data
- limited application of spatial statistics
- failure to adequately test predictive models

By taking these shortfalls into account, predictive models are more likely to be successful.

Prior to any remote sensing processes, uncorrected digital imagery requires data processing. This occurs in two forms, Radiometric and geometric corrections. Image rectification and restoration is undertaken as part of the pre-processing of the data prior to the data input and is used to correct errors that affect the quality of the imagery. However, due to the hybrid nature of this research, the pre-processing (correcting for geometric distortion and to correct for radiometry) was undertaken by SANSA prior to obtaining the necessary data (Schowengerdt 2006).

The focus of this section is on introducing the theory and methods used successfully in other remote sensing research. The theoretical base of the research is set out and then followed by the methodological process in the next chapter. The methods are discussed individually and then culminate in the combined model and the outcome of the different components.

Selecting components to be used in a predictive model for predicting rock art is not an easy task, however, the analysis of similar case studies and predictive models allows researchers the opportunity to understand the types of factors or characteristics that may influence site selection.

3.2.2 Case studies implementing similar techniques

Owing to the nature of this research, any processes (namely NDVI, slope, shaded relief, classifications, and predictive models) that could be of relevance are assessed and thus, any case studies of relevance are listed in the coming section. Therefore, identifying the ways these methods have been put to use in other studies would give an indication of whether a specific component would be effective or not. With the research looking to find exposed sandstone outcrops in mountainous terrain, there are certain processes that stood out from the rest, which included the use of NDVI, a DEM model (Kvamme 1992; Masini & Lasaponara 2007; Parcak 2009; Vaughn & Crawford 2009; Manap *et al.* 2010). Approaches such as predictive modelling were identified as a means of combining the different processes and aid in predicting or suggesting, where rock art sites could occur (Brandt *et al.* 1992; Kvamme 1992; Carleton *et al. 2012*). The processes that are identified as being applicable are listed below along with those that were believed to be

of importance, but which did not contribute towards effectively identifying areas that contained rock art sites.

3.2.2.1 Normalized Vegetation Difference Index

The NDVI normalizes green/fresh leaf scattering in the near-infrared wavelength and chlorophyll absorption in the red bands, of multispectral imagery. The NDVI is seen as one of the many ways of measuring vegetation abundance, vigour and health (Parcak 2009). An NDVI value greater than 0.4 will indicate an abundance of vegetation, whist positive values greater than 0.1 would indicate senescing or sparse vegetation, whereas, a negative value would indicate water, snow or ice and areas that are slightly higher than 0 represent soils and barren areas (Masini & Lasoponara 2012: 27). A lack of vegetation can be seen when there is more absorption of the red band compared to the reflection of the infrared band (Mather 2005: 142).

NDVI has been used extensively in archaeology to identify features that can have an impact on vegetation growth such as buried walls (Winterbottom & Dawson 2005; Aminzdeh & Samini 2006, Rowlands & Sarris 2006; Masini & Lasaponara 2006, 2007; Taheri 2010). The successful use of NDVI to identify such features across Italy has been a great success of Masini and Lasoponara (2006, 2007).

The NDVI is seen as a process that can contribute to identifying archaeological sites in the current study area, since, as noted in field surveys, there are numerous sites that occur in barren rocky outcrops. Different classes, such as densely vegetated areas, sparsely vegetated areas as well other barren areas of greener grass can be identified through the application of the NDVI (Campbell 2008; Lillesand *et al.* 2008).

Masini and Lasaponara (2007) effectively implemented NDVI to aid in locating sites in Italy and are discussed as a successful case study. A further example of the use of NDVI in predictive modelling is discussed as part of research that took place in Belize (Vaughn & Crawford 2009).

3.2.2.1.1 Detection of archaeological crop marks by using satellite Quickbird multispectral imagery

Research in the south of Italy on two different archaeological sites dating to the middle ages was performed by Masini and Lasaponara (2007). The purpose was to determine if differences in vegetation health could assist in the locating of buried archaeological sites.

The use of aerial photographs for the identification of buried archaeological remains has been prominent for most of the 20th century. The modern approach implemented by Masini and Lasaponara (2007) utilised Quickbird Multispectral imagery to aid in identifying buried archaeological remains. Quickbird's multispectral imagery offers a much higher spatial resolution (2.44-2.88 m) compared to (for example) Landsat's Thematic Mapper (30 m). The research focused on the identification of vegetation irregularities such as small areas of plant stress compared to surrounding areas that could be affected by buried archaeological remains impacting on the health of the vegetation. Through the application of NDVI to indicate areas of plant photosynthetic activity, it was predicted that at this high resolution, crop marks are visible.

The approach, using very high resolution multispectral data, provided the researchers with data that are unavailable if using aerial photography. The researchers identified that NDVI allowed for the better identification of crop marks covered by healthy plants, and secondly, that the near infrared channel was able to display areas with crop marks covered by dry plants (Masini & Lasaponara 2007).

3.2.2.2 Geological Mapping

Mapping geological formations can be done in a few different ways, although not completed in this research due to the poor geological data resolution. Spectral and spatial data from remote sensing can provide detailed information relating to geological formations. In barren areas, remote sensing can provide detailed information regarding the geology (Chen 2006, 2012). Although not used, a few examples of geological mapping are provided if the data resolution is of an acceptable standard, the first assessing the texture of remotely sensed images in Mongolia (Lucie *et al.* 2004). The second looks at the mapping of diagenetic heterogeneities in sandstone features in

Navajo sandstone (Bowen *et al*. 2007). Alternatively, the method and manner of soil mapping performed by Nield and Boettinger (2007) show promise when identifying areas of interest using Normalized difference ratios. The research was selected in regards to the identification of soils derived from sandstone rock features.

3.2.2.3 Hill / Relief Shading Analysis

Relief shading was initially developed to enhance the visual aspects of maps and to show relief and topography. Computer shaded relief maps incorporate colour and texture to aid visual aspects of terrain (Zhou 1992). The terms ‘relief shading’ and ‘hill shading’ are both used to describe the process of visually enhancing terrain maps. Two examples of hill/relief shading are discussed, first the research on automated hill shading.

3.2.2.3.1 Hill Shading and the Reflectance Map (Horn 1981)

Automated hill shading began by attempting to use the grey levels to determine how much light was reflected from the surface (Horn 1981). The hill shading process utilises algorithms to associate grey scale values to pixels which assist in creating visually enhanced two dimensional images (Hobbs 1999).

The hill shading process described in figure 4 set out by Horn (1981) will use the Shuttle Radar Topography Mission Digital Elevation Model (DEM) because it has the best vertical resolution available in Southern Africa. An automated process of relief shading will be undertaken to provide a visually stimulated topographical map. Features of interest (Shelters, kranslines and boulders) can be identified by understanding the types of shades that these features may have. Therefore, allowing those sets of shades to be identified on a large scale.

3.2.2.4 ***Terrain Mapping***

Mapping terrain and geomorphology in remote locations has used remote sensing for some time now, mainly for mapping areas for landslide susceptibility (Lee 2005; Biswajeet & Saro 2007; Hong *et al.* 2007). Research (Abd Manap *et al.* 2010) has taken to using remote sensing to identify aspects of geomorphology such as hillcrests, and different types of slopes. These techniques are ideal when looking to determine possible methods for mapping geomorphological features in mountainous terrain.

3.2.2.5 ***Application of remote sensing in the identification of the geological terrain features in Cameron Highlands, Malaysia.***

The process of terrain mapping was utilised in the Cameron Highlands, Malaysia by Abd Manap *et al.* (2010). This study used aerial photographs and Landsat images in an attempt to identify features of the terrain such as hillcrests, side slopes, foot slopes, convex slopes, concave slopes and straight slopes. The aerial photographs and Landsat images were draped over a digital elevation model to represent the environment in three dimensions. Abd Manap *et al.* (2010) recalled on the researchers that utilised similar methods prior to the research in the Cameron Highlands (Verstappen 1977; Davis & Mason 2000; Novak & Soulakellis 2000; Bocco *et al.* 2001; Ramli 2001; Chang 2002).

Verstappen (1977) was the first to use Landsat ERTS 1 in an attempt to identify geological features. Verstappen used band 5 and band 7 to distinguish between variations in geomorphic units and vegetation. Kayan and Klemas (1978) concluded that band 7 of the Landsat ERTS 1 was used for the identification of geological formations and geomorphological slope contrast. Of which, band 5 was used to reinforce the data obtained in band 7 as it provided detailed information on rock-soil boundaries, the tectonic relationships between vegetation and structures for determining between flat surfaces and steep slopes (Kayan & Klemas 1978). The false colour composite of bands 4, 5, 7 assigned to the red green and blue bands provided for the analysis of geology owing to the higher contrast.

Novak and Soulakellis (2000) were able to implement principle component analysis for the use of terrain mapping to identify geomorphological units. The purpose of the

research was to test the effectiveness of enhanced Landsat 5/TM multispectral imagery to determine likely geomorphological features such as dissected metamorphic terrains, lava plateaus, colluvial foothills, and alluvial plains (Novak & Soulakellis 2000).

Similar studies have carried out these techniques to map terrain, an example of this is Bocco *et al.* (2001) who utilised landform classifications to classify the landscape and determine areas such as low hills, high hills, sierras as well as flat land and piedmonts. The project provided valuable data for an area where forested areas are maintained by local communities. These landform classifications classified the major landforms and dominant land cover, both of which are useful for a country with minimal resources and a need for methods to classify land cover at a large scale (Bocco *et al.* 2010). Digital elevation models were identified as a valuable tool for the identification of geological and geomorphological features (Grover 1999; Davis & Mason 2000).

3.2.2.5.1 Method utilised by Manap *et al*. 2010

The initial stage of the terrain mapping procedure involved the development of a digital elevation model (DEM) from contour data derived from topographic maps (1:10 000 resolution) (Abd Manap *et al.* 2010: 2). The topographic map resolution of 1:10 000 were used to create a DEM with a pixel size of 5m. The DEM was then used to create a slope map, aspect map and a shaded relief map (Abd Manap *et al.* 2010: 2).

The panchromatic aerial photographs (1:20 000 resolution) were scanned and then georectified using ground features. The aerial photographs were then orthorectified using ground control points and a cubic convolution resampling to maintain the accuracy in the images. The aerial photographs were then mosaicked. The Landsat imagery undergoes different procedures compared with the aerial photographs, the first stage was implementing linear contrast stretching and histogram equalisation. The next stage was draping the orthophotographs and Landsat images over the DEM. Finally, the results were tested during field verification (Abd Manap *et al.* 2010: 4).

Manap *et al.* (2010) were able to identify the geological terrain through specific features that are of relevance to the model that is being developed in this research. These features include topography, drainage systems, vegetation, and land use. The bands of Landsat

used were valuable for geological terrain mapping, band 4 succeeds at demarcation of water bodies, band 5 identifies soil or areas with a lighter tone and band 7(NIR) suffers less attenuation and therefore is ideal for the identification of geomorphological slope contrast (Abd Manap *et al.* 2010: 2).

3.2.2.6 Predictive/Likelihood Model

Predictive models use samples of archaeological sites or theories on human behaviour to predict unknown site locations (Ebert 2004: 323). Predictive models have been used extensively in archaeology to assist with locating sites. Such models have been used to identify site locations for lithic assemblages, understanding hunter gatherer adaption, locating archaeological resources and much more. These models predict site locations using variables identified at known site locations. Duncan and Beckman (2005) describe archaeological sites as the distribution of decisions made by humans within the conditions presented within their environment (Duncan & Beckman 2005: 37).

Archaeological sites have a tendency to occur in environmentally favourable settings that are preferable for resources, hunting or protection. The assumption made is that the environment will impact on site locations and that these site locations will correlate with other site locations in regards to common features (Marozasa & Zack 1990: 105; Ebert 2004: 325). An example of this is the repetitive nature of rock art sites in rock shelters and boulders etc. Inductive modelling assumes a cultural-ecological view of human settlement systems, which focus on parts of the environment rather than the individual site (Ebert 2004: 235).

The method is somewhat criticised as there are limitations associated with the approach, mainly in regard to stating that human behaviour was based on environmental choices and conditions, these criticisms include a failure to account for environmental change (Kvamme 1992; Wheatley 2004), an approach being environmentally deterministic (Ebert 2004). Predictive modelling is reliant on two assumptions: firstly, site choice is influenced by the environment and secondly, that these environmental factors are portrayed in remote sensing images and, or, maps. Numerous studies have been successful or shown positives and were able to locate archaeological sites or understand human behaviour

and site selection due to these predictive models (Gaffney & van Leusen 1995; Dalla Bona 2003; Ebert 2004; Wheatley 2004).

Analysing successful and unsuccessful models provides this research with the foundation and approaches that need to be considered with regard to modelling the requisite variables. A secondary aspect of this project is to look at site selection decisions and how environmental factors possibly influenced these decisions. Assessing the positives of predictive models allows this research to replicate these successes and avoid some of the pitfalls of previous researchers.

Verhagen *et al*. (2008) show how archaeological predictive models are effective for use in heritage management and related surveys. The main justification behind using predictive models is their efficiency in locating areas that are more likely to contain archaeological sites. The idea of priorities is related to surveying, there is little point expending time and resources surveying areas that have a very small chance of containing archaeological sites. Therefore, it is better practice to survey the most likely areas first and then any other possible locations if time allows. Archaeology is arguably about discovery, which is the main reason why projects get funded (Verhagen *et al.* 2009: 19).

> "Archaeological predictive models will tell us where we have the best chances of encountering archaeology. Searching for archaeology in the high probability areas will 'pay off', as more archaeology will be found there than in low probability zones. It is a matter of priorities: we can not survey everything, and we do not want to spend money and energy on finding nothing. And there is also the political dimension: the general public wants something in return for the taxpayers' money invested in archaeology. It's not much use telling politicians to spend money on research that will not deliver an 'archaeological return'." (Verhagen *et al.* 2009: 19).

In an attempt to set a standard as to what is required of predictive models, Verhagen *et al*. (2009) raised some valid points to ensure that data quality and predictive models are acceptable. The points mentioned are generalised for most models but if achieved, would result in good, reliable, predictive models which should:

- Have a framework for site density patterns.
- Motivate why the prediction is made.
- Be transparent and reproducible.
- Give best possible prediction and therefore, be optimised.
- Perform well in future situations.
- Specify uncertainty and the risk of classifying zones in high, medium and low probability.

Verhagen (2009) sets out these criteria as guidelines to aid for predictive models and as such they allow for these models to be successful and reproducible.

Criticisms of predictive models have been raised by many researchers in the past (Ebert 2004: 327; Wheatley 2004) with most criticisms aimed at the accuracy of site locational data or environmental data. Ebert (2004: 237) notes that predictions based solely on environmental considerations are effective for hunter-gather settlement patterns but when the model is based on social or political practices the predictions are much less likely to succeed. A further point is that GIS is believed to reintroduce environmental determinism into archaeology but this is not necessarily the case because of the ability to add non-environmental data into a GIS (Gaffney & Van Leusen 1995; Ebert 2004: 334). The thorny issue of environmental determinism and its links to GIS and predictive modelling is addressed further (9.5.2: 173).

A useful consideration noted by Carleton *et al*. (2012) is that predictive models' efficiency is determined by the resolution of the data included, in their case, digital elevation model with 30m resolution was more than suitable for testing the model's potential although higher resolution data is available. Therefore, any data limitations need to be taken into consideration as well as the use of data at a standardised resolution throughout the research.

Wheatley's (2004) analysis of predictive models shows underlying problems that many other researchers wouldn't admit to. This research has noted that many researchers use predictive modelling as a research method when there are limited financial resources. That is, the researcher is unable to conduct research over the entire area and wants to focus on the best areas for archaeological data to occur. The problem related to this is that models in Wheatley's (2004) view do not work that well and the resultant model would not provide a representative archaeological record.

Landscape complexity contributes towards Wheatley's (2004) view of predictive models not working well. There is an underlying problem in trying to predict archaeological sites based on environmental characteristics (Kvamme 1990; Wheatley 2004: 5). Understandably, some landscapes are complex but in some cases trends can be mapped accordingly. Finally, Wheatley (2004) believes that the problem of predictive modelling is not always related to the models but rather the researchers. Most researchers implementing predictive models are trying to avoid the fieldwork and data collection involved with everyday archaeological prospecting and thus, using predictive models to predict known site locations that they used to create their model (Wheatley 2004). Justifiably, using a percentage of sites for validation is acceptable as it is a method to test the validity a model, but modelling to predict the archaeological sites used to construct the model is unethical and should be avoided.

Therefore, any predictive models that have been applied in a similar manner would be relevant. Three such models have been analysed, the first completed by Vaughn and Crawford (2009) and then Carleton *et al*. (2012) where both looked into ways of mapping and modelling Mayan site selection choices in Belize to determine what factors might have influenced these locations most. The third case study conducted by Kvamme (1992), attempted to predict open air lithic scatters and sandstone rock shelters and although the project was successful, technological limitations stifled the research. Finally, Brandt *et al*. (1992) discuss the applicability of a predictive model for using a weighted layer approach and demonstrate the issues of using predictive models to map human behaviour.

3.2.2.6.1 A predictive model of archaeological potential: An example from northwestern Belize

The study on the predictive modelling potential in north-western Belize (Vaughn & Crawford 2009) assessed possible alternatives to costly time consuming ground based surveys to identify and locate Mayan archaeological remains. The research focused on mapping the variable concerned with site locations (Vaughn & Crawford 2009).

Elevation data was obtained through EROS (Earth Resource Observation Services) of which this data included slope, aspect and hill shading. The slope data was used to determine two variables, first, the distance to flat land and second, the sum of the area of flat land. The slope layer was also used to identify areas suitable for agriculture and settlement, therefore, any areas with between one and five degrees of slope, because runoff at this more than 5 degrees of slope, would carry soils with it and second at this slope the relief would drain suitably during the wet season.

Further, variables included drainage patterns derived from 1:50 000 topographic maps, which were used to calculate the distance to water because it was seen as a likely indicator of site locations. Vegetation indices were also included in the predictive model. The indices used included the Normalized Difference Vegetation Index, Tasseled Cap Greenness, and Wetness Index. Both the NDVI and Tasselled Cap Greenness are vegetation indicators, whereas the Wetness Index is an index of water present throughout the area whether in soil or the canopy.

The model used a binary logistic model and consequently identified aspect, greenness and distance from known sites to arable land as the variables to identify Maya settlements. Other instances show that water, slope and soil characteristics have impacted Mayan site choices (Ford *et al*. 2009). Known non-site locations were also derived from the surveyed tract and influenced the use of a weight-of-evidence model (Vaughn & Crawford 2009).

Based on the initial predictions, the model successfully predicted two thirds of the known site locations and sixty percent of these sites that were retained for validation and testing purposes of future models. The predictive model performed well in locating areas of high archaeological probability when locating site locations that were withheld from the initial

predictions, however, without actual field testing to validate this model, the actual success rate is unknown (Vaughn & Crawford 2009).

3.2.2.6.2 A locally adaptive model of archaeological potential (LAMAP)

In an evaluation of predictive models, Carleton *et al*. (2012) discussed and critiqued two commonly used predictive modelling techniques. In attempting to predict site locations, ancient humans had a sense of where they needed to be in order to perform the functions that were desired and thus when attempting to model these behaviours, researchers needed to be cognisant of these decision making processes and how humans utilised the landscape (Carleton *et al.* 2012). A common problem recognised in these models is that they predict probable archaeological site locations instead of indicating areas of archaeological potential. Areas of probability or likelihood are likely to contain sites, whereas areas of potential may or may not contain archaeological sites based on the modelling parameters, these areas of potential are selected based on parameters but there is no expectation that there will be sites present. Most predictive models are capable of locating sites that are already known to the researcher and that were used in the model building process, but are unable to replicate this success due to landscape change and variability (Butler 1987; Fedick, 1995, 1996; Dunning *et al*, 1998; Fedick *et al*, 2000; Kunen, 2001; Penn et al, 2004; Ford *et al*, 2009; Patterson *et al*, 2010; Zhang *et al*, 2010).

Landscape variability is a problem that affects predictive models, as it introduces problems when trying to replicate a model's success in a different landscape. Considering the changes in landscapes, both weights of evidence and logit models, are weak and impervious to this change. This is relevant to this study as the model is created using site data for the Matatiele region which is located below the escarpment and will be tested in Sehlabathebe which is located above the escarpment.

The two techniques discussed are the basic Logit model and the Weight of Evidence model. The weight of evidence models looked at a breakdown of spatial variables for a region, whereas, logit models assessed odds of binary result for distribution of variables for a site without any assumptions being made about the distribution of the variables.

The method set out by Carleton *et al.* (2012) looked at the distribution of 69 Mayan sites, whilst retaining 8 sites for model validation. Elevation data was acquired for the research area from two sources namely ASTER and SRTM. The ASTER data was used to form a 15m stereoscopic DEM whilst the SRTM data was used replace cloud cover pixels on the ASTER data. The primary resolution of the data was 15m or 30m (when stated).

Identifying variables that are of relevance to a project is a crucial stage in a modelling procedure, Carleton *et al*. (2012) identified that the variables of relevance to their study included: elevation, slope, terrain roughness, aspect, distance to nearest river and soil types; however, aspect was discarded because it was indistinguishable amongst a group of known sites. As we shall see, this is reflected in the findings of this project where aspect was also discarded because of the underlying drainage basin which is determined by the topography of the area. The success of the LAMAP set out by Carleton *et al.* (2012) has advantages as listed below: the model is simple but robust, is able to account for issues of spatial data scale and provides an adequate understanding of the landscape and locational behaviour (Carleton *et al.* 2012).

3.2.2.6.3 Predictive Site Location Model on the High Plains: An Example with an Independent Test

Kvamme (1992) focused on an area within the Piñon Canyon, Colorado, USA to apply a predictive model to assist with locating sites in an ongoing archaeological survey. The area is home to open air lithic scatters and rock shelters sites within the sandstone layer in the canyons. The method of modelling took a representative sample of the sites for the region that consisted of known site locations as well as known non-site locations and applied a method of pattern recognition. The site and non-site locations were imported into a GIS consisting of areas that that have been surveyed as well as other areas which had not been surveyed.

An assumption of modern archaeology is that the behaviour of modern humans is not random and thus sites should not be randomly placed throughout the landscape.

> "With regard to the first assumption, it is a basic premise of modern archaeology that human behaviour is non-random and, therefore, activity

> places (i.e. sites) should be nonrandomly distributed. Numerous studies of empirical settlement data have repeatedly demonstrated the significant regional patterning exhibited by archaeological distributions (e.g. Judge 1973; Kvamme 1985; Roper 1979; Thomas & Bettinger 1976).” Kvamme (1992: 21).

Therefore according to Kvamme’s statement, because site distribution is non-random it is possible to be predicted (Kvamme 1992: 21; Brandt *et al.* 1992: 269). A limitation, however, exists in the sample of sites selected, because it is not always a truly accurate reflection of the sites discovered. Sites that were not found or possibly destroyed contribute towards a model, but without any presence of their individual characteristics, the factors associated with them would not be present in the model and would have an effect on any undiscovered sites that exist in similar conditions as they would not contribute any present in the initial site (Kvamme 1992: 20, 22). Therefore, it is important to note that the sample is the only representative of the known sites and those site conditions. A further point to consider is how the environment could have changed from the time the site was first used until the point of its discovery (Kvamme 1992).

With regard to rock shelter site selection, Kvamme (1992) notes that these sites are fixed and occur at the juncture of certain variables, namely geology and the occurrence of erosive factors. Shelters of a suitable size often display some form of occupation (Kvamme 1992: 23). At the time of the publication, Kvamme (1992) discussed the difficulties of applying a predictive model to rock art studies, namely because of there was no method or technology that allowed for the identification of rock shelters and overhangs. A secondary issue in this research was the inability to identify suitable rock faces for paintings because no model is able to provide information on whether there is a suitable rock face within a shelter to contain rock art. Only after surveying can a site be known for containing rock faces capable of containing rock art. Any regional model that is capable of locating and predicting rock shelters is valuable to archaeologists as, more often than not, these shelters contain some form of archaeological material.

There are certain factors that are common among locational studies. These include; slope, aspect, shelter, distance to water and view. These factors are listed and discussed in regards to how site locations were influenced. The first to consider is gradient of the slope. This is widely considered as an indicator of human settlement because of a

preference to occupy flat areas over rough steep terrain (Kvamme 1992: 24). However, the presence of rock shelters in steep mountainous terrain needs to be taken into account.

The second factor for consideration is an aspect. Site selection in the northern hemisphere is seen with multiple sites located on the south facing aspects due to greater warmth provided by the sun and trends have been identified to support this claim which makes it a useful modelling component (Kvamme 1992). In the southern hemisphere, this would obviously be reversed to a north-facing preference.

Local relief or terrain roughness has been investigated as a decisive factor in location studies because the nature of the terrain affects where settlement occurs. The values in roughness are dependent on the fluctuations in elevation. Higher fluctuations equate to rougher terrain, whereas, a smaller variation equates to flatter terrain.

Shelter is the final factor that Kvamme (1992: 26) considered, and is relevant because of the protection provided by shelter to elements such as wind, poor weather or sunshine. Shelter is measured in regards to how well sheltered a site location might be (Kvamme 1992).

Considering the description of deductive models (Kohler & Parker 1986), Kvamme (1992) illustrates how the selection of variables disproves the simplistic nature of the deductive models described because many of these deductive models make assumptions about human behaviour. In this case, the variables are based on empirical data. However, with regard to assigning weight to these models, guesswork and assumptions are needed at times in order to determine the balance of factors assigned (Brown & Rubin 1982; Kvamme 1992). Statistical processes are required for these weights to be scientific, such as using mean and standard deviation or other statistics to accurately determine the weighting.

3.2.2.6.4 An Experiment in Archaeological Site Location: Modeling in the Netherlands using GIS Techniques

In the Netherlands, the process of archaeological discovery is problematic owing to the nature of the archaeological sites: most sites, especially in densely populated regions in Europe are found beneath the surface of the ground. Site location models have been applied successfully in the United States of America, not only to show areas with archaeological sensitivity but also for their predictive power for locating undiscovered sites (Kvamme, 1992; Brandt *et al.* 1992).

A premise to be aware of when performing locational models in archaeology is the idea that human behaviour is patterned and therefore, so is locational behaviour (Brandt *et al.* 1992: 269). Sites across a landscape should, therefore, display non-random characteristics, which can then be used to predict undiscovered site locations. Most modelling studies have examined common site preferences such as soil conditions, elevation and terrain. Of these factors, data can be obtained for soils, geology, hydrology, and topography (Brandt *et al*. 1992; Kvamme 1992; Carleton *et al. 2012*).

The use of a weighted map layer approach to modelling was chosen to best distinguish subtle changes or combinations in the environmental dataset (Brandt *et al*. 1992). By using a weighted map approach, a single category can be assigned a value pertaining to the condition and whether it is favourable to contain archaeological sites. There are two possible ways of doing this. First, a binary option displaying favourable and unfavourable areas, and then second, a ranking system can be applied. Kohler and Parker (1986) believe that implementing ranks without deductive reasoning is problematic and that ranks need to be decided based on theory. These ranks are similar to the weights assigned within a weight of evidence model.

The goal of Brandt *et al*. (1992) was to give researchers an advantage in locating archaeological sites rather than an attempt to map human behaviour. Raster data is ideal for associating weights with specific characteristics due the grid-like nature of the data. After the modelling procedure was completed, the resultant weighted model is a summary of the six contributing map layers that were added to the modelling process. The summary of the weighted model would show areas ranging from favourable to less favourable areas to contain archaeological sites (Brandt *et al.* 1992: 271).

The classic use of predictive modelling in archaeology has been criticised since it uses environmental characteristics to not only predict site locations but also explain human behaviour (Brandt *et al.* 1992: 271). In this study predictive modelling will be used without making assumptions on human behaviour per se, but rather as a method for aiding desktop research on rock art in advance of the archaeological survey. This predictive model will focus solely on the identification of geomorphological proxies to identify areas of higher likelihood of rock art occurrence which will then be ground-truthed.

3.2.2.6.5 Remote sening based identification of Painted rock shelter sites: Appraisal using advanced wide field sensor, neural network and field observations.

Banerjee and Srivastava (2014) successfully applied a remote sensing method in Rewa and Mirzapur, Central India, which is used to delineate areas of exposed sandstone. The research area contained a total of 250 known rock art sites and subsequent to this method being applied a further 40 sites were located.

Using multispectral data from the IRS-P6 (ResourceSat-1) satellite that has advanced wide field sensor (AWiFS). The bands that the research focused on where bands 2-5. The GPS locations of each site were used for ground truthing purposes. Furthermore, digitized and geometrically corrected maps were used for classifying rock art into different landscapes. As a result the area was divided into five separate classes; forest, waterbodies, sandstone, alluvial land and cropland. All rock shelter sites were found within the sandstone complexes.

The first algorithm applied in the research was the artificial neural network (ANN). The ANN classifier identified five classes, forest, waterbodies, alluvial land, cropland and sandstone. The method of ANN used is particularly successful as it is capable of learning by pattern and therefore simplifying the process. The second method applied was the Maximum Likelihood Classification (MLC) and is known for its ability to classify both variances and covariances of the classes, subsequently assigning each to a pre identified signature class. The MLC was also successful at identifying the five aforementioned classes.

The ANN producer results differed significantly to the user results for each of the classes. The forest and water body classes differed slightly, whereas, the producer successfully identified 91.89% of the cropland compared with the user result of 61.82%. The user successfully identified 100% of alluvial areas, 93.62 % of sandstone whereas the producer identified 82.35 % and 69.84% respectively.

The MLC has similar classification results to the ANN, however slight differences occurred in the classification as it was less successful at identifying waterbodies (85.19%), cropland (89.19%) and sandstone (66.67%). User accuracy was similar for the forest, waterbody and alluvial classes, but both cropland (57.89%) and sandstone (91.30%) classes were less accurate. Overall accuracy of both methods differed slightly as the ANN (84.29%) was more accurate than the MLC (81.15%).

Both methods proved successful at delineating areas of sandstone, as such a linear trend of shelters were distributed across the Rewa Landscape. Although both the ANN and MLC had slight differences in accuracy, they were able to map sandstone outcrops and therefore assist rock art surveyors.

3.2.2.7 Interpretation

3.2.2.7.1 NDVI

This research assesses the successfully applied methods from others' research in an attempt to replicate the success of others and utilise it in a model for locating rock art in the Maloti-Drakensberg. Looking at the success that Vaughn and Crawford (2009) achieved by implementing NDVI to studies looking into human occupation based on vegetation, it appears useful for this research. However, owing to the nature of site locations, this research focuses on identifying barren rocky outcrops rather than highly vegetated areas.

Owing to the expansive wattle cover throughout the research area, NDVI is useful to delineate areas with this cover. The problem encountered with these vegetated areas is that the wattle was introduced subsequent to the paintings and thus, some highly vegetated areas are likely to contain rock art. It should be noted that the majority of wattle

growths occur adjacent to water courses and not the whole way up the side of a valley, however, there are exceptions.

3.2.2.7.2 Terrain Mapping

The mapping of terrain that was completed by Abd Manap *et al*. (2010) shows a possible method that can contribute towards locating specific geomorphological features. Although the specific features of interest are different, this method holds promise with regard to locating geomorphological features such as boulders, rock shelters and rock overhangs.

3.2.2.7.3 Geological Mapping/Soil Mapping

Texture-based segmentation was used successfully in research by Lucie *et al*. (2004) for mapping different geological units. This study shows relevance in mapping geology such as sandstones and basalt, two geological units of interest.

In the mapping of Navajo sandstone Hyperspectral techniques were shown to be a success (Bowen *et al*. 2007), however, due to the costs associated with the very high resolution data that was employed, it cannot be used for the purpose of this study.

The method for mapping soil through the use of Normalized difference ratios is important to this research as it shows the possibility of looking at ratios that could affect the distribution of sandstone which would assist in locating areas of interest.

3.2.2.7.4 Classifications

The different forms of classifications that have been displayed throughout the case studies (Inzana *et al.* 2003) have been assessed to identify the most relevant processes and which is most likely to have the best possible influence in trying to identify rock art shelters.

The classifications are performed to determine the distribution of land cover throughout the research area. The classifications were believed to be of use to ascertain the extent of the sandstone and other relevant geological formations but were unsuccessful at being selective for the purpose of this study. Mapping land cover for the research area would assist with predictive modelling by limiting areas that are unsuitable, such as areas that are classified as ‘farming’ or ‘urban’.

3.2.2.7.5 Predictive Modelling

Predictive models are assessed to illustrate their relative strengths or weaknesses. Certain conditions were laid out by Verhagen (2009) to ensure data quality and the reputation of the predictive models. The first condition is that researchers should motivate why the prediction is made, in our case predictive modelling was seen as a viable means to distinguish areas of likelihood based on environmental conditions. In the cases listed above (Kvamme 1992; Brandt *et al.* 1992; Vaughn & Crawford 2009; Carleton *et al.* 2012), predictive models might have been discredited by modelling primarily on environmental conditions.

Predictive models need to be transparent and reproducible, two conditions that this research hopes to achieve. Transparency is required in regards to how the model is produced and to the breakdown of variables included in the model. A requirement of this research is that the model is reproducible, in areas that the model was not constructed or based on. In essence, the model can be reproduced but the weight of the different variables might need to be altered to maximise the efficiency of the model when applied elsewhere and in another region.

Models should produce the best possible predictions so that they can be effective and optimised. In rock art research, surveyors require adequate knowledge of an area prior to the survey to enable the best possible outcome and the likelihood of locating the most sites possible for the time spent surveying. Therefore, any predictive model focusing on predicting likelihood for the occurrence of rock art sites needs to be extremely accurate and reliable.

As well as being reproducible models must have high predictive capacity. Ideally, any model that is used to locate archaeological sites should have the newly located sites added to the model to determine whether the likelihood of locating the previously 'known sites' using only the recently discovered sites.

Classifying zones of probability is a problem with predictive models especially when trying to derive areas of high, medium, and low probability. The difference in this case is that low areas of probability will not receive the same amount of research attention as high probability zones. The classification of these zones therefore needs to be accurate and limiting the chance of sites occurring in less likely areas.

Site samples need to be representative for a predictive model to be successful. In Vaughn and Crawford's study (2009), a site sample of 50 sites used was an adequate base but whether it is a true representation of the area is another problem that needs to be considered as 50 sites might be sufficient enough to reflect the diverse nature of site conditions across the study area. In modelling and validation, the MARA 2012 database to date has 106 sites to work with, from an array of different conditions, adding to the diversity of sites. Although there are 200 hundred sites within the overall MARA database, many of these sites represent rock shelters that contain archaeological data that is not rock art so it adds to the representation of the area and shows that even in cases where rock art might not be found, there is a possibility of locating other archaeological evidence.

Fieldwork and data collection are imperative for any predictive model which attempts to locate future unknown site locations. Vaughn and Crawford (2009) used validation to test the effectiveness of their predictive model which shows a circular argument, predictive models are supposed to be able to predict unknown site locations. Understandably, validation points are required to test the accuracy of models but they cannot display whether a model is effective or not.

However, rock art site locations are confined to areas with exposed sandstone, (predominantly Clarens or Elliot Formation and at times Molteno Formation) which occur on near vertical rock faces. Focusing solely on geology and slope will afford rock art researchers a huge advantage by substantially reducing the areas that need to be

surveyed. The inclusion of further variables such as NDVI, aspect, and shaded relief, it is possible that this model can be refined further to better predict rock art site locations.

The different case studies assessed show the potential of this research. Although few of these components have been previously used in conjunction, it is promising to see how the different aspects are able to contribute towards the researchers' objectives. As mentioned earlier, this research is undertaken with the knowledge that the methods have limited singular potential and is an attempt to determine the most useful combinations of variables for the prediction of features that are synonymous for containing rock art sites. With the limitations of some methods and the complex choices made with regard to site selection certain aspects will contribute more than others, and this determines how the model's variables are then weighted. Weighting therefore needs to be discussed, followed by how the variables are overlain to give a comprehensive picture.

Banerjee and Srivastava (2014) research methods were not available at the time of writing, however, it would a profitable avenue for future research. Ideally the methods applied within this research should be compared with those of Banerjee and Srivastava (2014), as this would take time to test this is beyond the scope of this dissertation The two models do differ in that the Banerjee and Srivastava model uses direct methods of predicting the locations of sandstone whereas the methodology within this research looks at indirect methods of locating sandstone rock shelters.

Chapter 4: Methods

4.1 Introduction

This chapter outlines the processes that were tested throughout this thesis and creates a discourse about the relevance of successful and unsuccessful remote sensing variables. The methodology in a remote sensing study can be a lengthy process owing to the multiple components that contribute towards a working output. Therefore, this chapter discusses all factors from data acquisition to how the predictive model was constructed and finally how surveying took place. The methodological process (Figure 4.1: 62) outlines basic data acquisition, shows how the procedural breakdown of the methods and how the individual remote sensing components contributed to the final likelihood model.

The remote sensing outputs or components are all discussed with regard to how the data were processed and their expected outcomes. The MARA database has been compiled from site record forms and was utilised in the identification of each individual remote sensing outputs threshold prior to the modelling procedure so that the thresholds would reflect potential rock art sites based on known site data. The remote sensing aspects that have been discussed previously are all expanded here with relevance to the input of data and how they were processed.

4.2 Data Acquisition

Initially, this research looked into the use of open-access imagery from platforms like the USGS (United States Geological Survey) and SANSA (South African National Space Agency). The data requested from the USGS included Landsat 7 and Landsat 8 multispectral imagery as well as DEM's such as SRTM (Shuttle Radar Topography Mission), ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and GMTED (Global Multi Resolution Terrain Elevation Data). The aforementioned imagery is freely available to students upon request from SANSA as well as the USGS. In addition, higher resolution SPOT 6 multi spectral data were sourced from SANSA.

Due to the hybrid nature of this archaeological/remote sensing study, the pre-processing that is required before calibrated data can be utilised was completed by SANSA. Throughout this research there is a mention of alternatives to SPOT 6 and other high resolution data, these different data sources (Landsat 7, Landsat 8, and SPOT 5) are freely available and are capable of providing adequate results[7]. This is to allow researchers with smaller budgets to implement these methods on lower resolution data and still provide more than adequate results. The difference between lower resolution data and SPOT 6 will be discussed further in subsequent chapters.

[7] Given the rapid improvement in image quality and turnover rate in software packages, SPOT 6 ought to be freely available within a year of submission of this dissertation.

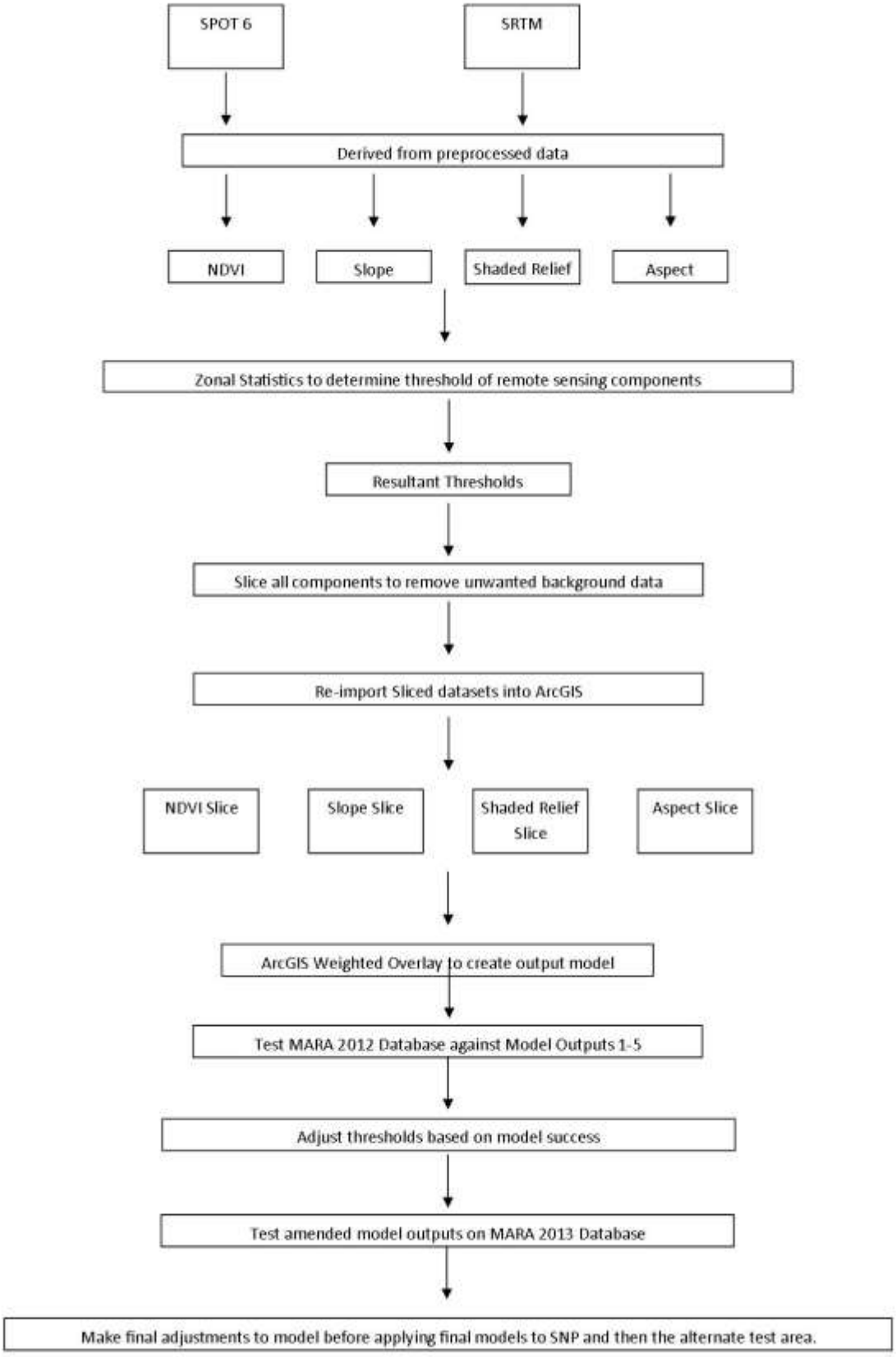


Figure 4.1: Methodological Process

4.3 Processes

The method process tested components thought to be of relevance to the prediction of sites. The success rate of those components determined whether they were included in the final model. Some remote sensing outputs (slope, shaded relief, and NDVI) were seen to be diagnostic of site location and these form the core components of the model. Aspect was deemed relevant only in certain situations because of regional variation.

The specific remote sensing outputs were then assessed to determine the thresholds that were synonymous with known rock art site locations. Hill shading/shaded relief, slope, and NDVI were all assessed against the known site data of the MARA database site in order to determine these thresholds.

The MARA site data was used to extract the common data ranges or thresholds that known rock art sites occur within. These thresholds were then applied to other areas to determine if they related to other possible site locations. If these thresholds identified areas with other rock art sites or potential rock art site locations, they would be indicators of site potential.

The thresholds were identified by overlaying the site data onto the slope, shaded relief, and NDVI that form part of the predictive model. By identifying these thresholds, the thresholds excluded areas that were irrelevant as they contained no site data.

After the thresholds were identified the different data components were then processed in ENVI to slice the data and, therefore, excluded any unlikely[8] areas. Upon the completion of the data slicing the different components were then imported back into ArcGIS 10.2 to incorporate the data into a weighted output which would compile the different sliced datasets into one combined output.

Subsequent to the data being sliced and re-imported into ArcGIS, the percentages of sites per class were identified to determine the mean, median of the data classes to show whether the class would be assigned a uniform weighting, or if specific aspects within the sliced data would require higher weightings.

[8] The term unlikely areas refer to the areas that fall outside the predetermined statistical threshold. This may be due to areas having slope which isn't identified as being steep enough or having a shaded relief value either exceeding the minimum or maximum threshold identified.

The remote sensing components were then added to the weighted overlay and assigned their relative weightings which were used to create an output map which showed potential rock art site features.

Areas of the output map were then tested against known site locations to determine if the model was accurate and able to predict known rock art site locations. The next stage was testing to see if the model would be successful or not by ground truthing the predictive model in unsurveyed areas in the Matatiele region. The Sehlabathebe National Park was selected as the secondary test area and used to determine the percentage of features that the predictive model could identify.

The final part of the testing procedure involved testing known sites that were not from Sehlabathebe or Matatiele. Finally, this model is applied to areas that have not been surveyed as part of the research, the model tested the locations of well-known sites in the vicinity to the research areas to determine whether or not the model is applicable to alternate areas.

4.4 Components used for predictive modelling

The remote sensing components that were used in this predictive model were selected to cover a broad spectrum and, therefore, maximise the likelihood of locating potential rock art sites. The logic behind the model was to attempt to model the landscape, which is theoretical if features of the landscape can be replicated within a model. Certain features of the landscape can be replicated by remote sensing data such as the use of DEM's to recreate the topography.

The different components were all tested against the known site data compiled from the MARA database in order to identify the thresholds of these sites, and so that they could be replicated. The threshold range was identified in the following way:

Equation 4.1 Calculation for the threshold maximum

$$Threshold\ maximum = Mean + Std\ Deviation$$

Equation 4.2: Calculation for the threshold minimum

$$Threshold\ minimum = Mean - Std\ Deviation$$

The aforementioned formula was used to calculate a minimum and maximum extent for the thresholds and then applied to the data during the slicing stage, whereby the data was processed in ERDAS Imagine to remove areas of unwanted pixels that were uncharacteristic and unsuitable for rock art sites. The sliced partitions were then assigned values based on the mean of the specific remote sensing component. This statistical approach aimed to replicate the mean areas that were associated with rock art sites. The partitions were prioritised so that the partitions nearest the mean had the highest values and partitions closer to the minimum and maximum extent had lower values. Although rock art sites are found outside of these thresholds, the combinations of thresholds aimed to exclude areas that had lower potential than others. Because some rock art sites have uncharacteristic features, the thresholds were used to maximise the likelihood of locating the majority of sites based on the mean values.

4.4.1 Normalized Vegetation Difference Index

The NDVI was applied in ENVI (ENVI 5.0). The process required the analysis of the red and the infrared bands of the SPOT 6 imagery. This process compared the absorption of chlorophyll in the red (R) band and the reflection of the mesophyll in the infrared (IR) band.

$$NDVI = \frac{Infrared - Red}{Infrared + Red}$$

Equation 4.3: Formula to calculate NDVI (Campbell 2008, Lasaponara and Masini 2012: 27)

The NDVI was effective because it analysed areas with vegetation cover as well as those that are barren. Identifying the exact thresholds of the NDVI and rock art sites provided a good base to exclude irrelevant areas.

4.4.2 MARA database and Site Record Sheets

Compiled from site record sheets for the sites found to date, the MARA database is the record of the existing sites from the Alfred Nzo and Joe Gqabi region of the Eastern Cape, South Africa. The data obtained from the site record forms were inserted into the database. Initially[9], the database as of 2012 had a total of 119 sites of which 106 contain rock art, the remaining 13 are other archaeological sites which include stone walled sites, Later Stone Age scatters, and more. The database provided a substantial record for the characteristics of sites in the region, and as the surveying continued, the database was and still is continuously updated and expanded. The non-site areas are provided by the existing track log. The database contributed to the model by providing the site characteristics and locations of rock art sites that are required to formulate the thresholds of the different data components.

The MARA database provides a diverse representation of rock art sites across the Matatiele region. The majority of sites are what could be considered as mountainous sites, however, there is still a range of low-lying sites which add to the diversity of this site register. This database was, therefore, more than adequate to create data slice thresholds to delineate and exclude areas of low potential and even more applicable when trying to predict rock art sites within the mountainous terrain. Owing to the similarity in nature of the terrain of Sehlabathebe National Park, the MARA database was seen as an accurate representation of rock art in a mountainous terrain to be used to predict rock art potential but determining

[9] To date the MARA database contains 206 archaeological sites, 176 Rock art sites and 30 archaeological sites.

whether the thresholds were applicable to the SNP region or not could only be seen after the testing was complete.

4.4.3 Hill/Relief Shading

Hill shading, as discussed by Horn (1981), Zhou (1992), and Hobbs (1999) can be used to display topography on a two dimensional image. Hill shading can be used to create a three dimensional representation of a map by adding shadows based on hypothetical lighting from a specific angle and altitude of the sun. The hill shading analysis uses the SRTM DEM because the SRTM DEM has the best vertical resolution for a DEM in South Africa.

The hill shading analysis focuses on identifying areas that are indicative of rock shelters or similar rock features. Areas of lower shades represent flatter terrain, whereas darker shades indicate steeper terrain. Therefore, by identifying steeper terrain areas that are not consistent with the surrounding areas it may provide a geomorphological proxy for identifying rock shelters. The indicators could include: areas with a sudden drop that is indicative of a rock shelter or a sheer rock face and secondly, areas that are adjacent to sudden drops in elevation being flat.

4.4.4 Slope

The slope parameter was expected to be the most reliable component of this model due to the nature of where rock art sites are found. Due to their locations in steep mountainous terrain, characteristics like slope can eliminate flat areas which do not correspond with known site locations. The known site data was used to identify the thresholds of slope. Two thresholds were used for slope, the one that is applied to all other variables, and then another threshold that takes into account the maximum slope values. This is to accommodate sites occurring in steeper conditions, which have higher slope values that were excluded using the initial threshold. The second threshold calculation for slope was refined to include all areas of the lower range of the threshold calculation like other variables but needed to include the maximum range for the slope to include sites that occur in steep areas.

Rock art researchers would not expect to find sites within the Alluvial Formation because it is flat and has no outcrops, this is also true for the valley bottoms where very few shelters are located. However, buttresses and other features occurring within these flat areas are reflected on the slope maps and contain possible rock art site locations. The slope is valuable because it is the best means for discriminating between flat areas and those which are not. This means of discrimination is vital as it excludes all areas of terrain which were unsuitable. Flat areas are excluded however in some cases boulders are located in flat areas as they roll from steep areas into adjacent flat areas and come to rest.

4.4.5 Predictive Modelling

Based on the assessment of the aforementioned case studies, different predictive models can be applied. However, with the numerous data sources and components that can contribute towards the effectiveness of the model, the weight of evidence model allows the researcher to control weightings of the components according to importance in accordance with terrain and the assigned thresholds. As the predictive model needs values prioritised, certain components impact on site location more than others.

Specific remote sensing components focus on select characteristics of a landscape, in order to ascertain which attributes of this landscape could be effectively incorporated into a predictive model.

Outlining the process and how it was computed is important in a methodological study such as this to demonstrate how it may be replicated. Listing the exact processes that were undertaken during the methods of a research project will assist other researchers in trying to implement the same processes.

4.4.5.1 The procedure

The steps that were taken throughout this research are listed in order below. The method initially created the different components from the datasets. These components were then tested to identify the statistics for the distribution of sites across the research area. The individual components were then imported into ERDAS Imagine (Erdas Imagine 9.1) to slice

the dataset and remove the unwanted portions that were irrelevant for locating rock art sites. Once the data had been sliced and it was then exported from ERDAS and reimported into ArcGIS. This process was completed for each of the components. Once all the components were imported into ArcGIS, they were added to the 'Weighted Overlay'. The weighted overlay was used to compute the overall predictive model, therefore, the different components were assigned values during this stage to prioritise the different components that had a higher influence on the presence of geomorphological features. Once the weighted overlay was computed, the output map showed the distribution of areas that were expected to contain possible rock art sites and areas without. The final stage tested whether the areas predicted to contain rock art actually correlated with known site data.

4.4.6 Applying Predictive Models to Alternate Areas

A problem encountered in most predictive models occurs when the researcher attempts to apply a predictive model to an alternate area. This is because so many models are regionally specific and, therefore, are not successful when applied elsewhere. Models become regionally specific because many of the characteristics included are based on landscape features which are inherently specific to that region such as vegetation type, geology, topography. This model was not created with the intention of being regionally specific, however, the unique nature of the different components that form part of the model enforce this regional drawback. Although some models are more regionally specific than others, models that focus on specific attributes that are environmentally constant are likely to be replicated and thus more successful.

An example of how site distribution changes with landscape is seen across four separate regions within Lesotho (Smuts 1983, refer to: Table 3.1: 32, Table 3.2: 33, Table 3.3: 34, Table 3.4: 34). Exposure is a problematic characteristic listed by Smits (1983) as it is not explained to demonstrate what it actually refers to. Secondly, much of the ARAL compiled data has been outstripped by powerful remote sensing tools and imagery. As this research was compiled during the 1980s, there are much newer more powerful tools available to researchers today which are capable of providing the same results at a higher resolution.

Aspect is useful for determining site usage, however, there is no substitute for field work as the aspect from within a rock shelter can differ from the general aspect of the hillside.

Secondly, aspect is a regionally specific attribute of this research as can be seen in the ARAL distribution of sites against aspect (Table 3.4: 34). Aspect is determined by the underlying drainage system and especially in regions adjacent to the Maloti-Drakensberg Mountains the drainage system is perpendicular to the escarpment. Therefore, if the Maloti-Drakensberg faces east, the runoff from the escarpment would be in an easterly direction and the valleys below the escarpment would run perpendicular and therefore, the aspect of the hillsides on either side of the valleys are north and south. The discussion of site use will follow in the subsequent section based on how aspect affects seasonal usage of sites.

Although the landscapes might vary drastically, it needs to be understood that possible site distribution is affected by landscape however the site choice is determined by the human agency. For example, numerous possible rock shelters can occur throughout a landscape that could be potential rock art sites, however, because of human agency, only a select few were chosen as rock art sites. Therefore, the presence of rock art within a rock shelter is a conscious action and reliant on the human agency for it to occur.

The distribution of sites across varying features provides an insight into the problems that a researcher implementing a predictive model may encounter. This problem can be rectified by the application of a broad range of remote sensing components.

4.4.7 Weightings

Assigning weights to the different remote sensing components is non-trivial. Firstly, the researcher had to determine what factors affected the presence of geomorphological features and then determine what other characteristics would affect site selection. Two factors were seen to determine the locations of areas that could contain rock shelters or similar features and these are: slope and the presence of ideal geological formations such as Clarens Sandstone Formation and Elliot Sandstone Formation. The combination of these two factors was able to limit areas that were unlikely to contain rock shelters but also promote areas of the higher likelihood for the existence of rock art sites (however, the resolution of the geological data for this model was unsuccessful at 1:250 000). Further aspects that were believed to impact site selection included elevation, NDVI, aspect, shaded relief.

The biggest determinant for the location of rock shelters is the geology. Two specific sandstone formations were identified as having the most impact on the research area, these include the Clarens Sandstone Formation and the Elliot Sandstone Formation. The Clarens Formation is probably better known for the presence of rock shelters as it was known as Cave Sandstone Formation however Elliot sandstone also has numerous shelters present. Molteno Sandstone is a further sandstone formation that has shelters and rock art. However, the Molteno Sandstone Formation has received less surveying and is not as widely distributed as the Elliot and Clarens, and is limited to lower lying areas to the south and south-east of Matatiele. The distribution of sites within the Molteno Formation was therefore not a true representation of the geomorphological features because of the limited number of sites located within the Molteno Formation.

With the sandstone formations widely regarded as the most likely areas to contain rock art sites, any modelling procedure would assign these areas the highest values and focus on locating these areas first. Other geological formations contain rock art sites but not to the same extent as the sandstones. Alluvium is a geological formation that has been noted to contain rock art sites, although these sites are more likely located on sandstone lenses occurring within the general Alluvium Formation. The basalt formation has a lower potential for rock art sites owing to the limited discovery (Vinnicombe 1976; Pinto *et al.* 2014), however, the areas with intercalated Clarens Formation are likely to contain rock shelters or other related features. All these different components are taken into consideration when weighting values for the weight of evidence model.

Table 4.1: Geological Breakdown for MARA Rock Art sites

Geology	Sites present per geological formation	Percentage of sites per class
Alluvium	6	5.66
Basalt	1	0.94
Basalt w/t sandstone	0	0.00
Clarens	30	28.30
Dolerite	5	4.72
Elliot	51	48.11
Molteno	8	7.55
Tarkastad	5	4.72

The slope is a factor that determines where sites are likely to occur. It is not an indicator of site selection but rather an indication of areas that could contain rock shelters and similar features such as boulders, rock faces etc. After evaluating the distribution of rock art sites against slope, it was identified that there are areas that are more likely to be used than others. Although initial expectations were that the steepest areas (>29˚) were used more than less steep areas whereas areas of intermediate slope (10˚-29˚) were used most.

Table 4.2: Breakdown of slope for MARA sites

Slope˚	Breakdown of sites per class	Percentage of sites per class
0 - 9.99	10	9.52
10-19.99	41	39.05
20-29.99	46	43.81
30-39.99	8	7.62
40-49.99	0	0.00
50-59.99	0	0.00
60-69.99	0	0.00

The site data from the MARA database was used to determine the distribution of archaeological sites against the different remote sensing components. Tables showing the distribution of sites against the different components were used to determine the percentage of sites and this was then used to determine the exact weighting of the model to enable the best possible outcome.

The next step involved identifying whether aspect affected known site selection. Smits (1983) showed how aspect was irrelevant in their study of the rock art of Lesotho, and the availability of rock shelters and smooth rock faces to paint on where more important.

Aspect was assessed as it may have had an impact on site selection. The distribution of sites was, however, rather generalised with sites occurring in a range of different aspects. Although it must be noted that due to the general topography of the area and the nature of the escarpment, the natural drainage direction of the escarpment changes from Qacha's Nek to Mount Fletcher and, therefore, the aspects of the shelters on either side of the valleys

would change as well. At Qacha's Nek the drainage direction is southerly whereas nearer to Nene Gate the escarpment curves south and the drainage direction is south-east at this curve and finally from Ongeluks Nek towards Mount Fletcher the direction of drainage is easterly.

Aspect turned out to be of less relevance to the modelling procedure, while, it may be of use on a more local scale whereby the dominant drainage direction won't change. The drainage direction is not of importance to this research, however, the drainage direction affects aspect of the valleys which contain the rock art sites.

Table 4.3: Breakdown of MARA sites against Aspect

Aspect	Breakdown of sites per class	Percentage of sites per class
0-44.99	13	12.38
45-89.99	19	18.10
90-134.99	21	20.00
135-179.99	15	14.29
180-224.99	8	7.62
225-269.99	13	12.38
270-314.99	8	7.62
315-360	9	8.57

In areas between Qacha's Nek and Nene Gate, the drainage is southerly, therefore, sites occur predominantly on east and west facing slopes, whereas the drainage nearer to Nene gate and Pack Ox Nek is south easterly and, therefore, sites occur predominantly with aspects of Northeast or Southwest. Finally south of Pack Ox Nek towards Mount Fletcher the drainage is easterly, therefore, sites occur on either north or south facing slopes.

A further comment is required on aspect as most of the surveying for the MARA database occurred between Qacha's Nek and Nene Gate, the prevailing drainage systems run predominantly north to south and, therefore, the majority of shelters would be east or west facing. Consequently, any assumptions that take aspect as a possible indicator of site selection in this study have to be aware of the local terrain before doing so as this affects the aspect of rock shelters. Other points to take into consideration include the possibility of sites having seasonal usage, for example, south facing sites being used in summer due to cooler temperatures and North facing shelters in the winter months.

NDVI was seen to have a possible influence in locating areas of exposed rock and thus possible help with locating rock art sites, however, with the sites occurring in such a broad range of conditions there was a minimal correlation between the location of sites and specific attributes of the NDVI. The range of values was however useful at discriminating against certain areas that were considered unlikely to have rock shelters.

Table 4.4: Breakdown of MARA sites against NDVI

NDVI	Sites present in class	Percentage of sites per class
0-0.099	9	8.57
0.1-0.199	17	16.19
0.2-0.299	49	46.67
0.3-0.399	50	47.62
0.4-0.499	20	19.05
0.5-0.599	6	5.71
0.6-0.699	8	7.62
0.7-0.799	0	0.00
0.8-0.899	0	0.00
0.9-1	0	0.00

Elevation was the first characteristic to be evaluated against the MARA database. The sites were distributed amongst four classes and showed a possible preference for site choices. The majority of sites occur between 1300-1800m above sea level. Although this could show elevation as an indicator of site selection, it must be noted that majority of surveying occurred between 1200 and 2000 meters, thus owing to the lack of sites at higher or lower elevations. A secondary aspect to take note of is that elevation is related to the geological strata, therefore, the areas that contain the most sites are also the areas that contain the most suitable geology for shelters to occur.

Table 4.5: Breakdown of MARA database against shaded relief

Elevation	Breakdown of class	Percentage of sites per class
300-499	6	5.71
500-699	14	13.33
700-899	19	18.10
900-1099	17	16.19
1100-1299	31	29.52
1300-1499	13	12.38
1500-1699	4	3.81
1700-1899	1	0.95
1900-2099	0	0.00
2100-2299	0	0.00

4.5 How the models were applied?

The MARA database with all known rock art sites located prior to the start of surveying in 2013 was used to determine the initial site thresholds against the remote sensing components. This initial survey data was then used to construct the individual components that were used to model for sites within the MARA survey area. Subsequent to surveying these areas, all new sites that were located were then used to reverse model for the original known sites of the MARA database. In some instances, variations in the threshold values allowed for models to have higher as well as lower potential areas. These higher potential areas focus on the mean values of the thresholds, whereas, areas of lower potential constitute threshold values that are further from the mean are thus less likely to have potential.

Upon the completion of the MARA data models, the thresholds identified were then applied to Sehlabathebe National Park. The entire park was surveyed as part of the UNESCO Survey. The thresholds for the Sehlabathebe were then applied to the MARA region to determine if there were possible improvements that could be applied to the thresholds.

The last stage of the modelling procedure was to test the cumulative model – comprised of the MARA and Sehlabathebe survey data – to some well-known sites that fall into the area covered by the remote sensing data.

4.6 Comments on the initial models

The initial predictive model formulated from remote sensing outputs (slope, shaded relief, and NDVI) was the first combination to be tested for predictive ability. These initial models looked at identifying the thresholds and excluded data that existed outside of these thresholds, these areas would represent the areas of highest likelihood based on MARA 2012 data thresholds. The model and all others to follow were scrutinised by the MARA database. The testing stage looked at identifying the most likely breakdown of remote sensing outputs or weights of these outputs that were able to best replicate and identify areas within similar threshold values. The initial combinations looked at applying equal weights to the different remote sensing outputs, however, it was seen that slope was the most effective at isolating potential rock art site locations.

The initial weightings were also set to exclude background values from the model because they occurred outside of the threshold range. However, a problem encountered was that the slope threshold was excluding too many areas from the output model. Due to the critical nature of the slope threshold, it was decided that it needed to be expanded to include a wider range of slope values. The range of slope values that were mentioned in Table 4.2: Breakdown of slope for MARA sites 72 is discussed in the coming subsection.

Inspecting the initial weighted output compiled on the data thresholds set out by the MARA 2012 site data, the predictive model analysed three different weightings to test the effectiveness of the model. These weightings looked at the application of near equal weightings to each of the remote sensing outputs (slope 34%, shaded relief 33%, and NDVI 33%). The second weighting looked at using the higher rate of discrimination of the slope and gave equal values to the shaded relief and NDVI (slope 50%, shaded relief 25%, NDVI 25%), the final weighting looked at including the effect of aspect to see if it had any relevance to the presence of rock art sites within the model (aspect 25%, slope 25%, shaded relief 25%, NDVI 25%). These weightings were only possible with the expanded slope threshold as excluding the background would classify only the areas within the slope threshold. By expanding this threshold then allowed other variables to occur outside of their initial thresholds.

4.7 Fieldwork

The research applied foot surveys to the Matatiele region under the auspices of the MARA programme and these surveys covered a large portion of the region in a systematic fashion from Qacha's Nek border post towards the Ongeluks Nek border post. Although surveying had taken place throughout this region there were still noticeable areas that needed completion. Prior to 2012, surveyors were not required to log their tracks as part of the MARA mandate. The track logs are what constitute the surveyed areas and as can be seen in Figure 9.1: 153 there were areas that had no track logs with known site locations.

The database used to model consisted of 106 rock art sites of which 80 could be classified as high lying – located in the valleys below the escarpment – and a further 20 sites – located in low lying areas. These low lying areas are not within the valleys below the escarpment and therefore, provide a diverse sample that can be used to model. These 106 rock art sites were located up to the end of December 2013.

MARA sites prior to 2012 were located using ground survey teams working in a systematic manner walking up and down both sides of a valley in an attempt to locate rock art. During 2012 the introduction of a Google Earth derived survey method was used to identify areas that looked promising for rock art sites. Thereafter, the MARA programme moved away from the intensive walking survey to a more focused survey trying to identify areas that could contain rock art sites based on features identified in Google Earth (Pugin 2012).

Subsequent to this, the MARA programme employed a local survey team to continue the survey throughout the area and this team was able to cover a substantial portion of the research area. However, the survey tracks were accidentally overwritten on the GPS and, therefore, some gaps still exist. Fortunately, some tracks were saved and are displayed in Figure 9.1: 153.

Upon the development of a successful model, this research looked at surveying areas adjacent to previously surveyed regions (yet to be surveyed but were seen as having the potential for possible rock art site locations). The adjacent areas included regions with high and low potential to determine if rock art sites occurred outside of the threshold range. By locating sites outside these thresholds allowed for adjustment before applying the model to Sehlabathebe.

The survey data from the UNESCO World Heritage Survey within Sehlabathebe National Park, Lesotho provided an opportunity to test an area that had been surveyed exhaustively by the survey teams in order to locate all the rock art within the park.

4.8 Conclusion

The methodological process led to the production of a model that is able to predict a percentage of known rock art site locations. Whether this model is able to predict further possible site locations is where it will succeed or not. Remote sensing has been successful and shown that individual components have assisted in identifying areas that do contain known rock art sites. Initially, slope and geology were identified as the main indicators of rock features like boulders, rock shelters and overhangs. However, the inclusion of data such as NDVI, shaded relief have aided this process and added extra components that discriminate areas that have low potential.

The exclusion of the geological maps due to limited spatial resolution and the supervised, unsupervised classifications could have impacted negatively on this study, but the other components were more than effective in identifying the areas of interest. The geological map combined with slope provided positive results and was able to identify areas that were initially identified as problematic. Although it was able to achieve these results there can be no guarantee about the accuracy and resolution of the geological data and therefore, it could not be included. Future predictive models could include geological data, provided the resolution was at an acceptable level and if it had the required accuracy. In that case, it would be successful.

Initial results of the output data indicate certain trends and early results show that certain processes are more effective than others. Initial expectations were that some processes were more beneficial than they actually were as is the case with the supervised and unsupervised classifications. Conversely, assessing an aspect of the sites and using similarities of the two research areas may shed light on local site preference.

Chapter 5: Results

Rock art sites may occur within similar rock features, however, there are numerous sites that do not contain rock art at all. Therefore, any understanding that can be achieved as a result of the findings of these models would be of great value to rock art research. Thresholds calculated for the MARA 2012 database were used as a starting point for all modelling procedures. The testing of the models was done using the known site locations to identify the percentage of sites that occur within predicted areas. The distribution of rock art sites against the different weighted output models for the MARA 2012 database allowed for the identification of the thresholds, which were used and contributed towards the improvement of the models being applied to the other research areas.

Initial thresholds were amended to allow for the positive identification of rock art sites within the MARA database and then the thresholds were applied first to Sehlabathebe National Park and then to surrounding random areas as a further test.

Breaking down the individual remote sensing components provides insight to how the distribution of sites could be affected by the thresholds of the dataset and, therefore, adjust them accordingly before being applied further. The individual remote sensing outputs that are assessed include slope, shaded relief, NDVI, and aspect for each dataset/research area starting with the MARA 2012 dataset, then focusing on the resultant MARA 2013 results, and finally looking into the effects of each remote sensing output for Sehlabathebe National Park. The differences in each characteristic were assessed to see how the distribution of sites vary across the different research areas whilst paying particular attention to how these values differ from the original values of the MARA database.

This was followed by the comparison of the research areas and how these characteristics for each model contributed and affected the success or failure of this research. Finally, the combined threshold dataset is analysed against 31 random site locations in the vicinity of Sehlabathebe to test the regional variability of this research.

5.1 The Individual Thresholds

5.1.1 MARA Database

The distribution of rock art sites across the MARA research area displays the distribution of the MARA sites against different terrain categories. A large percentage exist in areas below the escarpment as well as many others in lower lying areas and this demonstrates the distribution of known sites overlaid against the painted relief. This representation shows the importance having site data in order to calculate the thresholds of sites throughout the different mountainous terrain. The painted relief map is overlaid with all MARA sites found prior to or as part of this research.

The model assisted with identifying three major regions for surveying; Phuting, New Stands, and Military Hill; all of which have high site densities. Although these regions would have been surveyed as part of the systematic survey, based on the output predictions, these areas were prioritised for surveying sooner than they would have been surveyed if the original methods were still in place.

As proof of the findings of the predictive models, some of the findings of the subsequent surveys are placed in the appendices.

5.1.2 Slope

By using the MARA sites as of 2012, a representative sample distribution of 106 rock art sites were used to analyse the occurrence of known rock art sites against an area likely to contain other rock art sites. The application of the aforementioned threshold equation (Equation 4.1: 65; Equation 4.2: 65), afforded the research the opportunity to determine the slope that refers to areas that correspond most with areas with known rock art site locations. Therefore, replicating areas that are most relevant based on environmental characteristics.

	MARA 2012	MARA 2013	MARA Combined
Mean	19.63	19.45	19.57
Standard Deviation	7.39	5.97	6.93
Threshold Minimum	12.24	13.48	12.64
Threshold Maximum	27.02	25.43	26.50
Minimum	1.41	7.22	1.41
Maximum	38.47	31.17	38.47

Table 5.1: Slope values for the MARA research areas.

The range of slope values from the different datasets within this research, show that the MARA 2012 database is and was representative and provided an acceptable initial slope threshold range for the other sites to occur within (Table 5.1: 81). The presence of rock art sites shows the relevance of this threshold Figure 9.14: 166.

Due to its larger standard deviation, the initial threshold accounted for the sites located during 2013. This broad range was an acceptable base and included a percentage of outliers that broadened the standard deviation. The 1.5 expansion to the slope threshold was a good adjustment that included an increased percentage of sites (Figure 9.15: 167). Prior to the expansion, slope was discriminating acceptable values that were of relevance to rock art site locations.

Initial thoughts and expectations were that slope values would not be constrained by a maximum threshold, however, depending on the area and the topography, the values of slope are determined by the overall terrain. The slope threshold is determined by the standard deviation and therefore, certain steeper values will be excluded from occurring outside of the target threshold. The slope is the main constraint for where rock art sites can occur as rock shelters require a slope to be eroded in order for the overhang or shelter to occur.

The presence of steeper areas within the Alluvial Formation is one such way the slope output excels at limiting areas with the right terrain features. The majority of the area shows the underlying painted relief output which reflects areas with a slope value of less than 4.980°, which includes flat areas synonymous with flat alluvial plains.

The second component to consider is the data range that is selected by the slope threshold, these values are reflected by the red and purple values, whereas the blue values show the

varying degrees of slope that are excluded by the slope threshold. The majority of sites in this area fall into the threshold values set out by the slope slice (Figure 9.15: 167).

The data slice for slope removes a substantial portion of the research area based on the statistical breakdown, these areas are, therefore, less likely to contain rock art.

Areas below the escarpment are steep enough to be considered within the threshold, however, the alluvial plain discussed previously, which is reflected by the substantial white area, (Figure 9.15: 167) and is excluded because it is flat or near flat and has no sudden changes in slope indicative of areas with possible site characteristics.

The slope slice was the biggest discriminant because the thresholds identified were able to exclude the majority of areas which were unlikely to contain rock art sites (Figure 9.15: 167). The areas that are excluded are all areas with values that occur outside the slope threshold and these include all flat areas, along with the extremely steep sided values that could potentially contain rock art sites.

The expansion to the slope slice allowed for further discrimination without excluding the crucial areas that are seen to correspond with rock art sites (Figure 9.15: 167). The expansions also discriminated flat areas that are of little importance to the research. The slope slice was one of the only variables to exclude background data because the expanded threshold covered an adequate range.

5.1.3 Shaded Relief

The second characteristic assessed is the shaded relief and this displays a different trend when compared to the slope thresholds. This is because the MARA 2012 dataset has a greater mean value and a smaller standard deviation compared to that of the MARA 2013 sites (Table 5.2: 83). The combination of the MARA databases does, however, provide a sample which is adequate for areas below the escarpment of the Maloti-Drakensberg. The higher mean for the MARA 2012 dataset relates to a higher maximum threshold, which exceeds that of the MARA 2013 sites. The MARA 2013 values do not differ drastically from the MARA 2012 dataset and when combined to see the entire MARA dataset reflects how similar the two datasets are.

Table 5.2: Shaded relief values for the MARA research areas.

	MARA 2012	MARA 2013	MARA Combined
Mean	1009.75	936.68	985.40
Standard Deviation	314.43	336.48	322.73
Threshold Minimum	695.33	600.20	662.66
Threshold Maximum	1324.18	1273.16	1308.13
Minimum	398.00	351.00	351.00
Maximum	1716.00	1540.00	1716.00

The shaded relief slice displays how the shaded relief can be used to discriminate areas for rock art potential (Figure 9.16: 168). The majority of sites occur within the threshold, and the threshold excluded areas above the escarpment, which is based on the threshold values all occurring below the escarpment. However, the minimum and maximum values do not occur within the range, and therefore, this contributes towards the inclusion of the background data.

This threshold does limit the specific areas from the model but not to the same extent as the slope threshold. Due to the presence of sites within a broad range, the model included the background data of the shaded relief threshold. These areas are optimised by incorporating the other remote sensing components.

5.1.4 NDVI

Although the MARA 2013 has a broader threshold, it is based on the occurrence of rock art sites in areas with higher NDVI values thus contributing to the greater maximum values and greater maximum threshold values.

There are a few possibilities for the slight variations between the different datasets. Firstly, the MARA 2012 dataset is composed of sites that occur in lower lying areas some of which could occur in barren areas or areas with poorer vegetation. Allowing for the lower minimum values, of the NDVI threshold. Secondly, the MARA 2013 dataset has some of the higher NDVI values for the research and this is due to the sites found in the vicinity of black wattle forests and clumps of trees adjacent to the rock shelters (e.g. Malithethana Source 6).

Table 5.3: NDVI values for the MARA research areas.

	MARA 2012	MARA 2013	MARA Combined
Mean	0.25	0.46	0.32
Standard Deviation	0.08	0.10	0.14
Threshold Minimum	0.16	0.37	0.18
Threshold Maximum	0.33	0.56	0.45
Minimum	0.00	0.07	0.00
Maximum	0.69	0.66	0.69

These greater values also increase the mean of the MARA 2013 dataset substantially. These maximum values add to the representative nature of the combined dataset, therefore, expanding the likelihood of a predictive model identifying areas that occur closer to the extents of the threshold.

Based on the above thresholds, the NDVI slice was less critical at excluding areas than the slope slice, because the NDVI threshold that was used to create the NDVI slice covered a broader range of values (Figure 9.17: 169). The majority of NDVI values largely exist within or near the extents of ranges set out by the maximum and minimum threshold. The majority of areas that were excluded were steep areas that coincide with Lesotho Highland Basalt Grassland, which occurs on the slopes of the escarpment. These areas have exposed Drakensberg Basalt Formation or soil with little or no vegetation cover that has reflected low NDVI values.

The NDVI thresholds show that areas adjacent to the escarpment fall into the maximum extent of the threshold, whereas the minimum threshold exists more above the escarpment and in further low lying areas below the escarpment. The NDVI slice does not discriminate areas as much as other processes because of the vast range of values that occur at the sites. However, due to the minor correlation that exists it does contribute towards the greater model. The data slice for the NDVI excluded fewer areas than other processes, such as slope, due to the NDVI's broad ranging threshold. Therefore, the values of the NDVI threshold needed to cover this broader spectrum and focus on the mean and less on the data extents.

The NDVI extended threshold was a supplementary approach that was used to increase the predictive potential of the output model and second; to increase the areas discriminated

as part of the model (Figure 9.18: 170). By expanding the maximum and minimum thresholds by 150%, this includes a broader spectrum of values. By applying this slice along, with excluding background data during the weighting procedure incorporated more relevant areas but excluded areas that were of little potential.

Comparing the differences between the thresholds of the MARA 2012 and 2013 area discrimination, the MARA 2013 dataset discriminates areas based on the greater threshold values. The areas that are represented in the MARA 2013 threshold occur in regions that contain rock art sites as can be seen in (Figure 9.6: 158). The MARA 2013 slices discriminated areas that are unlikely to contain rock art, such as the alluvial plain (Figure 9.3: 155; Figure 9.4: 156. Although NDVI covered a wide range of values, the major part of the area discrimination occurred when combined with the slope slice to exclude areas of little relevance.

5.1.5 Aspect

Aspect initially was identified as a component that varied substantially and was of little use to this research for predictive purposes. However, the distribution of sites is valuable as it can lend to the discussion surrounding seasonality and provide an idea as to when certain rock art sites may have been used. The aspects that fall within an acceptable range between the mean and the standard deviation demonstrate the areas that are considered favourable for occupation. The possibility of seasonality and seasonal occupation will be discussed further in the ensuing section.

Table 5.4: Aspect values for the MARA research areas.

	MARA 2012	MARA 2013	MARA Combined
Mean	152.69	123.78	143.05
Standard Deviation	97.79	92.51	96.74
Threshold Minimum	60.17	54.90	46.31
Threshold Maximum	245.20	250.48	239.79

The aspect slice is selective but includes the vast majority of the MARA research area (Figure 9.19: 171). The threshold includes most of the valleys, as the majority of the valleys

head south-east and have sites that occur on either side of the valley which face north east or south west. The aspect slice does exclude just over half of the possible aspects.

The aspect threshold for the MARA region could provide some interesting points to discuss. The mean aspect of 143° could suggest that there is a possible preference to paint in rock shelters with a south easterly facing. The possibility of seasonal site usage could be discussed further as certain aspects could have been preferential at certain times of the year, but not others.

It was thought that aspect would have an effect but only in specific areas and that is based on the nature of the terrain and position in relation to the escarpment. Comparisons for the aspect between the MARA research area and Sehlabathebe should either support or contradict this claim.

5.2 The Predictive Model based on MARA 2012 dataset

The modelling stage involved testing multiple different combinations of components to determine which was the most successful. Success is determined not only by the percentage of sites successfully identified but also the portion of research area excluded. Therefore, a model that successfully identifies a high percentage of sites but fails to discriminate other areas from surveying is considered a failure.

The threshold (Figure 5.1: 87) was hypercritical and needed broadening to be practical. The initial model discriminated the majority of areas and needed improvement because of its poor predictive potential and inability to locate known site locations. Subsequent to updating the slope threshold the weighted output for the MARA research area was reapplied in the *Model Output 2*, the update to this component of the weighted output improved the amount of known sites located within areas of potential from 22% to 51.4%.

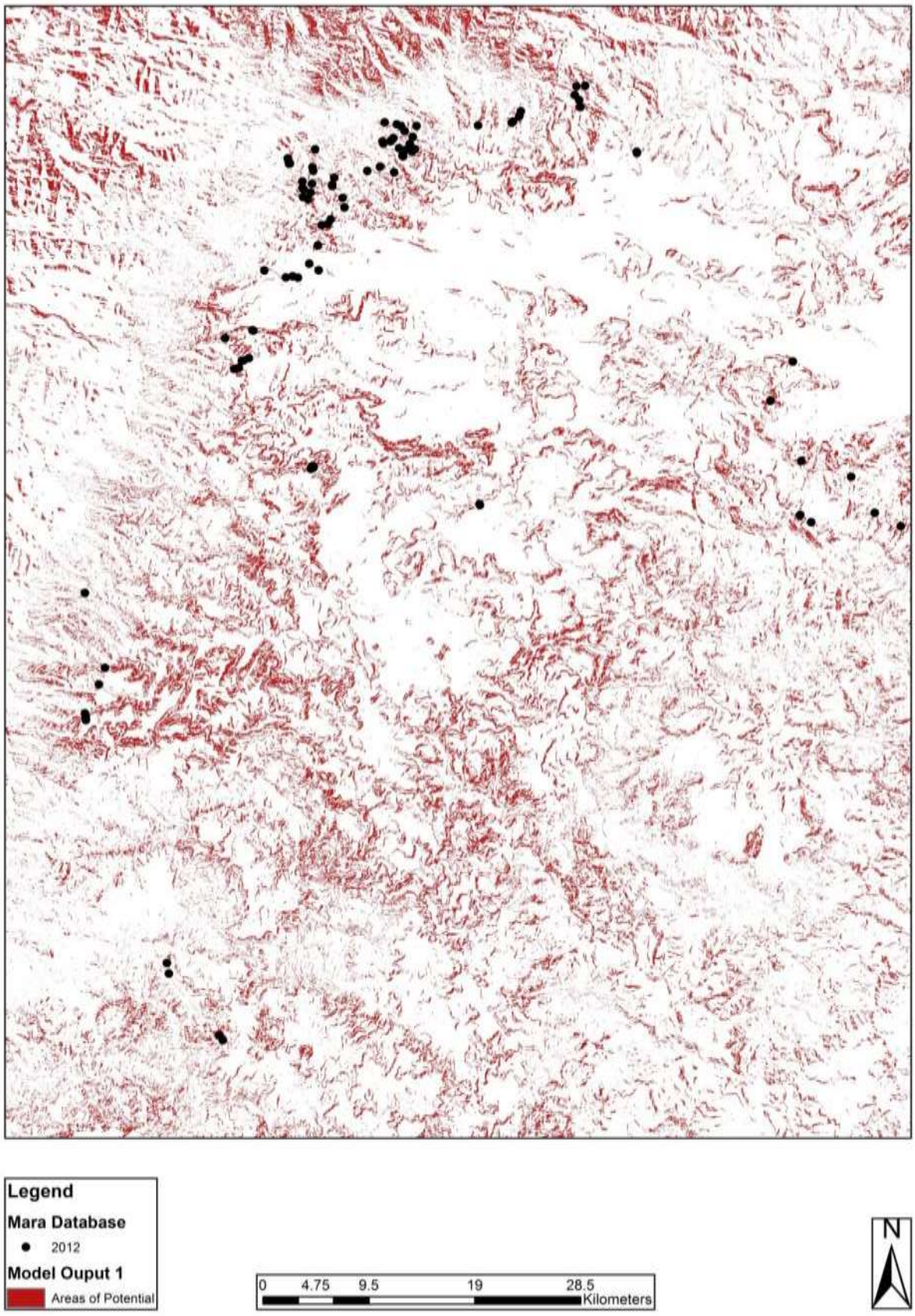


Figure 5.1: Model Output 1 with near equal value weightings and individual remote sensing components background data negated, white background reflects areas with null values.

The two expansions that were applied to the slope thresholds were meant to increase the likelihood of rock art sites occurring within the threshold. By doubling the standard deviation of the slope, the threshold range was too broad as it included values as small as 1.627771 and provided ‘blanket coverage’ of the region, identifying far too many areas to possibly survey based on potential.

To isolate areas of steepness (Figure 5.2: 89) demonstrated the lack of effectiveness at identifying and reducing areas that required surveying, due to the broad threshold selected.This slope threshold was successful at identifying 98% of known rock art sites because of the broader threshold, however, due to excluding background data, Figure 5.2 was only able to identify 51.4 % of the sites.

The *Model Output 2* Figure 5.2: 89 emphasised the need for an intermediate slope threshold and secondly, the need to include background data or to expand the shaded relief and NDVI thresholds to the same degree as that expansion applied to the slope.

Although it was thought that the slope was the main reason for this poor distribution, it was discovered that it was, in fact, the exclusion of background data. The lack of sites predicted is a result of site threshold values occurring within one or two of the remote sensing components but the third value occurred outside the range and, therefore, was excluded. Identifying which dataset values occurred outside of the range allowed for future manipulation, thereby increasing the success of the other model equations.

The third version of the MARA output turned out to be more successful as it focused on a smaller slope threshold (8.63°-30.61°) and included the background data for the NDVI and shaded relief slice but assigned lower values for areas occurring outside the thresholds. The MARA output model was able to identify an improved percentage of sites as it located 69.8% within areas of high potential and a further 16.9% if the sites occurred within lower potential areas, which is a substantial improvement on the 51.4%. The improvement in the slope threshold allowed for this increase in the final output model and facilitated the exclusion of a substantial portion of the research area.

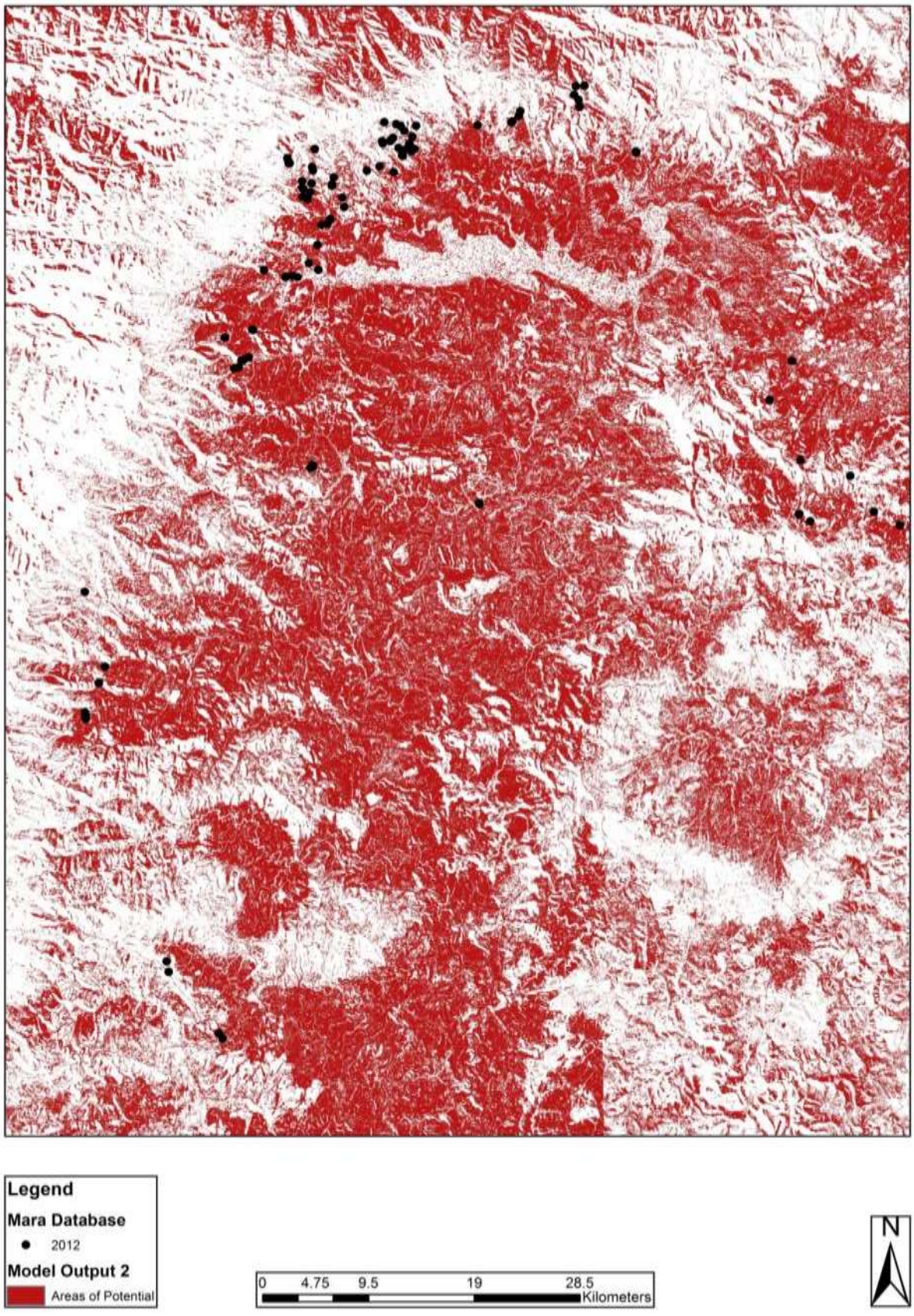


Figure 5.2: Model output 2 with doubled slope thresholds and individual remote sensing components background data negated, showing so called 'blanket coverage', white background reflects areas with null values.

By analysing the distribution of sites against the different models, the shortcomings of the individual models were identified and improved upon. Although the intention was to identify the best possible thresholds based on the initial MARA 2012 data, the occurrence of sites outside of these thresholds is welcomed as they expand the threshold range and improve the likelihood of future sites falling into these thresholds.

Although all the models delineated areas of potential, it was of relevance to identify which set of thresholds returned acceptable results for future predictions. It was also noted that due to the exclusion of the background data for both shaded Relief and NDVI, this contributed to this model only identifying 51.4% of sites. The Output Model 1 was seen as a failure as it was only able to positively identify 22% of the sites, and second, it discriminated a large portion of the research area.

The *Model Output 3* (Figure 5.3: 91) was reliant on the thresholds that were expanded and excluded for modelling processes. This allowed for a more streamlined approach that took into account the broad nature of values for both NDVI and shaded relief.

Excluding the background data of the slope allowed for the threshold to be maintained without disturbing the output with fuzzy results that could obscure the final model. Applying a 1.5 expansion to the thresholds of NDVI and shaded relief was tested in the next version of the output model, in an attempt to reduce the areas of potential.

By applying increased weightings to areas with values that occur within the NDVI and shaded relief thresholds, *Model Output 7* effectively discriminated areas by selecting the least pixels of the models and positively identifying 68.98% of the MARA 2012 rock art sites (Figure 5.4: 92). Although the objective was to use the expanded thresholds of the NDVI, the background values were important to contribute towards the larger success of the model.

The expansion of NDVI values contributed towards the improvement in the model, however, by expanding NDVI in a similar fashion to the slope would allow for more areas of potential to be included, but by excluding the background data, more unwanted areas should be removed.

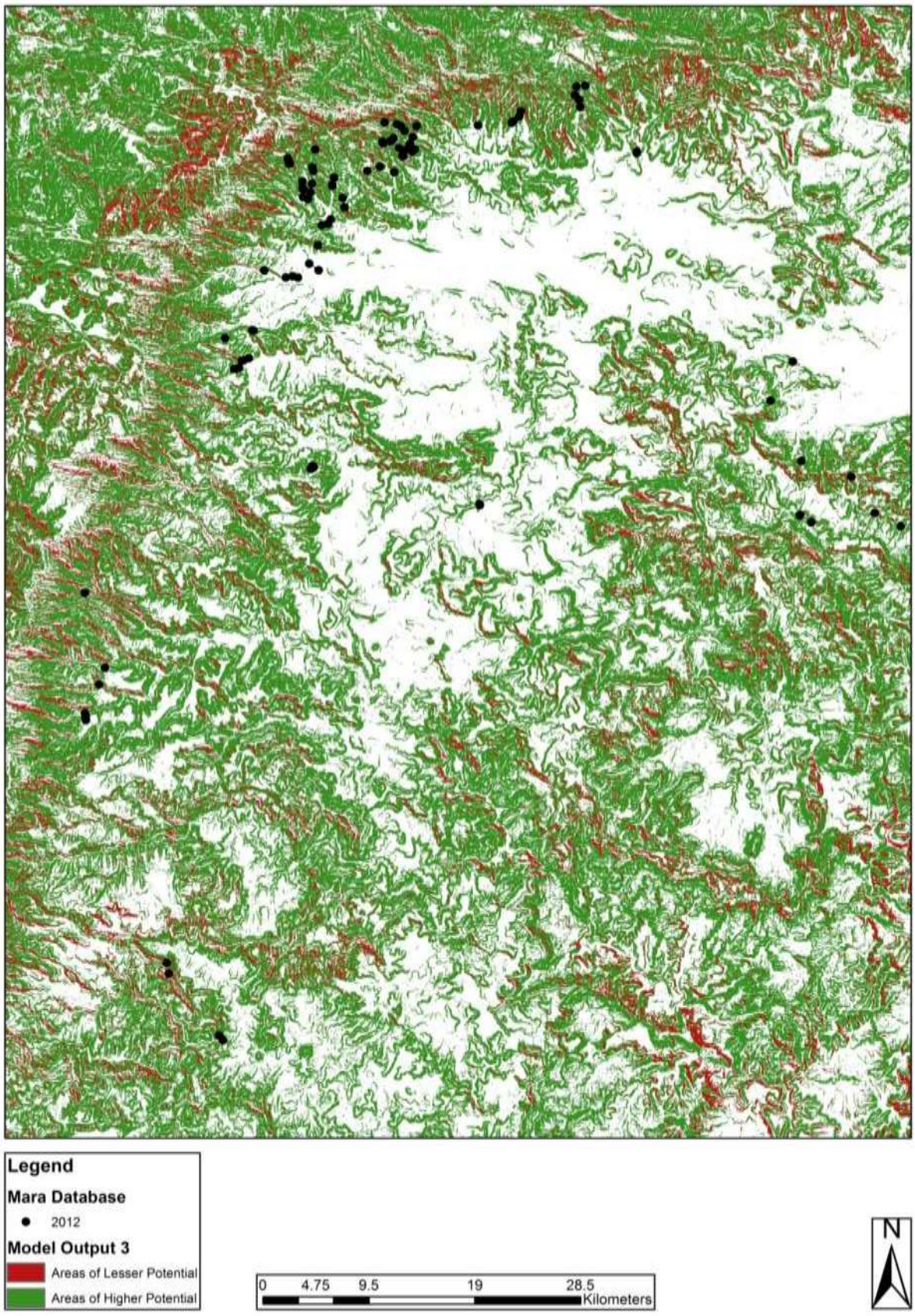


Figure 5.3: Model Output 3 with the 1.5x threshold for slope, individual remote sensing components background data negated, white background reflects areas with null values.

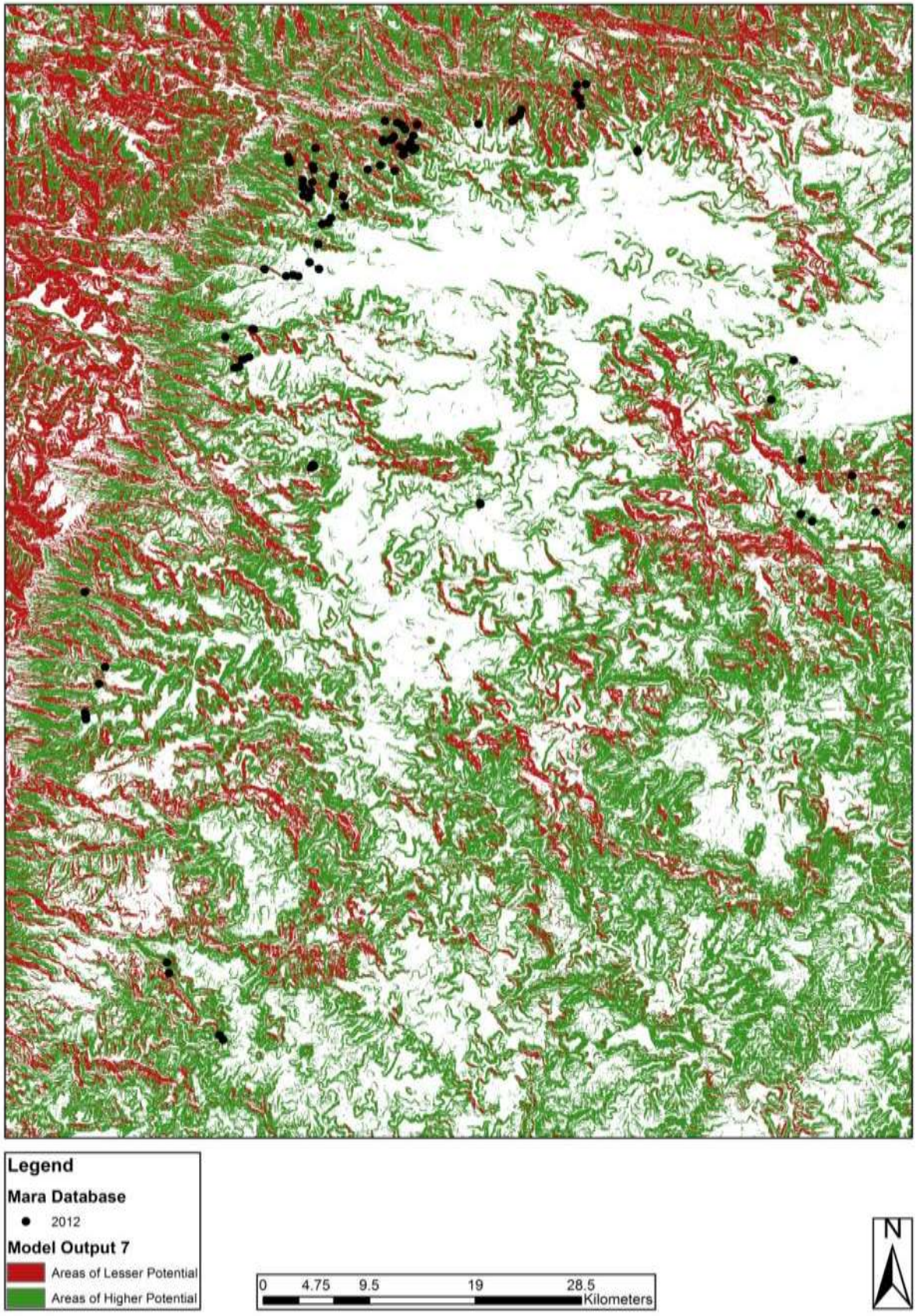


Figure 5.4: Model Output 7 with expanded slope and NDVI thresholds, white background reflects areas with null values.

On completion of the different models, additional surveying was completed. This further surveying added a further 54 rock art sites to the MARA database and this comprises the MARA 2013 dataset. Some of these sites were located using the predictive model to identify areas of potential whilst others were added through systematic surveying.

The success of the different models is displayed in Table 5.5: 94.This shows how each model performed at identifying sites with known characteristics that comprise the MARA 2012 dataset as well as sites with unknown characteristics from the MARA 2013 dataset.

The representation of site distribution demonstrates the effectiveness of each model and shows the likelihood of identifying unknown site location in the future. By analysing the values of the sites located, the following sections will elaborate on the site threshold values for slope, NDVI, and shaded relief in an attempt to rectify or adjust the thresholds to accommodate for the most likely characteristics that are synonymous with rock art site locations. According to the distribution of sites, the *Model Output 9* was the most effective at identifying possible site locations but negated no areas. A few of the other models offered similar results, but the *Model Output 10* and *Model Output 3* identified the second and third highest percentage of the sites and both discriminated a high portion of the area. These models were then applied to Sehlabathebe National Park.

Table 5.5: Breakdown of the initial output models.

Model Name	Subclass	Sites Predicted		Percentage of sites positively identified by model		Percentage of MARA Sites Idenitified	Total pixels predicted as high likelihood	Percentage of reserarch area identified as high potential
		2012	2013	2012	2013			
Model Output 1		25	13	23.58	24.07	23.75	34386903.00	35.25443425
Model Output 2		34	20	32.08	37.04	33.75	14939970.00	15.31688358
Model Output 3	Lower Potential	18	5	16.98	9.26	14.38	33070168.00	33.90447995
	Higher Potential	74	40	69.81	74.07	71.25	13196800.00	13.52973595
Model Output 4		47	28	44.34	51.85	46.88	93080432.00	95.4287151
Model Output 5		47	28	44.34	51.85	46.88	93080432.00	95.4287151
Model Output 6		25	13	23.58	24.07	23.75	37671149.00	38.62153697
Model Output 7	Lower Potential	21	9	19.81	16.67	18.75	52625785.00	53.95345655
	Higher Potential	71	38	66.98	70.37	68.13	11234970.00	11.51841185
Model Output 8		57	35	53.77	64.81	57.50	11177827.00	11.45982722
Model Output 9	Lower Potential	23	8	21.70	14.81	19.38	75509485.00	77.41447882
	Higher Potential	83	46	78.30	85.19	80.63	22029743.00	22.58552118
Model Output 10	Lower Potential	15	2	14.15	3.70	10.63	25080372.00	25.71311309
	Higher Potential	76	44	71.70	81.48	75.00	13995780.00	14.34887305

5.3 Predictive model vs SNP

Applying a predictive model formulated below the escarpment and attempting to apply it to a region that is dissimilar was always thought to be an issue as the likelihood of thresholds for rock art are based on the environment that the sites occur within. The difference with Sehlabathebe is that this area occurs above the escarpment but as an outlier with rather flat slope values, higher shaded relief values and similar NDVI values. Modelling for rock art is dependent on a good starting range of thresholds. Three of the most successful Model Outputs from the MARA research area were selected to model for the presence of rock art within the park.

The ARAL survey of Sehlabathebe located approximately 65 rock sites within the park and it was hoped that the application of one or more of the Model Outputs were successful at assisting the research team in identifying the areas of interest. However, surveying the park as part of the UNESCO World Heritage Survey discovered a total of 105 rock art sites. The Model Outputs success rates were determined based on the percentage of sites located within areas of high potential in the same manner that was applied to the MARA research area.

The three most successful Model Output (*Model Output 3, 7, 10)* combinations from the MARA research area were applied to Sehlabathebe National Park, to map areas of potential for containing rock art sites. The first Model Output that was applied to the national park performed adequately identifying 70 of the 105 (66.66%) within areas of moderate or higher potential areas (Figure 5.5: 96). The Model Output struggled to identify sites outside of the thresholds due to the occurrence of rock art sites on shallower slope values within the park.

The *SNP Model Output 2* (Figure 5.6: 97) performed similarly to the *SNP Model Output 1* as it also identified 70 of the 105 rock art sites, however, *SNP Model Output 2* classified 69 of the 70 sites as higher potential. The model also disregarded the shallower slope values that were classified as outside of the expanded threshold. Finally, *SNP Model Output 3* (Figure 5.7: 98) illustrated the improvement required, as it identified an increased amount of sites. The *SNP Model Output 3* positively identified 76 of the 105 rock art sites as high potential areas and a further 29 rock art sites in lower potential areas. Nonetheless, these lower potential areas include all areas that do not correspond with the thresholds of the Model Output.

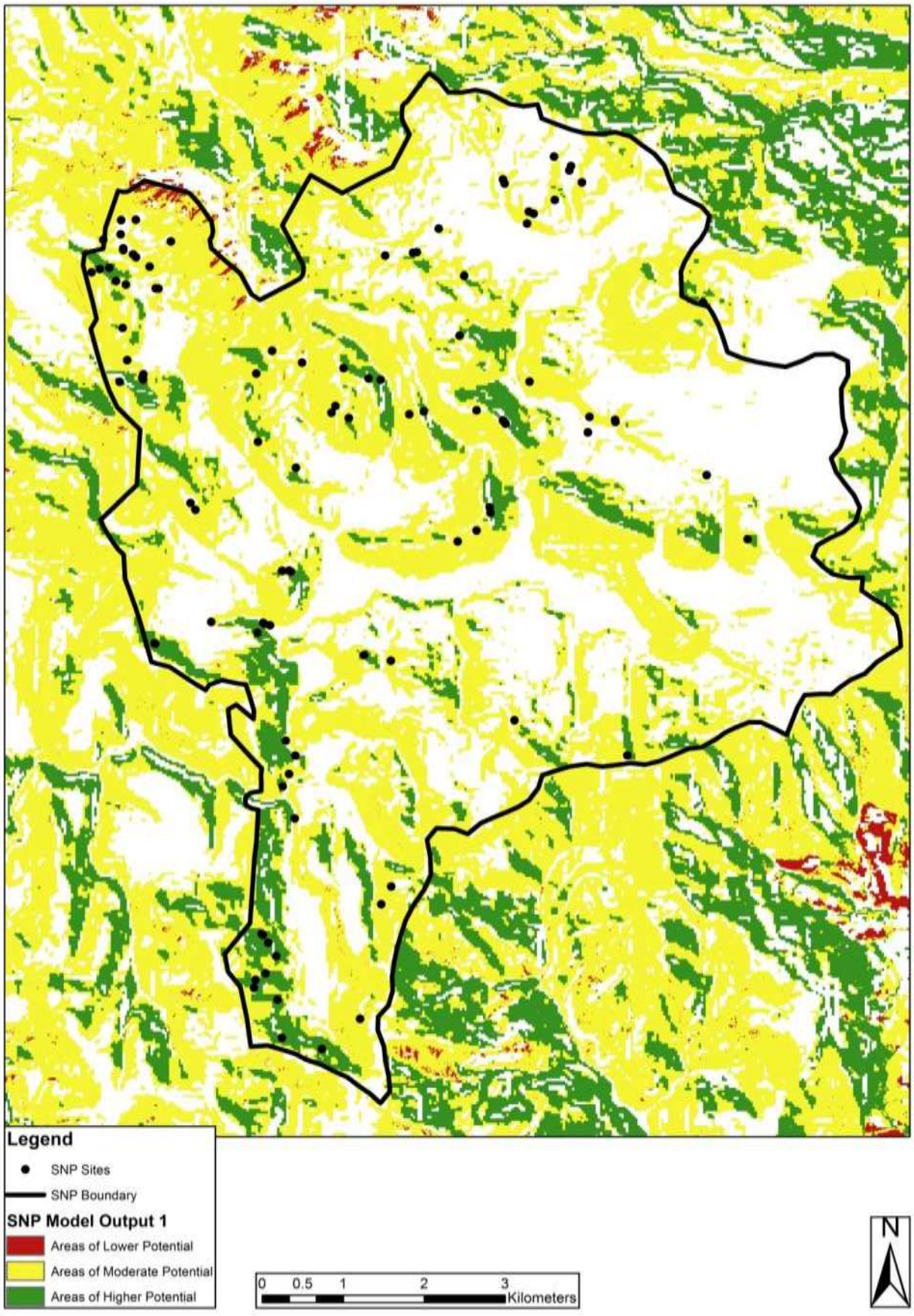


Figure 5.5: SNP Model Output 1, white background reflects areas with null values.

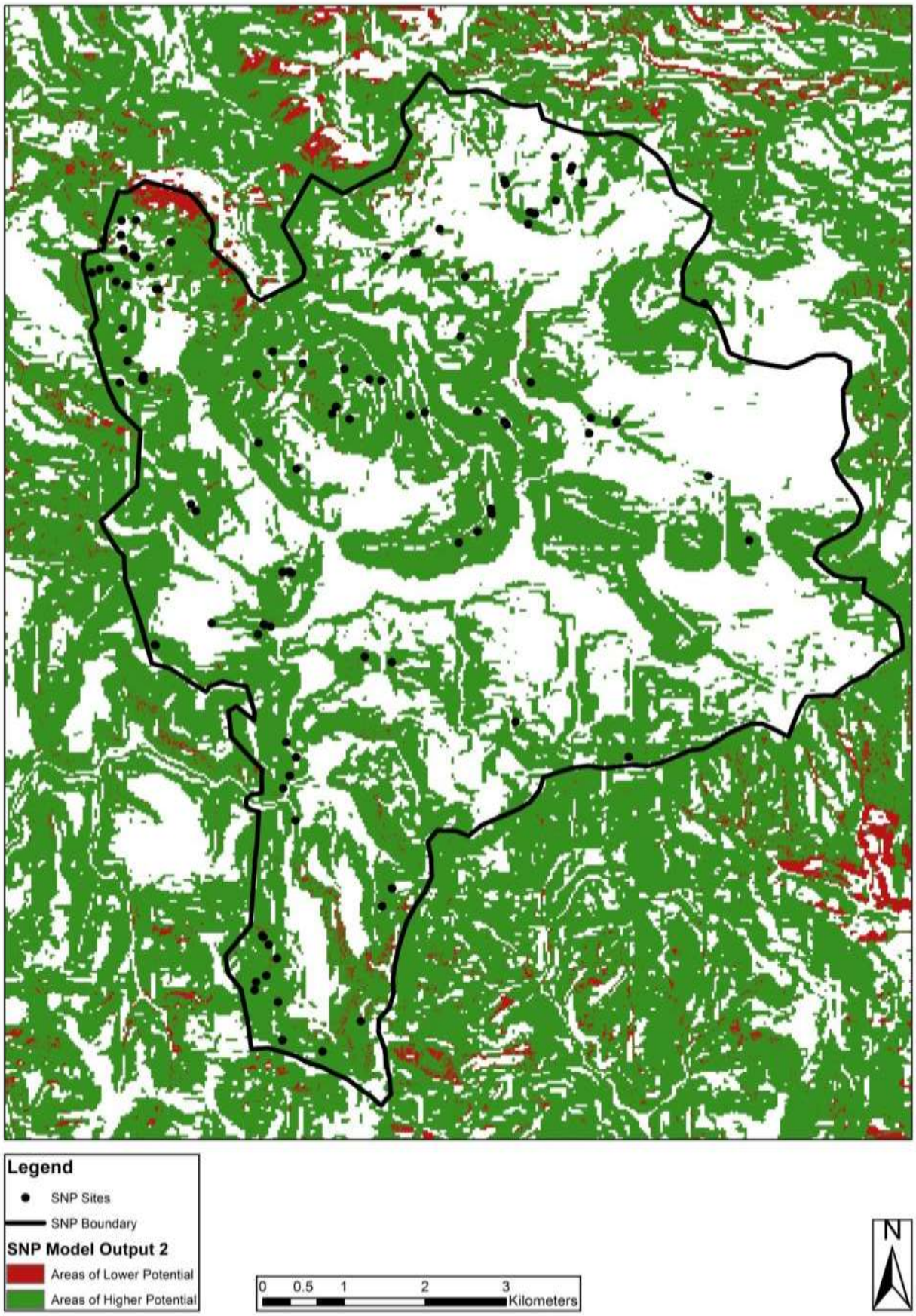


Figure 5.6: SNP Model Output 2, white background reflects areas with null values.

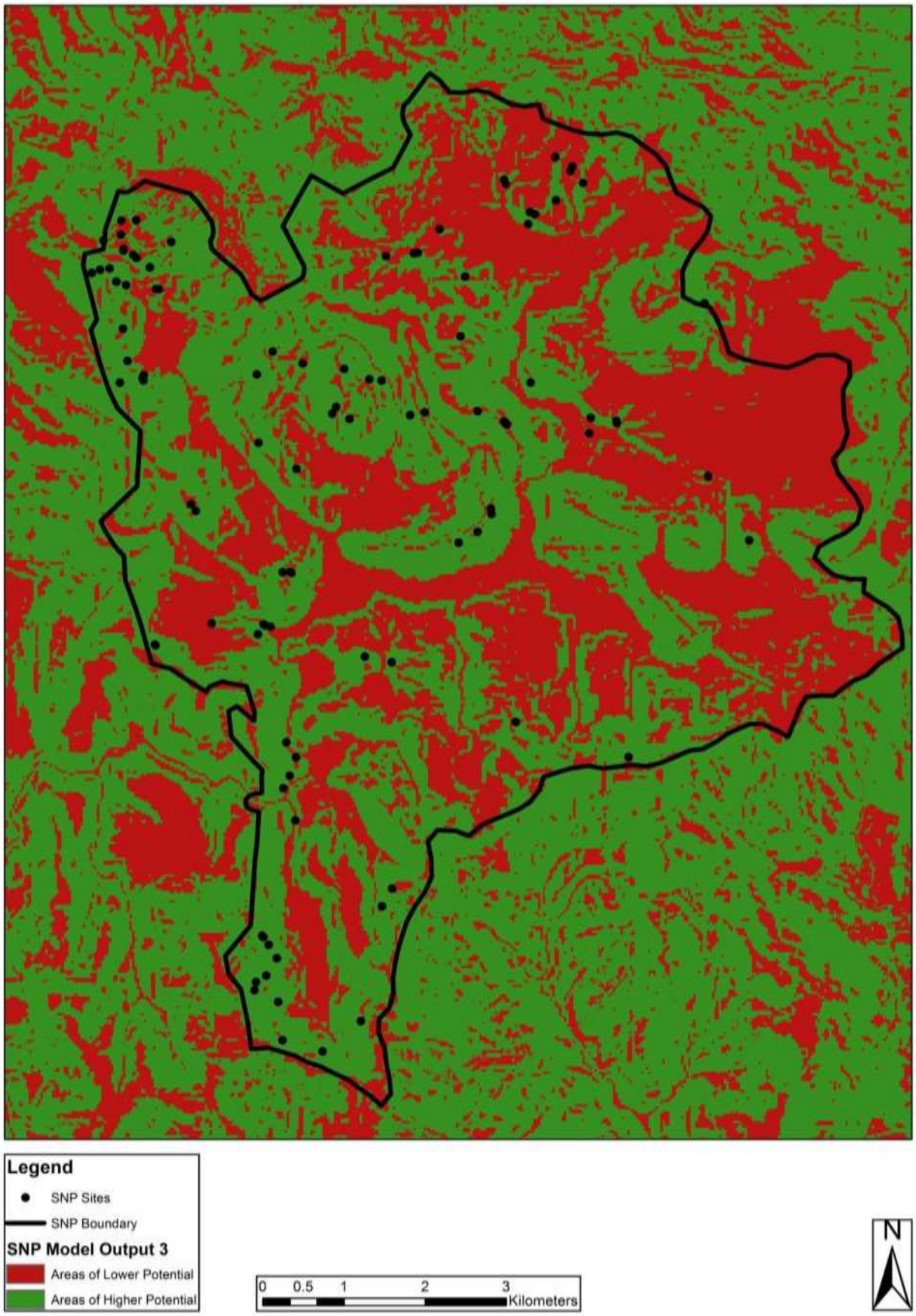


Figure 5.7: SNP Model Output 3.

5.3.1 Slope

The Sehlabathebe National Park sites slope range is much more varied because of the gentle terrain and gradual slope throughout the park. However, certain parts of the park still display signs of sites occurring in steep areas a factor that is illustrated by the larger standard deviation. An observation taken from Sehlabathebe shows the occurrence of large boulder fields to the Northeast of the old lodge which occur in reasonably flat terrain.



Photo 5.1: Image showing nature of terrain northeast of the old lodge, Sehlabathebe. Photo: James Pugin 2015

The general trend is that the majority of sites occur in areas that are not as steep, this is reflected by the lower mean value (16.08° compared to 19.56°). Although some slope values occur outside of these ranges, these ranges have been identified as a diverse sample for mountainous areas with similar characteristics to the Maloti-Drakensberg.

Although the range of sites for Sehlabathebe falls outside of this range, this is expected as the sites are located on the escarpment whereas the MARA sites are below. A change in slope threshold between the original MARA dataset to the Sehlabathebe dataset is seen in the model as certain areas were excluded from the model due to the thresholds identified for the MARA region. Better modelling procedures require better thresholds for the area in

focus because thresholds based on other areas exclude certain areas based on the initial thresholds.

5.3.2 Shaded Relief

The shaded relief threshold values for Sehlabathebe exceeded the ranges of all the MARA values, with certain of the Sehlabathebe values occurring within the MARA thresholds. The maximum threshold values exceed the values of the MARA threshold. The higher values could tentatively be associated with the higher proportion of sites in higher elevation regions. This change in range values contributed to the overall model's success rate within Sehlabathebe National Park and would account for the higher proportion of rock art sites occurring outside of the predicted areas. This is rectified by including the background data of the shaded relief as rock art sites within Sehlabathebe occur over a broader range of shaded relief values.

5.3.3 NDVI

NDVI is the least varied characteristic throughout the different research areas and seems to be comparable for the MARA 2012, MARA Combined and SNP datasets. The NDVI values for Sehlabathebe (0.14-0.44) are less broad and occur within the values of the MARA (0-0.69) research area. The distribution of sites with higher NDVI values for the MARA research area are related to the occurrence of rock art sites within invasive Black Wattle forests.

5.3.4 Aspect

Aspect may offer very little predictive power, but it is of use in determining the common trend that exists between the two research areas. The mean aspects for the MARA and SNP research areas have very similar aspects (143° and 145° respectively). The preference in the two areas is to paint mainly in sites with a south easterly aspect. Although most of the sites occur between north east and south west, the similarity might be based on the general drainage basin and the prevailing direction of run off.

5.4 Predictive model vs random SARADA Rock Art Sites

A final testing component of the research involved testing the most successful predictive models in areas that are unrelated to both the MARA research area and Sehlabathebe National Park. The research was tested against 31 rock art sites in the vicinity of Underberg. These sites fall into a similar terrain that are found in the MARA research area, therefore, it would be interesting to compare how a threshold derived from rock art sites located below the escarpment fares up against the general threshold developed throughout this research.

The three models that were applied to Sehlabathebe National Park were then applied to the surrounding areas with known sites locations. The three models were successful at identifying sites, however, the third model was the most successful identifying a higher percentage of rock art sites but also the least effective at discriminating the areas.

Model	Level of Potential	Sites per class	Percentage of sites identified	Combined Percentage of sites identified	Total Pixels
Further Test 1	Area of No Potential	7	22.58		
	Low Potential	0	0.00		1287666.00
	Moderate Potential	11	35.48		30317354.00
	High Potential	13	41.94	77.42	8501069.00
Further Test 2	Area of No Potential	7	22.58		
	Low Potential	5	16.13		2836541.00
	High Potential	19	61.29	77.42	37269548.00
Further Test 3	Low Potential	5	16.13		14763300.00
	High Potential	26	83.87	100.00	43656565.00

Table 5.6: Comparison of test models

Furthermore, *Further Test 1* and *Further Test 2* identified the same overall percentage of rock art sites for areas of no potential. Additionally, *Further Test 2* identified more sites in areas of higher potential. Although both models identified the same amount of sites the *Further Test* 2 model identified a larger amount of pixels.

In a similar fashion to the models applied to Sehlabathebe National Park, the models are applied using the same parameters and therefore excluded areas in the same fashion. The *Further Test 3* model was the most successful as it identified 83.87% of the test sites. However, it was not extremely critical at discerning areas of potential and due to the threshold parameters and including the background data, no areas were excluded, which resulted in a higher amount of pixels identified.

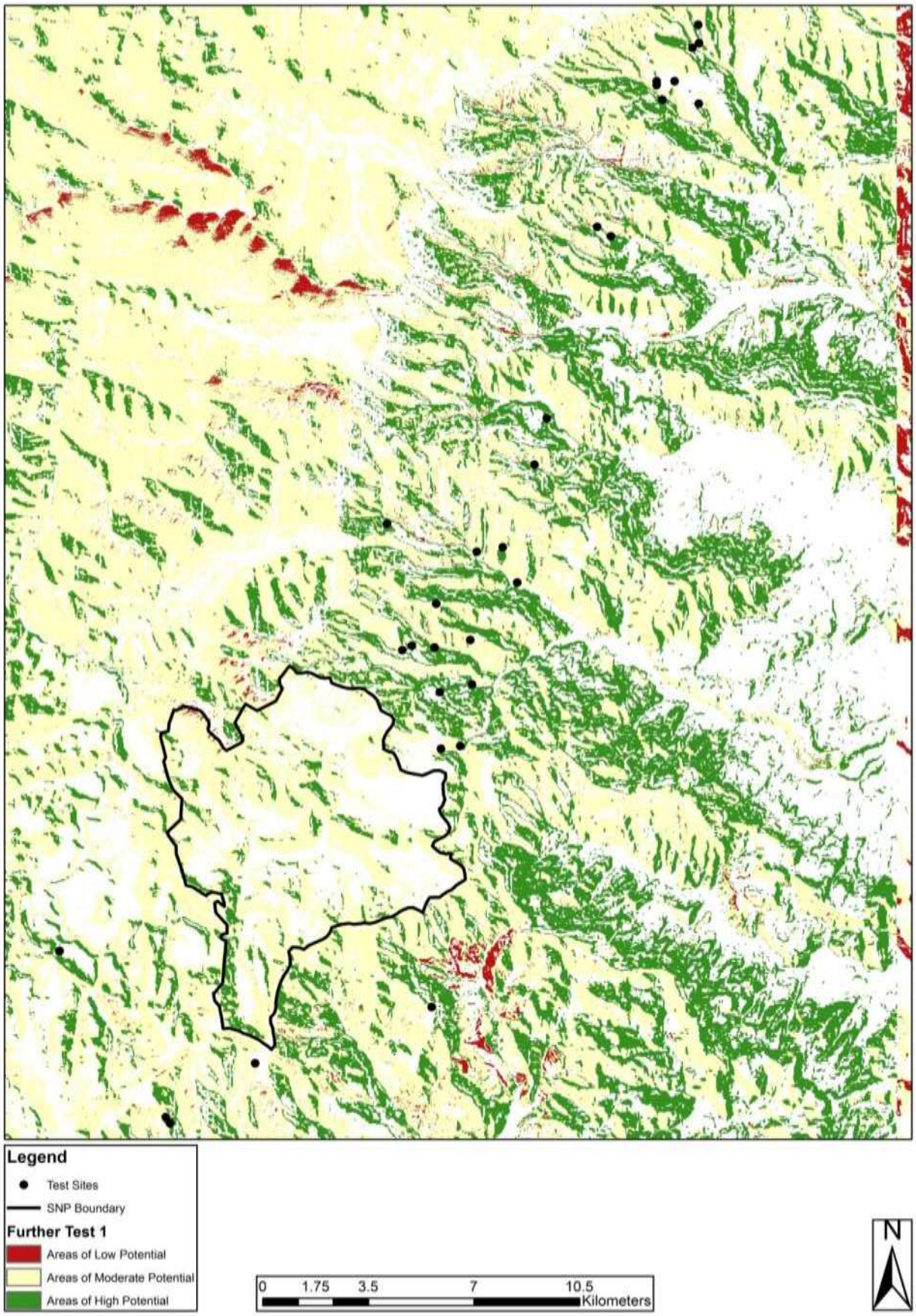


Figure 5.8: Further test 1, white background reflects areas with null values.

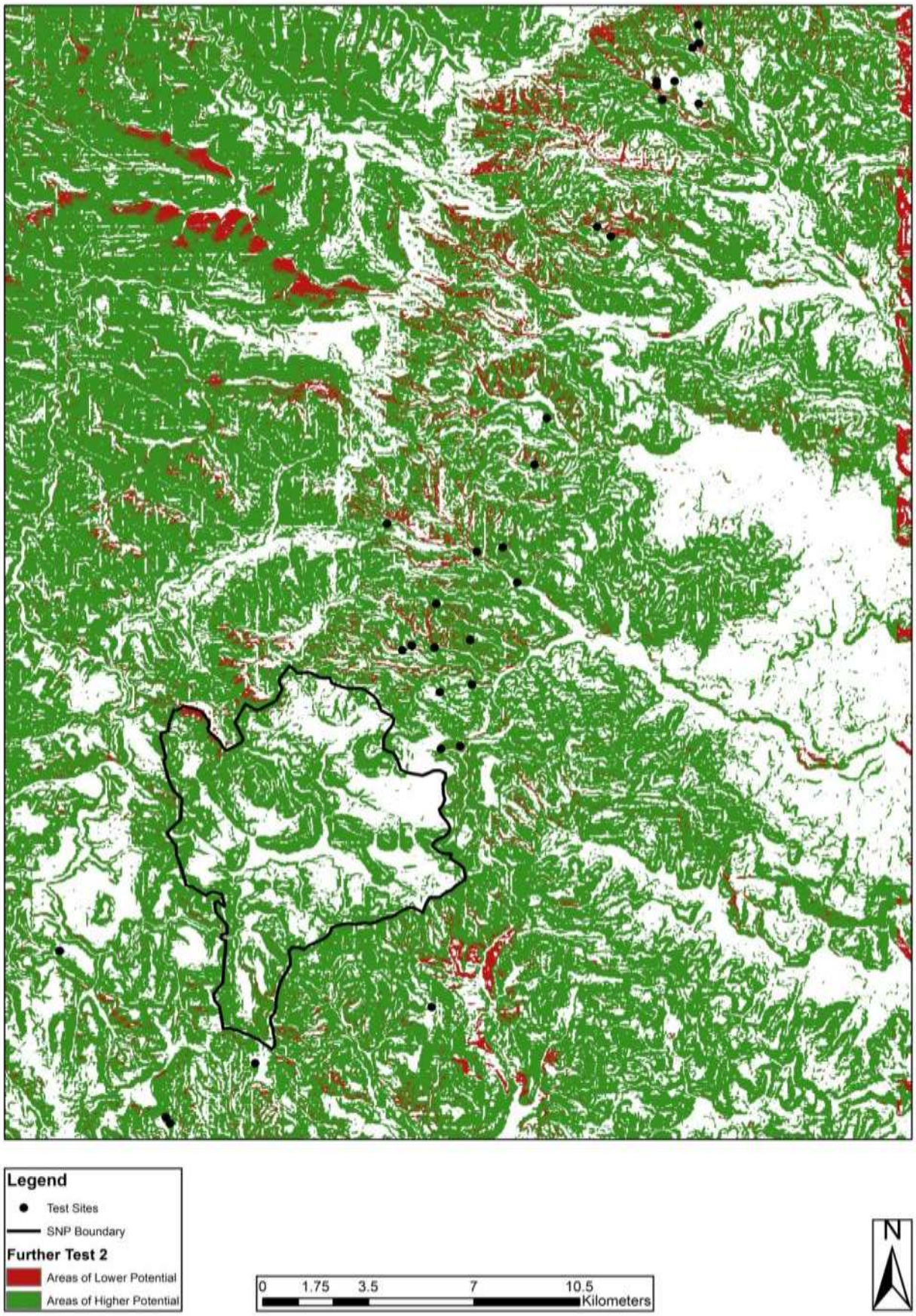


Figure 5.9: Further test 2, white background reflects areas with null values.

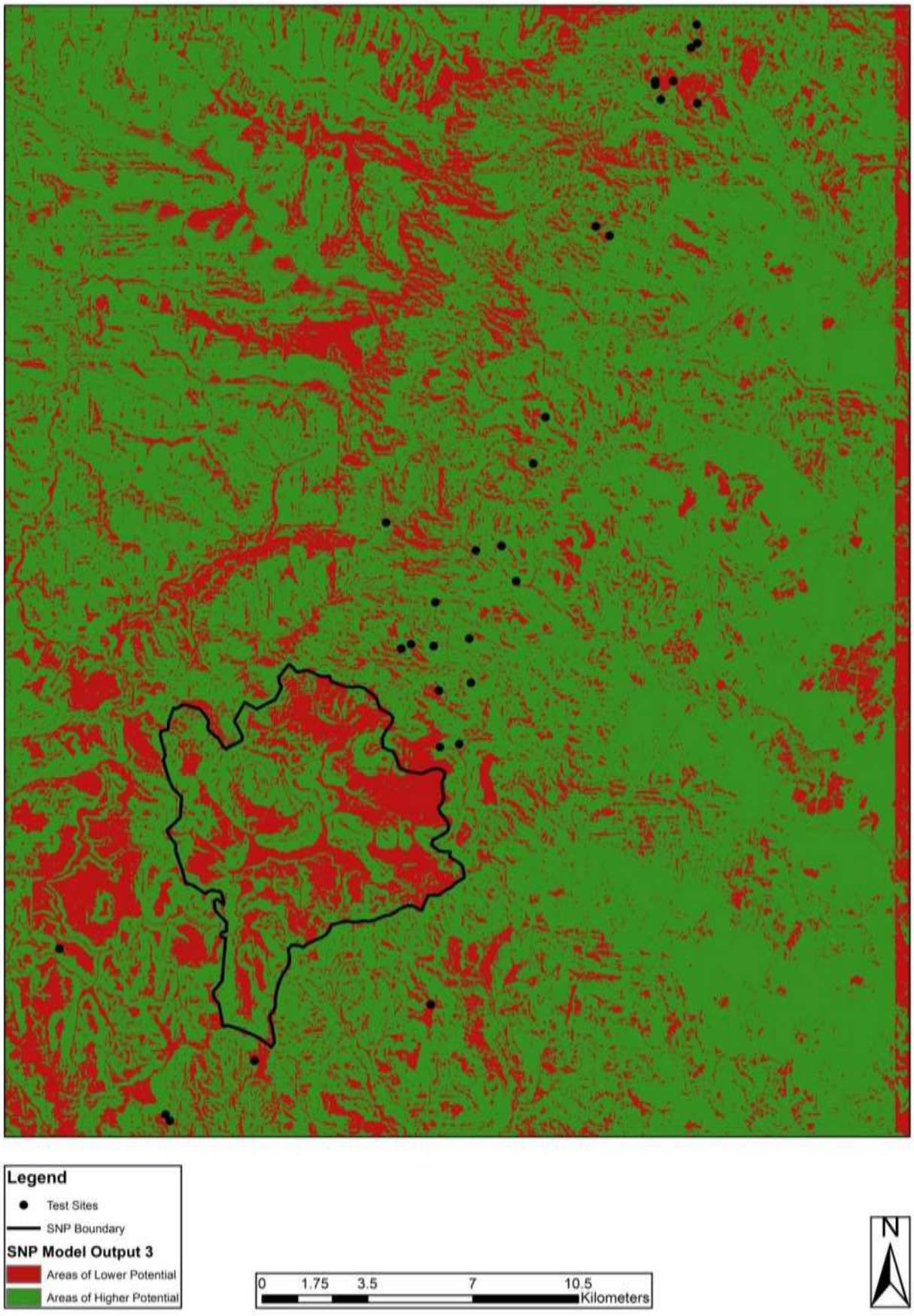


Figure 5.10: Further test 3

5.5 Conclusion

The research presented here set out to measure the percentage of possible shelters or possible rock art site locations that could contain rock art instead of judging against a number of sites found. However, it was found it is better to judge it on the percentage of rock art that falls into predicted high potential areas. By applying the predictive models in more than one area, this research was able to determine the different conditions that affect these models and thus rectify these issues and identify the best threshold ranges to identify the majority of promising areas for containing rock art. The testing of these models in three different areas adds to the strength and adaptability of these models.

Owing to the nature of the formula and principle of standard deviation, only 68.2% of sites fall into the first deviation. Therefore, it was dependent on the inclusion of background data in order to improve the percentage of sites occurring within the threshold range. In all likelihood, sites should and will occur outside of these thresholds and accounting for these outliers is a demanding task.

Determining the possible rock art site locations is a limitation of this research. Understandably, the surveyors can only judge rock art site likelihood by the availability of a rock panel within a rock shelter, which could contain rock art.

Initial thoughts were that the model was applicable to areas below the escarpment and another model was needed for areas above the escarpment. However, by applying the model to Sehlabathebe National Park, and regions surrounding both Matatiele and Underberg, allows this model to test and refine the thresholds on an expansive area. Applying the model to steeper areas predominantly covered in basalt formation may require some further changes to thresholds but at this stage, the models should be applicable to areas along the Maloti-Drakensberg as long as the values occur within similar thresholds.

Chapter 6: Discussion

This study demonstrates the potential of predictive models to rock art studies and archaeology whilst particularly demonstrating their effective application to rock art studies. Although the model focuses on the landscape aspects of rock art research, site locations are inherently situated within this landscape and the approach identifies the characteristics of the landscape that correspond most with known rock art locations. Owing to the range of features that contain rock art sites, this method is capable of identifying the thresholds that are pertinent to housing rock art sites.

This discussion interprets the findings of the research in order to determine whether the research is successful or not. The interpretation will look into how the results were formulated and explain what the results mean, how they can be improved, consider whether the aims of the research were achieved, and to make recommendations for future research to consider.

6.1 Components that were tested but excluded

There were several remote sensing components that were tested as part of the research and excluded either due to a lack of relevance, resolution, or assisting with predictions effectively. These components could have been included in the model but due to one or more of these aforementioned problems would have impacted on the overall predictions and, therefore, decreased the effectiveness of the model. The excluded components were the following; aspect, supervised classification, unsupervised classification, and geological maps. Delving into greater detail will explain why these specific components were excluded.

6.1.1 Aspect

Aspect was excluded due to the large degree of variance that occurs between the different rock art sites. However, unlike the other variables, aspect has shown potential not for predictions but rather for understanding possible site usage patterns and seasonal use or occupation of specific rock art sites. Due to the large variance that occurs, predictions that included aspect excluded some areas of potential just based on the direction that the site faced.

6.1.2 Supervised and Unsupervised Classification

Both classifications offered little assistance to predictions as they lacked the ability to accurately distinguish potential rock art sites from other areas of no potential. By failing to accurately locate rock art sites on their own, there was little point obscuring overall predictive results by including these classifications in the predictive model setup.

6.1.3 Geological Map

A remote sensing component that certainly has the potential for future predictions is the use of accurate geological maps to aid with predicting sandstone locations. The 1:250 000 geological map that was georeferenced lacked the resolution to accurately discern whether areas of the map were Clarens Formation sandstone or Elliot Formation sandstone, although this may not be a problem for a geological map, detailed predictions that rely on accurate data would suffer as a result. The inclusion of high resolution geological data is a component that can contribute towards predictive modelling in the future as long as the spatial resolution is similar to the other remote sensing components.

6.2 The different predictive models

As part of the analysis, different model combinations will be discussed to determine their relevance for rock art surveys, whilst looking at the individual success rates of each model. *Model Outputs 1-5* were applied using the initial MARA 2012 database and subsequent to further surveying the data thresholds were amended to include the thresholds that were formulated from the entire MARA database. The adjusted thresholds included a large range of NDVI and shaded relief values, which were included in *Model Output 6-10* and the *SNP Models*.

6.2.1 MARA Models

6.2.1.1 Model Output 1

The first version of the predictive model looked at including equal valued components that would not include any user bias. Like the following two models, the *Model Output 1* was set to exclude background data that was comprised of values which occurred outside of the thresholds identified. This model lacked the predictive ability due to the majority of sites occurring outside of at least one threshold as this model output was too critical.

6.2.1.2 Model Output 2

The second version of the predictive model looked at including double the thresholds that were identified in the hope of increasing the success of the model. This model provided 'blanket coverage' of the region and was thought to have predicted the majority of rock art sites but similarly to *Model Output 1* the exclusion of background data once again impacted on the amount of known rock art sites identified by the model.

6.2.1.3 Model Output 3

Model Output 3 was the first version of the predictive model to include background data (values that occurred outside of the thresholds) for two components the NDVI and shaded Relief, as well as, an expanded slope threshold. This model immediately improved on the success rate as it was able to identify 69.81% of rock art sites within high potential areas and a further 16.98% of sites within lower potential areas. The model was able to effectively discriminate areas of higher and lower potential as it identified a total of 13196800 pixels within the MARA research area as areas of high potential. The MARA research area contained a total of 97539228 pixels, therefore, this model identified 13.5 percent of the entire research area as having the potential for rock art sites.

*6.2.1.4 **Model Output 4 and 5***

Model Output 4 and *5* looked at including an expanded slope slice but excluding the background data of all the components in an attempt to increase the areas discriminated by the model, but failed due to a lack of sites occurring within areas of high potential.

*6.2.1.5 **Model Output 6***

Model Output 6 failed to identify rock art sites but did include the combined thresholds of the MARA database for shaded relief and NDVI. However, once again the exclusion of background data caused the model to fail.

*6.2.1.6 **Model Output 7***

This version of the predictive model attempted to include the background data of the shaded relief and NDVI but not the background data of the extended slope. This combination proved successful in identifying 66.98% of MARA 2012 rock art sites and 70.37% of the MARA 2013 rock art sites. The model was effective at discriminating areas of potential and identified a total of 11234970.00 pixels.

*6.2.1.7 **Model Output 8***

Model Output 8 looked to build on the success of the previous model by incorporating extended slope and NDVI thresholds and in the process excluding background data. This combination was successful (identifying 53.77 % of the MARA 2012 sites and 64.81% of the MARA 2013 rock art sites) but not to the same degree as the previous model.

*6.2.1.8 **Model Output 9***

In a similar manner to the *Model Output 2*, this model looked at trying to identify all sites but without discriminating areas of potential. By including all background data of the remote

sensing components and extended thresholds for slope and NDVI, *Model Output 9* successfully identified 78.3% of the MARA 2012 rock art sites as high potential areas and a further 21.7 % of the sites as occurring within areas of lower potential. Results for the MARA 2013 sites increased because this model was able to identify 85.19% in high potential areas and a further 14.81% of sites within areas of low potential.

6.2.1.9 Model Output 10

The final Model Output that was applied to the MARA research area included the extended NDVI threshold and background data, the extended slope threshold without background data and the shaded relief threshold including background data. The Model identified 71.7% of the rock art sites as high potential and 14.15% as lower potential for the MARA 2012 database. Assessing the results for the MARA 2013 database showed an increase as 81.48% of sites occurred within high potential areas and 3.7% of the sites occurred within lower potential areas.

6.2.2 SNP Models

The SNP models were formulated using the data derived from the MARA database and predictive models that were applied to the research area. However, because of the location of SNP and the success of models that included the background data, the initial thresholds that were applied to SNP were set to include background data. The three models that were tested were the three most successful models from the MARA survey area.

6.2.2.1 SNP Output 1

By assigning equal values to the remote sensing components and including all background data except that of the slope background data. This version of the predictive model is based on *Model Output 7* from the MARA research. This model performed adequately and identified 70 of the 105 rock art sites within the SNP.

6.2.2.2 SNP Output 2

Continuing the exclusion of the slope background data, the *SNP Output 2* model included background data for the shaded relief and NDVI. The model proved successful in identifying rock art sites within SNP. Accurately identifying a total of 69 sites within areas of high potential and a further site in low potential areas.

6.2.2.3 SNP Output 3

The final SNP model included the background data of all components and assigned lower values to the background data to discern lower potential areas from areas of higher potential. The distinction between higher and lower potential areas allowed for the successful identification of 76 sites occurred within areas of high potential whilst the remaining sites occurred within areas of lower potential.

6.2.3 Test Models

The final testing procedure was designed to test the regional applicability of the predictive model and tested the model against 31 sites in similar environmental conditions to that of the initial models.

6.2.3.1 Further Test 1

The first test model applied to the random sites identified 77.42% of the 31 rock art sites and placed 41.9% of the sites within high potential areas. This model showed potential but when applied to alternate areas it may struggle to identify sites within high potential areas.

6.2.3.2 Further Test 2

The second model based on the same components as the first model achieved the same success rate but it had placed more sites into higher potential areas. This model placed

61% of the rock art sites within areas of high potential but in the process selected more areas than *Further Test 1* as high potential.

6.2.3.3 Further Test 3

The final model identified 83.87% of the rock art sites within areas of high potential. With the overwhelming majority of rock art sites located by this version of the model, shows its potential for being applied to regions with similar environmental conditions. By adapting the threshold that contributes to this model, the regional variability could be further improved.

6.3 Was the research a success?

Initial observation of the success rate of the different predictive models shows that the research is successful. This success is based on the data quality and could be improved in a number of ways. The research had its limitations, and although it was successful, improvements to specific remote sensing components would improve the spatial resolution of the overall predictive model, as this would decrease the pixel size of the predictive model and would have a positive effect on the predictions.

> "Another way to assess the performance of a predictive model is to measure its gain in accuracy over a random or null classification". (Warren & Asch 2000)

Assessing a predictive model such as this can be problematic and whether or not it is successful all depends on the testing procedure. Testing a model like this is based on the testing criteria. In this case, cross validation was used for testing the initial model in three different areas and then using the findings of these areas to manipulate the thresholds strengthened the model and improved the accuracy of the overall research. With a systematic rock art survey, there is an expectation of finding all rock art sites because the surveyors will walk up and down a valley whilst checking all rock outcrops for the presence of rock art (although supposed 100% systematic surveys are still capable of missing sites).

A model such as this cannot be expected to find and locate every rock art site – that is not what it is designed to do – but it should put researchers in areas of higher likelihood more quickly, and effectively reduce survey time and costs.

Interpreting the results of predictive models can be misleading in that these results could show the influence of human agency, where in fact, rock art sites are located on rock surfaces which are not necessarily an indication of the agency but rather a consistency in regards to site choice.

6.4 What the results mean

In a simplistic manner, the results display how many sites fall into areas of high potential. This should be a given seeing as the site locations are used to determine the areas of high potential. However, owing to the use of multiple thresholds certain sites may be excluded due to a specific threshold that the characteristics do not adhere to. This leads to sites that were excluded and, in turn, reduced the size of potential areas, in those models. Therefore classifying potential areas without the potential for rock art and, therefore, reducing the amount of surveying. Therefore, by expanding specific thresholds, this problem was rectified. Second, owing to the use of standard deviation as a method of determining thresholds for the individual components, there is a percentage of sites excluded based on the relevant values because the standard deviation only accounts for 68% of the sites.

Owing to the multiple testing procedures, that the predictive model was exposed to showed the robust nature of the model, and the ability to be applied to alternate areas. Although these areas differed in geographic location, they shared similarities and thus the model proved successful. It is pointless applying this model to an area with no similarities to the model as it would literally be attempting to predict sites in the dark.

The high percentage of sites found within the high potential areas of the test models shows the value a model like this has for future research.

6.5 Limitations

Research must take limitations into consideration in order to progress and being aware of *how* these limitations affect the research, and how to manage them, are crucial factors for understanding how to improve.

6.5.1 Data resolution

In most cases data resolution is the biggest constraint of remote sensing research, and by using Shuttle Radar Topography Mission DEM's with a resolution of 1 arc second (*c*. 30m) limits the resolution of the predictions. However, resolution of 30m pixels is still detailed enough to render positive results through applications like slope and shaded relief. The SRTM data was more than adequate for accurate predictions, however, higher resolution digital elevation models would result in better discrimination of unlikely areas due to the smaller pixel size of higher resolution data.

6.5.2 Site characteristics

Although the MARA database has a representative sample of sites that were used to model for unknown site locations, the likely that every site will fall into this specific range is small allowing for possible outliers. Rock art sites occur in a multitude of different locations, which is a problem that can only be addressed by including all sites from a representative environment. Therefore predictive models that are applied below the Maloti-Drakensberg escarpment should use sites that occur throughout the region as this increases the thresholds capacity to identify unknown sites. However, it need only include the regions that have similar conditions as data from other areas would impede the success of the model.

6.5.3 Remote Sensing Thresholds

Based on the equation for determining the remote sensing thresholds, specific outliers were excluded because of the standard deviation. Therefore stream-lining the sites that were included and removing any outliers that could affect the integrity of the predictive model. The standard deviation derived equation was used as an exploratory method for

determining the data thresholds and seemed to provide adequate results. Further investigation into the exact threshold could have a positive impact on results.

6.5.4 Site Database

This representative data source was a prerequisite for modelling unknown rock art sites, as the sample covers more variables than a smaller sample would. The sparse distribution of sites throughout this area is owing to the nature of the initial survey, which was based on local knowledge of rock art sites and then later surveys adapted the systematic approach of walking up and down valleys. This technique of survey was able to locate the rock art sites thus contributing to the higher density of rock art sites in the northern section of the research area as can be seen by the two clusters of black dots depicting site locations.

The database was large and exceeded the usual 100 site prerequisite but because of the unique nature of rock art sites and it is unlikely to account for every unknown site characteristic. The presence of 106 sites at first proved useful but, as we have seen, there are still sites that can occur outside of the threshold range. An example of this is the presence of sites within the alluvial plain that comprised the MARA 2013 database as these were located using the MARA 2012 database and were not accounted for, however, due to slope thresholds they were identified. These sites occur within the alluvial plain although within sandstone lenses on the sides of steep hills that occur throughout this region as can be seen in the case of New Stands and Military Hill. Locating sites in unlikely areas such as this is one of the strengths of the modelling procedure as it identifies areas with common values that correspond to the thresholds identified.

6.6 How can the results be improved?

If better resolution data was to be used instead of the datasets used throughout this research, it is likely to improve on the data as the thresholds could be manipulated better due to smaller pixel sizes. Although the thresholds as is are able to determine the locations of rock art sites, for example being able to determine the exact slope values of the near vertical rock faces that contain the rock art sites. As is, the 30m slope is able to differentiate areas of steep and shallow slopes, higher resolution DEM’s would be better suited to tease apart these areas and offer an immediate improvement.

A speculative benefit of improved data resolution may not necessarily be associated with the success rate of the model but rather the ability to discriminate a higher proportion of areas from the regions that are likely to contain rock art. The higher resolution data might also impact on the slope thresholds of the sites as higher resolution data would be better suited to identify small changes that could be missed within a 30m pixel.

6.7 Were the aims achieved?

An objective of this research was to test the applicability of a predictive model to a rock art survey. The use of this predictive model will certainly benefit rock art surveys as the majority of rock art sites fall within the thresholds of the research and can, therefore, be used to outline areas that need surveying. Although higher resolution data will better delineate areas of interest for research, the data used throughout this project proved to be more than adequate in identifying the areas with rock art sites.

6.8 Recommendations for future research

Further research can certainly look at engaging the methods and results of this research to determine if higher resolution data could benefit this research. Other aspects include the use of SARADA (South African Rock Art Digital Archive) national site database as site locations as this consists of thousands of rock art sites that occur throughout southern Africa. Applying this research to other areas could also be beneficial although it is possible that the thresholds would change it, is interesting to see how the results of the models are affected.

Site choice and environmental determinism are two broader archaeological topics that could influence the use of predictive models (9.5.1: 173, 9.5.2: 173).

The locations of other archaeological sites regularly occur within rock shelters. Therefore, this predictive model could benefit broader archaeological fields and assist with locating a greater array of sites that occur within rock shelters. Kvamme (1992) understands the value of a model that is capable of locating rock shelters and as described that in an American context more of often than not shelters contain sites.

6.9 Remote sensing components and exclusions

Although the research initially looked at a multitude of different approaches to achieve a successful predictive model, some of these approaches that were excluded include supervised classifications, unsupervised classifications, and geological classifications.

A further change to the research was the scope of the project and the exact methods that were used. It was thought that processes such as the supervised and unsupervised classifications would be effective at locating and isolating the pixels of interest to likely known rock art sites. These categories were expected to have correlations with known rock art sites but due to the lack of any direct correlations, these methods were excluded. The supervised and unsupervised classifications were unable to isolate the characteristics that corresponded with the known rock art sites of the MARA database and the geological map lacked the required resolution to relate to the other components of the predictive model.

Chapter 7: Conclusion

Locating the rock art of the Maloti-Drakensberg is aided by the application of remote sensing techniques employed throughout this research. Predictive models have had a positive impact on archaeology together with broader fields of science. The unique application of this research expands on the ground made by previous researchers (Kvamme 1992, Brandt *et al.* 1992, Vaughn & Crawford 2009, Carleton *et al.* 2012). Many studies have tried to apply predictive models to their research but often fail during the testing stage as the models cannot be reproduced in other research areas. Owing to these failures, this research employed a strict testing procedure that would be used across multiple site databases relating to different terrain.

7.1 Achievement of aims

7.1.1 Test methods/components that had been effectively applied elsewhere

Remote sensing has been effectively applied to archaeological research worldwide and was seen to have the potential for use with rock art surveys. Specific processes were believed to have the potential for evaluating areas for parcels of land that would be of use for rock art surveys. The inclusion of multiple processes allowed the evaluation of these different processes to determine whether they are effective or not.

7.1.1.1 Normalized Difference Vegetation Index

One of the most effective remote sensing components for identifying rock art site locations is the NDVI. The majority of sites occurred within a specific NDVI threshold thus allowing for the consistent identification of areas suitable for other rock art sites.

7.1.1.2 Slope

The slope is the most critical element of this research as it contributed towards the models' success and allowed for the identification of slope values most synonymous with known rock art site locations.

7.1.1.3 Shaded Relief

A further component that teased apart areas with rock art site. The shaded relief was successful at identifying areas that had the potential for rock art sites. Additionally, the shaded relief component was even more effective when used alongside the NDVI and slope.

7.1.1.4 Aspect

A component that contains valued data but offered little assistance for locating rock art sites. Aspect is valuable because it can be used to contribute towards discussions of site selection and usage as well as looking into topics such as seasonal usage of sites based on aspect. Aspect varies based on the underlying drainage basin and is influenced as in this case by mountainous features and surface runoff from the Maloti-Drakensberg Mountains.

7.1.2 Test whether predictive models had any value to rock art surveys

Predictive Modelling, when used correctly, can be a valued tool for archaeological research and especially for surveying purposes, however, it cannot be used for predicting human behaviour. For the locating of rock art sites, the predictive models combined the remote sensing components to build on the individual successes.

7.2 Implications for rock art research

Successful applications of predictive models will contribute to future research and allow for more precise surveying where rock art sites are likely to occur. The model can be adjusted to accommodate other research areas by changing the individual threshold values for the individual remote sensing components as seen with the changes made to allow for the models success when applied to Sehlabathebe National Park.

The inclusion of higher resolution data would allow for more successful identification of potential areas because of the reduced pixel size which would be more accurate as there would be a smaller range of values that occurred within that pixel. Higher resolution DEM data would account for better results and discrimination, because smaller pixel sizes would record changes in altitude. Whereas lower resolution images would lack the detail and show a value showing the average of the pixel.



Photo 7.1: An example of sudden drop that is unlikely to be present in poorer resolution data. Photo: Dr Sam Challis 2012

:

7.3 Future Work

The application of predictive modelling to rock art studies has the potential for further research within the broader context of South African rock art research, as there are still numerous areas that require surveying. Expanding the predictive model applied by Banerjee and Srivastava (2014) to include modelling parameters that assess the environmental characteristics such as slope and shaded relief. Furthermore, the inclusion of higher resolution remote sensing data along with the incorporation of enhanced geological data, these predictions could be refined further to narrow areas with potential for rock to occur. As shown, there are broader uses for such a method as long as the researcher is attempting to find rock art shelters or areas of similar geomorphological characteristics.

Testing procedures have illustrated the effective nature of the process at identifying areas of potential, the next progression would be based on improvements in the discrimination of unsuitable areas. Specific datasets could be sorted based on regional occurrences to reduce the fluctuations to thresholds, therefore improving the accuracy of a model on a smaller scale.

Chapter 8: References

Abd Manap, M., Ramli, M. F., Sulaiman, W. N. A. & Surip, N. 2010. Application of remote sensing in the identification of the geological terrain features in Cameron Highlands, Malaysia. *Sains Malaysiana* 39(1): 1-11.

Abrams, M.J., Brown, D., Lepley, L. & Sadowski, R. 1983. Remote sensing for porphyry copper deposits in southern Arizona. *Economic Geology* 78: 591–604.

Altschul, J. H., Sebastian, L. & Heidelberg, K. 2004. Predictive Modeling in the Military: Similar goals, divergent paths*. Rio Rancho: SRI Foundation*. Campbell, J. B. 2008. *Introduction to Remote Sensing*. London: Taylor and Francis.

Aminzadeh, B. & Samani, F. 2006. Identifying the boundaries of the historical site of Persepolis using remote sensing. *Remote Sensing of Environment*. *102*(1): 52-62.

Arthur, C. & Mitchell, P. J. 2009. Metolong Cultural Resource Management Phase 1, Volume 1: Inventorisation and Assessment. Unpublished report prepared for the Lesotho Government's Commissioner for Water. Oxford: University of Oxford.

Arthur, C. & Mitchell, P. J. 2009. Metolong Cultural Resource Management Phase 1, Volume 2: Building Sustainable Cultural Resource Management in Lesotho. *Unpublished report prepared for the Lesotho Government's Commissioner for Water.* Oxford: University of Oxford.

Banerjee, R. & Srivastava, P.K., 2014. Remote sensing based identification of painted rock shelter sites: appraisal using advanced wide field sensor, neural network and field observations. In Remote sensing applications in environmental research (pp. 195-212). Springer International Publishing.

Battiss, W. W. 1948. *The Artists of the Rocks: Art in South Africa*. Pretoria: Red Fawn Press.

Bester, S. P. 1998. Vegetation and flora of the southern Drakensberg escarpment and adjacent areas. Unpublished MSc Thesis. Pretoria: University of Pretoria.

Beukes, N. J. 1969. *Die Sedimentologie Van Die Etage Holkrans-sandsteen Sisteem Karoo.* Unpublished PhD dissertation. Bloemfontein: University of the Orange Free State.

Biswajeet, P. & Saro, L. 2007. Utilization of optical remote sensing data and GIS tools for regional landslide hazard analysis using an artificial neural network model. *Earth Science Frontiers 14*(6): 143-151.

Bocco, G., Mendoza, M. & Velázquez, A. 2001. Remote sensing and GIS-based regional geomorphological mapping - a tool for land use planning in developing countries. *Geomorphology* 39(3): 211-219.

Bowen, B.B., Martini, B.A., Chan, M.A. & Parry, W.T., 2007. Reflectance spectroscopic mapping of diagenetic heterogeneities and fluid-flow pathways in the Jurassic Navajo Sandstone. *AAPG bulletin*, *91*(2): 173-190.

Brandt, R., Groenewoudt, B. J. & Kvamme, K. L. 1992. An experiment in archaeological site location: modeling in the Netherlands using GIS techniques. *World Archaeology* 24(2): 268-282.

Campbell, J.B., 2008. *Introduction to remote sensing*. CRC Press.

Carleton, W. C., Conolly, J. & Ianonne, G. 2012. A locally-adaptive model of archaeological potential (LAMAP). *Journal of Archaeological Science* 39(11): 3371-3385.

Carter, G.M., Karis, T. & Stultz, N.M., 1967. *South Africa's Transkei: the politics of domestic colonialism* (Vol. 19). Evanston: Northwestern University Press.

Carter, P. L. 1977. *The Prehistory of Eastern Lesotho.* Unpublished PhD dissertation, Cambridge: University of Cambridge.

Carter, P. L., Mitchell, P. J. & Vinnicombe, P. 1988. Sehonghong: the Middle and Later Stone Age industrial sequence at a Lesotho rock-shelter. British Archaeological Report International Series 406.

Challis, W. & Laue, G. 2001. COMRASA. Rock Art Documentation Course Manual (Kasama) Zambia 1-14 July 2001.

Challis, W. 2008. The impact of the horse on the AmaTola ‘Bushmen’: new identity in the Maloti-Drakensberg Mountains of Southern Africa. Unpublished PhD thesis. Oxford: University of Oxford.

Challis, W. 2011 http://www.marasurvey.com/mission.php consulted 12/05/2014

Challis, W., Mullen, A. & Pugin, J. 2015. Rock Art and Baseline Archaeological Survey of the Sehlabathebe National Park, Kingdom of Lesotho: Final Report to the World Heritage Committee of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Chan, Y. 2011. *Location Theory and Decision Analysis*, 2nd ed. Berlin: Springer.

Chang, K. 2002. *Introduction to Geographic Information System,* New York: Mc Graw-Hill.

Chen, C. H. 2007. Signal and Image Processing for Remote Sensing. Miami: CRC press.

Chen, C. H. 2012. Signal and Image processing for remote sensing. Miami: CRC press.

Conolly, J. & Lake, M. 2006. *Geographical information systems in archaeology*. Cambridge: Cambridge University Press.

Cooke, C.K., 1969. *Rock art of southern Africa*. Minnesota: Books of Africa.

Cowling, R. M., Richardson, D. M. & Pierce, S. M. 2004. *Vegetation of southern Africa*. Cambridge: Cambridge University Press.

Dalla Bonna, L. 2003. Protecting cultural resources through forest management planning in Ontario using archaeological predictive modeling. In: Wescott, K. L. & Brandon, R. J. (eds.). *Practical applications of GIS for archaeologists: A predictive modelling toolkit*. Miami: CRC press.

Davis, A.M. & Mason, P.J. 2000. Three dimensional of landslide in SE Spain using a digital elevation model (DEM) and orthophotography. *Landslides in research, theory and practice,* London: Thomas Telford. 403-408

de Neergaard, A., Saarnak, C., Hill, T., Khanyile, M., Berzosa, A. M. & Birch-Thomsen, T. 2005. Australian wattle species in the Drakensberg region of South Africa – An invasive alien or a natural resource? *Agricultural Systems* 85(3): 216-233.

Derricourt, R. M. 1977. *Prehistoric man in the Ciskei & Transkei*. New York: Lawrence Verry Incorporated.

Douek, D. 2013. 'They Became Afraid When They Saw Us': MK Insurgency and Counterinsurgency in the Bantustan of Transkei, 1988–1994. *Journal of Southern African Studies* 39(1): 207-225.

Du Toit, A.L. 1954. *The geology of South Africa*, 3rd ed. Edinburgh: Oliver and Boyd.

Duncan, R.B. & Beckman, K., A. 2005. The application of GIS Predictive Site Location Models within Pennsylvania and West Virginia. In: Wescott, K. L. & Brandon, R. J. 2003. *Practical applications of GIS for archaeologists: A predictive modelling toolkit.* Chicago: CRC Press.

Dunning, N., Beach, T., Farrell, P. & Luzzadder-Beach, S., 1998. Prehispanic agrosystems and adaptive regions in the Maya lowlands. *Culture & Agriculture* 20(23): 87-101.

Ebert, D. 2004. Applications of archaeological GIS. *Canadian Journal of Archaeology/Journal Canadien d'Archéologie*, 319-341.

Espa, G., Benedetti, R., De Meo, A., Ricci, U. & Espa, S. 2006. GIS based models and estimation methods for the probability of archaeological site location. *Journal of Cultural Heritage* 7(3): 147-155.

Evans, D. 1988. Multisensor classification of sedimentary rocks. *Remote Sensing of Environment* 25(2): 129-132.

Fabbri, A. G., van der Meer, F. D., Valenzuela, C. R. & Kushigbor, C. A. 1993. Shape analysis and multispectral classification in geological remote sensing. *Mathematical Geology 25*(7): 773-793.

Farnden, T. H. G. 1966. Excavation of a Late Stone Age Shelter at New Amalfi, East Griqualand. *The South African Archaeological Bulletin* 21(83): 122-124.

Fedick, S. L. 1995. Land evaluation and ancient Maya land use in the Upper Belize River area, Belize, Central America. *Latin American Antiquity* 6(1): 16-34.

Fedick, S. L. 1996. Managed mosaic. In Conference on Ancient Maya Agriculture and Biological Resource Management (1991: University of California, Riverside). Utah: University of Utah Press.

Fedick, S. L., Morrison, B. A., Andersen, B. J., Boucher, S., Acosta, J. C. & Mathews, J. P. 2000. Wetland manipulation in the Yalahau region of the northern Maya lowlands. *Journal of Field Archaeology* 27(2): 131-152.

Feely, J. M. 1987. The early farmers of Transkei, southern Africa, before AD 1870). British Archaeological Report International Series 378.

Ford, A. & Nigh, R. 2009. Origins of the Maya forest garden: Maya resource management. *Journal of Ethnobiology* 29(2): 213-236.

Gaffney, V. & van Leusen, P. M. 1995. Postscript- GIS, Environmental Determinism and Archaeology. In: Lock, G. and Stancic, Z. *Archaeology and Geographical Information Systems: A European Perspective* 367-382. London: Taylor and Francis.

Goodwin, A. J. H. 1949. A Fishing Scene from East Griqualand. *The South African Archaeological Bulletin* 4(14): 51-53

Grover, S., 1999. Perspectives of GIS modelling in hydrology. *Asia's first GIS/GPS/RS/monthly magazine (November-December)*.

Hamilton, G. N. G. & Cooke, H. B. S. 1960.*Geology for South African students: an introductory textbook*. Johannesburg: Central News Agency.

Harris, T. M. & Lock, G. R. 1995. Toward an evaluation of GIS in European archaeology: The past, present and future of theory and applications. *Archaeology and Geographical Information Systems: A European Perspective.* London: Taylor and Francis.

Haughton, S. H. 1969. Geological history of southern Africa. Cape Town: Geological Society of South Africa.

He, G., Desai, M. D. & Zhang, X. 1999, March. Minimum component eigen-vector based classification technique with application to TM images. In: *Acoustics, Speech, and Signal Processing, 1999. Proceedings. 1999 IEEE International Conference on* 6: 3533-3536). IEEE.

Hobbs, K.F.1999. An investigation of RGB multi-band shading for relief visualisation. *Journal of Applied Gerontology* 1(3/4): 181-186

Hong, Y., Adler, R. & Huffman, G. 2007. Use of satellite remote sensing data in the mapping of global landslide susceptibility. *Natural Hazards* 43(2): 245-256.

Horn, B.K.P. 1981. Hill Shading and the Reflectance Map. Proceedings of the Institute of Electrical and Electronics Engineers 69(1): 14-47.

Huffman, T. N. 1996. Archaeological evidence for climatic change during the last 2000 years in southern Africa. *Quaternary International* 33: 55-60.

Iiames, J. & Congalton, R. 2006. A Comparison of Inter-Analyst Differences in the Classification of a Landsat Etm+ Scene In South-Central Virginia ASPRS 2006 Annual Conference Reno, Nevada May 1-5, 2006.

Inzana, J., Kusky, T., Higgs, G. & Tucker, R. 2003. Supervised classifications of Landsat TM band ratio images and Landsat TM band ratio image with radar for geological interpretations of central Madagascar. *Journal of African Earth Sciences 37*(1): 59-72.

Irwin, P., Akhurst, J. & Irwin, D. 1980. *A field guide to the Natal Drakensberg*. Durban: Natal Branch of the Wildlife Society of Southern Africa.

Johnson, M. R., Anhauesser, C. R. & Thomas, R. J. 2006. *The Geology of South Africa*. Cape Town: Geological Society of South Africa.

Karimi, H. A. & Peng, J. 2004. Using Maximum Likelihood (ML) and Maximum A Prior Probability (MAP) in Iterative Self-Organizing Data (ISODATA). *Geocarto International* 19(1): 29-36.

Kayan, I. & Klemas, V. 1978. Application of LANDSAT Imagery to studies of structural geology and geomorphology of the Mentese region of southwestern Turkey. *Remote Sensing of Environment* 7(1): 51-60.

Kennelly, P. 2008. “Terrain maps displaying hill-shading with curvature.” *Geomorphology* 102: 567–577.

Killick, D. J. B. 1963. An account of the plant ecology of the Cathedral Peak area of the Natal Drakensberg. *Memoirs of the Botanical Survey of South Africa 34:*

Kohler, T. A. & Parker, S. C. 1986. Predictive models for archaeological resource location. *Advances in archaeological method and theory* 9: 397-452.

Kunen, J. L. 2001. Ancient Maya agricultural installations and the development of intensive agriculture in NW Belize. *Journal of Field Archaeology* 28(3-4): 325-346.

Kusky, T.M. & Ramadan, T., 2002. Structural controls on Neoproterozoic mineralization in the SE Desert, Egypt: an integrated field, Landsat TM, and SIR C/X approach. *Journal of African Earth Sciences* 35: 107–121.

Kvamme, K. L. 1990. The fundamental principles and practice of predictive archaeological modelling, in: Voorips, A. (eds.) *Mathematics and information science in archaeology: a flexible framework*, vol. 3, *Studies in modern archaeology*. 257-295. Bonn: Holos-Verlag.

Kvamme, K. L. 1992. A predictive site location model on the High Plains: An example with an independent test. *The Plains Anthropologist* 37: 19-40.

Laake, A. 2011. Integration of Satellite Imagery, Geology and Geophysical Data, Earth and Environmental Sciences, Dr. Imran Ahmad Dar (Ed.), ISBN: 978-953-307-468-9, In Tech, Available from: http://www.intechopen.com/books/earth-and-environmental-sciences/integration-of-satellite-imagery-geology-and-geophysical-data

Lasaponara, R. & Masini, N. 2007. Detection of archaeological crop marks by using satellite QuickBird multispectral imagery. *Journal of Archaeological Science* 34(2): 214-221.

Lasaponara, R. & Masini, N. 2011. Satellite remote sensing in archaeology: past, present and future perspectives. *Journal of Archaeological Science* 38(9): 1995-2002.

Lee, S. 2005. Application of logistic regression model and its validation for landslide susceptibility mapping using GIS and remote sensing data. *International Journal of Remote Sensing 26*(7): 1477-1491.

Lewis-Williams, J. D. 1972. The syntax and function of the Giant's Castle rock-paintings. *The South African Archaeological Bulletin* 27: 49-65.

Lewis-Williams, J.D. & Thorp, C.A., 1989. Archaeology: Lesotho Highlands Water Project environmental study. Unpublished Report by E.R Ltd: Lesotho Highlands Development Authority.

Lillesand, T. M. & Kiefer, R. W. 1994. Remote sensing and image interpretation. *Remote sensing and image interpretation* (Ed. 3). New York: Wiley.

Lillesand, T. M., Kiefer, R. W. & Chipman, J. W. 2008. *Remote sensing and image interpretation.* New York: Wiley.

Liu, J. G. & Mason, P. 2013. *Essential image processing and GIS for remote sensing.* New York: Wiley.

Lock, G. R. & Stancic, G. (eds.). 1995. *Archaeology and geographic information systems: a European perspective*. Miami: CRC Press.

Loendorf, L., 2001 Rock Art Recording. In: Whitley, D. S. (eds.) *Handbook of rock art research*. Lanham: Rowman & Littlefield.

Loyd, C. 2013. Putting Landsat 8's Bands to Work (Consulted October 2013): https://www.mapbox.com/blog/putting-landsat-8-bands-to-work/

Lucieer, A., Tsolmongerel, O. & Stein, A. 2004. Texture-based segmentation for identification of Geological units in Remotely Sensed Imagery. In *Proceedings of the 3rd International Symposium on Spatial Data Quality ISSDQ* 4: 117-120.

Malan, B. D. 1955. *A preliminary account of the archaeology of East Griqualand*. Johannesburg: University of the Witwatersrand.

Marozas, B. A. & Zack, J. A. 1990. GIS and archaeological site location. In: Allen, K.M.S., Green, S. W. & Zubrow, E.B.W. (eds.) *Interpreting Space: GIS and Archaeology*, Taylor & Francis: London.

Masini, N. & Lasaponara, R. 2006. Satellite-based recognition of landscape archaeological features related to ancient human transformation. *Journal of Geophysics and Engineering* 3(3): 230.

Mather, P.M. 2005. Computer Processing of Remotely Sensed Images: An Introduction (3rd Edition). London: Wiley.

Mauder, K. 1982. Atlas of Transkei - a cartographical project in a developing country. *GeoJournal* 6(6): 573-574.

Mazel, A. 2008. Presenting the San Hunter-Gatherer past to the public: A view from the uKhahlamba-Drakensberg Park, South Africa. *Conservation and Management of Archaeological Sites* 10(1): 41-51.

Mazel, A. D. 1981. Up and Down the Little Berg: Archaeological Resource Management in the Natal Drakensberg: Final Project Report to the Department of Water Affairs, Forestry and Environmental Conservation. Sub-project Code: 23/1/2-1/3/10/03/02.

Mazel, A. D. 1984. Archaeological Survey of the Natal-Drakensberg, Natal, South-Africa. *Journal of Field Archaeology* 11(3): 345-356.

Mazel, A. D. 1996a. Maqonqo Shelter: The excavation of early and mid Hoiocene deposits in the eastern Biggarsberg, Thukela Basin, KwaZulu-Natal, South Africa. *Natal Museum Journal of Humanities* 8: 1-39.

Mazel, A. D. 1996b. A special place: Maqonqo Shelter in the Thukela Basin, South Africa. In Pwiti, G. & Soper, R. (eds.), Aspects of African Archaeology: Papers from the Tenth Congress of the Pan-African Association for Prehistory and Related Studies, University of Zimbabwe, Harare, pp. 343-354.

Mazel, A. D. 1997. Mzinyashana Shelters 1 and 2: excavation of mid and late Holocene deposits in the eastern Biggarsberg, Thukela Basin, South Africa. *Southern African Humanities* 9: 1-35.

Mazel, A.D. 1993. kwaThwaleyakhe Shelter: the excavation of mid and late Holocene deposits in the central Thukela Basin, Natal, South Africa. Natal Museum. *Journal of Humanities* 5: 1-36.

Mehrer, M. W. & Wescott, K. L. (eds.). 2005. *GIS and archaeological site location modeling*. Miami: CRC Press.

Mehrer, M. W. 2002. A GIS-based archaeological decision-support model for Cultural Resource Management. *Archeologiae calcolatori* 13: 125-134.

Meiklejohn, K. I., Hall, K. & Davis, J. K. 2009. Weathering of rock art at two sites in the KwaZulu-Natal Drakensberg, southern Africa. *Journal of Archaeological Science* 36(4): 973-979.

Mendoza, M.E., Bocco, G., López-Granados, E. and Bravo Espinoza, M., 2010. Hydrological implications of land use and land cover change: Spatial analytical approach at regional scale in the closed basin of the Cuitzeo Lake, Michoacan, Mexico. *Singapore Journal of Tropical Geography*, *31*(2), pp.197-214.

Mitchell, P. 2000. The organization of Later Stone Age lithic technology in the Caledon Valley, southern Africa. *The African Archaeological Review* 17(3): 141-176.

Mitchell, P. 2002. *The archaeology of southern Africa*. Cambridge: Cambridge University Press.

Mitchell, P. J. 1995. Revisiting the Robberg: new results and a revision of old ideas at Sehonghong Rock Shelter, Lesotho. *The South African Archaeological Bulletin* 50: 28-38.

Mitchell, P. J. 2009. Gathering together a history of the People of the Eland: towards an archaeology of Maloti-Drakensberg hunter-gatherers. *The Eland's People: New Perspectives in the Rock Art of the Maloti-Drakensberg Bushmen. Essays in Memory of Patricia Vinnicombe.* Johannesburg: Wits University Press.

Mitchell, P. Plug, I. Bailey, G. & Woodborne, S. 2008. Bringing the Kalahari Debate to the mountains: late first millennium AD hunter-gatherer/farmer interaction in highland Lesotho. *Before Farming* 2: 1-22.

Mitchell, P.J. 1996. Sehonghong: the late Holocene assemblages with pottery. *South African Archaeological Bulletin* 51: 17-25.

Mokoena, T. 2015 Community involved heritage Management- the Case of Matatiele South Africa. Unpublished Master's Thesis. University of the Witwatersrand: Johannesburg.

Mucina, L. & Rutherford, M. C. 2006. *The vegetation of South Africa, Lesotho and Swaziland*. South African National Biodiversity Institute.

Nield, S. J., Boettinger, J. L. & Ramsey, R. D. 2007. Digitally mapping gypsic and natric soil areas using Landsat ETM data. *Soil Science Society of America Journal* 71(1): 245-252.

Novak, I. D. & Soulakellis, N. 2000. Identifying geomorphic features using LANDSAT-5/TM data processing techniques on Lesvos, Greece. *Geomorphology* 34(1): 101-109.

Ouzman, S. 2001. Seeing is deceiving: rock art and the non-visual. *World Archaeology* 33(2): 237-256.

Parcak, S. 2007. Satellite remote sensing methods for monitoring archaeological tells in the Middle East. *Journal of field archaeology 32*(1): 65-81.

Parcak, S. H. 2009. *Satellite Remote Sensing for Archaeology*. Routledge: Oxford.

Parkington, J. 1976. Follow the San: An Analysis of Seasonality in Prehistory of the South Western Cape PhD dissertation. Cambridge: University of Cambridge.

Patterson, M., Sarson, G., Sarson, H. & Shukurov, A. 2010. Modelling the Neolithic transition in a heterogeneous environment. *Journal of Archaeological Science* 37: 2929-2937.

Pearce, D. G. 2002. Changing men, changing eland: Sequences in the rock paintings of Maclear District, Eastern Cape, South Africa. *American Indian Rock Art* 28: 129–138.

Penn, M., Sutton, D. & Monro, A. 2004. Vegetation of the greater Maya mountains, Belize. *Systematics and Biodiversity* 2(1): 21-44.

Pinto, H. 2014. Lesotho Highlands Water Project Phase II: Report of Baseline Archaeological and Heritage Survey. Lesotho Highlands Development Authority.

Preston-Whyte, R. A. & Tyson, P. D. 1988. *Atmosphere and weather of southern Africa*. Oxford: Oxford University Press.

Preston-Whyte, R. A. & Tyson, P. D. 2004. The weather and climate of southern Africa. Cape Town: Oxford University Press.

Pugin, J.M. 2012. Improving rock art survey: finding the sandstone shelters of the Maloti-Drakensberg. Unpublished honours dissertation. Johannesburg: University of the Witwatersrand.[10]

Quinn, J.W. 2001. Landsat Band Combinations (Consulted September 2013): http://web.pdx.edu/~emch/ip1/bandcombinations.html

Ramli, M. F. 2001. The use of remotely-sensed imagery for investigating landslides in temperate environments. Unpublished Phd. thesis. University of Portsmouth, 277p

Regensberg R. M. 2013. The changing social character of a shelter: A case study from Matatiele. Unpublished honours dissertation. Johannesburg: University of the Witwatersrand.

Regensberg, R. 2013. Scratching the surface: rock art and traditional medicine. ASAPA Conference Proceeding. Gaborone: University of Botswana.

[10] Available on research gate and academia

Renfrew, C. & Bahn, P. G. 2004. *Archaeology: theories, methods and practice*. London: Thames & Hudson.

Richards, J. A. & Jia, X. 2006. Remote Sensing Digital Image Analysis. Remote Sensing Digital Image Analysis, an Introduction. Berlin: Springer.

Roe, G. H. 2005. Orographic precipitation. *Annual Review of Earth and Planetary Sciences.* 33: 645-671.

Rowlands, A. & Sarris, A. 2007. Detection of exposed and subsurface archaeological remains using multi-sensor remote sensing. *Journal of Archaeological Science* 34: 795–803.

Russell, T. M. 2012. The position of rock art: a consideration of how GIS can contribute to our understanding of the age and authorship of rock art. In: Smith B.W., Morris, D. & Helskog, K. (eds.). *Working with rock art: recording, presenting and understanding rock art using indigenous knowledge.* Johannesburg: Wits University Press. 37– 45.

Schlüter, T. 2008. Geological atlas of Africa (pp. 110-113). Berlin: Springer. Science, 34(5): 795-803.

Schowengerdt, R.A., 2006. *Remote sensing: models and methods for image processing*. Academic press

Schweitzer, F. R. & Scott, K. J. 1973. Early occurrence of domestic sheep in sub-Saharan Africa. *Nature*, 241: 547.

Scollar, I., Tabbagh, A., Hesse, A. & Herzog, I. 1990. *Archaeological prospecting and remote sensing*. Cambridge: Cambridge University Press.

Sharpe, K. & Barnett, T. 2008. Recording England's Rock Art: A Handbook for Project Officers.

Shezi, M. I. Z. & Poona, M. N. K. 2010. Invasive Alien Plant Species Project: An investigation into using different satellite remote sensors and techniques to identify, map, monitor and predict the spread and distribution of some of the major current and emerging invasive alien plant species in KwaZulu-Natal. Durban: UKZN/DAEA.

Smith, R. B., Jiang, Q., Fearon, M. G., Tabary, P., Dorninger, M., Doyle, J. D. and Benoit, R. 2003. Orographic precipitation and air mass transformation: an Alpine example. *Quarterly Journal of the Royal Meteorological Society* 129: 433–54

Smith, B., Helskog, K. A. & Morris, D. (eds.). 2012. Working with Rock Art: Recording, Presenting and Understanding Rock Art Using Indigenous Knowledge. Johannesburg: Wits University Press.

Smits, L. G. 1983. Rock paintings in Lesotho: site characteristics. *The South African Archaeological Bulletin* 38: 62-76.

Smits, L. G. A. 1973. Rock-painting sites in the upper Senqu Valley, Lesotho. *The South African Archaeological Bulletin* 28: 32-38.

Sultan, M., Arvidson, R.E. & Sturchio, N.C., 1986. Mapping of serpentinites in the E. Desert of Egypt using Landsat Thematic Mapper data. *Geology* 14: 995–999.

Taheri, S. 2010. Hyper temporal NDVI images for modelling and prediction the habitat distribution of Balkan green lizard (Lacerta trilineata). Unpublished Master's Thesis. Enschede, Netherlands: International Institute for Geo-information Science and Earth Observation.

Thorp, C. 1997. Evidence for interaction from recent hunter-gatherer sites in the Caledon Valley. *African archaeological review* 14(4): 231-256.

Tyson, P. D., Preston-Whyte, R. A. & Schulze, R. E. 1976. *The climate of the Drakensberg* (Vol. 15). Town and Regional Planning Commission.

Van Leusen, M. 2009. Archaeological predictions contested: the role of the Dutch Indicative Map of Archaeological Values (IKAW) in local planning procedures in Kamermans, H. van Leusen, M. Verhagen, Ph. (eds.). *Archaeological Prediction and Risk Management: Alternatives to Current Practice*. Leiden: Leiden University Press. 49-55.

Van Zyl, D. 2003. *South African weather and atmospheric phenomena*. Pretoria: Briza Publications.

Vaughn, S. & Crawford, T. 2009. A predictive model of archaeological potential: an example from northwestern Belize. *Applied Geography* 29(4): 542-555.

Verhagen, P. 2008. Testing Archaeological Predictive Models: A Rough Guide. In: Posluschny, A., K. Lambers and I. Herzog (eds.) Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, April 2–6, 2007 (Kolloquien zur Vor- und Frühgeschichte, Vol. 10). Dr. Rudolf Habelt GmbH, Bonn, pp. 285-291.

Verhagen, P., Kamermans, H. & Leusen, M. V. 2009. The future of archaeological predictive modelling. In Kamermans, H. van Leusen, M. Verhagen, Ph. (eds.). Archaeological Prediction and Risk Management: Alternatives to Current Practice. Leiden: Leiden University Press. 49-55.

Verstappen, H.TH. 1977. *Remote sensing in geomorphology,* New York: Elsevier Scientific Publishing Company.

Vinnicombe, P. 1976*. People of the Eland.* Pietermaritzburg: University of Natal.

Visser, P.J.L. 1989. The Geology of the Republics of the South Africa, Transkei, Bophuthatswana, Venda and Ciskei and the Kingdoms of Lesotho and Swaziland: Explanation of the 1: 1000000 Geological Map, 1984. Department of Mineral and Energy Affairs, Geological Survey.

Volker, W. 1998. Automatic classification of remote sensing data for GIS database revisions. In: Fritsch, D., Englich, M. & Sester, M. (eds.) 'IAPRS', 32(4): 641-648, ISPRS Commission IV Symposium on GIS - Between Visions and Applications

Ward, V. 1997. A century of change: rock art deterioration in the Natal Drakensberg, South Africa. *Southern African Humanities* 9: 75-97.

Wescott, K. L. & Brandon, R. J. 2003. *Practical applications of GIS for archaeologists: A predictive modelling toolkit.* Chicago: CRC Press.

Wheatley, D. 2004. Making space for an archaeology of place. *Internet Archaeology* 15.

White, G. G. & King, T. F. 2007. *The archaeological survey manual*. California: Left Coast Press.

Whitley, D. S. (eds.). 2001. *Handbook of Rock Art Research*. Lanham: Rowman & Littlefield.

Whitley, D. S. 2005. Introduction to rock art research. California: Left Coast Press.

Whittow, J. B. 2000. *The Penguin dictionary of physical geography*. Oxford: Penguin Publishers.

Willcox, A. R. 1956. *Rock Paintings of the Drakensberg*. Johannesburg: Thomas Nelson and Sons.

Willcox, A. R. 1963. *The rock art of South Africa*. Johannesburg: Thomas Nelson and Sons.

Winterbottom, S. J. & Dawson, T. 2005. Airborne multi-spectral prospection for buried archaeology in mobile sand dominated systems. *Archaeological Prospection* 12(4): 205-219.

Wiseman, J. R. & El-Baz, F. 2007. *Remote sensing in archaeology*. Berlin: Springer.

Wright, J. B. & Mazel, A. D. 2007. Tracks in a mountain range: exploring the history of the uKhahlamba-Drakensberg. Johannesburg: Wits University Press.

Wright, J. B. & Mazel, A. D. 2012 Umlando Wezintaba ZoKhahlamba: History of the Ukhahlamba Mountains. Johannesburg: Wits University Press.

Wright, J. B. 1971. Bushman Raiders of the Drakensberg 1840-1870: A Study of Their Conflict with Stock Keeping Peoples in Natal. Pietermaritzburg: University of Natal Press.

Zenobia, J., Roberts, R.G., Galbraith, R.F., Deacon, H.J., Grün, R., Mackay, A., Mitchell, P., Vogelsang, R. & Wadley, L. 2008. Ages for the Middle Stone Age of southern Africa: implications for human behavior and dispersal. *Science* 322(5902): 733-735.

Zhang, H., Bevan, A., Fuller, D. & Fang, Y. 2010. Archaeobotanical and GIS-based approaches to prehistoric agriculture in the upper Ying valley, Henan, China. *Journal of Archaeological Science* 37 (7): 1480-1489.

Zhou, Q. 1992. Relief Shading Using Digital Elevation Models. *Computers and Geosciences* 18(8): 1035-1042.

Chapter 9: Appendix

9.1 Tables

Table 9.1: SNP Database

Site Number	ARAL	Description
A01		A single panel of images makes up rock art and stonewalled site A01. These paintings are located on the back wall and ceiling of a small, low-lying natural recess in the rock face of a boulder.
A02		Both panels at A02 are exposed to the elements. They are faded and flaked in places. Panel B has vegetation growing very close to the paintings. Panel B has the clearest paintings at A02- one small eland and three human figures all in red are still visible.
A04		Indeterminate figures thought to be eland. There are also some finger dots on north eastern corner of shelter. Stone walling also present and three walls are connected to the shelter, which is built with dry rocks and mud used as mortar. There is a possible fourth enclosure.
A05		The images are very faded. It is not located on any tourist route and therefore is unlikely to experience serious further damage
A07		A07 is damaged and very faded. What images remain are difficult to make out. It is possible to judge, however, that the site contains no rare imagery and will not contribute to future research. It is not a likely tourist attraction and therefore it does not require any immediate conservation.
A12		There are three stonewalled structures in A12 This panel contains a very large eland (damaged by the construction of the wall- smudged). Panel A consists of bichrome eland, human figures and figures in karosses. Panel B is very faded and contains eland, a fragmented antelope back line in the centre of the panel, red bag-shaped dots in the centre of the panel, another fragmented antelope back line on the right side of panel B and a fragmented eland body on the bottom of panel B in red.
A16		Rock art and stonewalled site A16 is located within an elliptically shaped shelter measuring 30m in width, 4m in height and 9m in depth. This shelter is identifiable by the large grass mound in the centre of the shelter on top of which are a natural collection of large rocks. The shelter faces north. The rock art is located on the western side of the back wall of the shelter. The site has been divided into a single panel (panel A)
A19		Two antelope painted in red. The tail of the left antelope is slightly unusual. However, the overall ranking of the site remains low because the visibility of the second antelope is low, the complexity of site is low. There is little potential for future research. Not suitable for tourists. Panel A is located in the centre of the shelter. It contains two images in red. The leftmost image is well preserved.
B01	184	Panel A is located on the rear wall of shelter B01, on the western side of the shelter above a ledge 5m from the shelter floor. It contains a single polychrome eland in a standing position facing south (right). This eland is 30cm in length. The head and neck are somewhat faded, but the rest of the animal is very clear. Panel B is located on the eastern end of B01 on a fallen section of rock on the shelter floor. No representational images, only smudging of paint. One structure (A) present at B01. A is a stonewall measuring 1.5m in height which runs east-west under the drip line of the shelter, enclosing it at either end of the shelter.

B04		Rock art and stonewalled site B04 is located under a shallow overhang of a boulder. The rock art at B04 consists of indeterminate red paint marks upon the back wall of the overhang which is possibly an eland body and 3 faded finger smears.
B05	244	Two rock art panels at site B05, Panel A consists of a few faded figures, caused by animal rubbing. Panel B consisted of 5 figures (2 Elands, 3 human figures of which 1 is kneeling, second is walking along back of eland and final figure legs are stretched out).
B10		Indeterminate dark red patch that which is badly flaked. Some light red smudging also present.
B14		Indeterminate markings, indeterminate antelope and red human running figures
B17	236	Site with multiple panels. Consisting of human figures with karosses, sticks. A figure painted in white. Eland painted in dark red.
B19		Natural markings that could be mistaken as rock art
B24		Square dwelling that is partially collapsed.
B28		There are three panels of rock art at B28 along with stone walled structures. The rock art panels consist of red smears, flaked eland body that is still reasonably clear, other eland and indeterminate red lines. Three stonewalled structures built against boulders. Large stone walled kraal
B29	186	Two shelters containing one and three rock art panels respectively. Remnants of shaded polychrome eland. Approximately 15 human figures painted in dark red and more. Shelter enclosed and abutted by five distinct structures.
B31	240	Site with fifteen rock art panels. Consisting of human figures, red smears, figure in kaross, and bichrome eland.
B33	194/195	Site with multiple panels. Some partially faded whilst others are clear. Rock art includes eland, rhebok, and indeterminate figures.
B35	189	Rock art panel with 8 red painted human figures and an unidentifiable animal figure also painted in red.
B36		Complex stone walled site with two dwellings within larger enclosure. Multiple rock art panels present within shelters a and b.
B37		Panel with indeterminate markings.
B38	204	Site consisting of four rock art panels indeterminate paintings which are faded in places. Two rheboks that are clear exist in panel C.
B39		Site with stone walling and rock art panels. Two panels with some indeterminate red figures and two rheboks painted in white.
C02		Two small red paint marks; one red dot, two short thin red lines.
C03		Indeterminate red paint marks
C08	229	Panel has one faded indeterminate antelope figure. One possible jackal painted in orange. Site also consists of a small stone walled enclosure.

C14		Red human figures walking some faded antelope painted in red. Most art badly faded.
C16		Indeterminate figure that is damaged badly by water and salt wash. Panel is badly flaked.
C17	205	Stone walling abutting the shelter. A kraal and collapsed semi-circular structure exist. Four rock art panels exist and consist of multiple eland, indeterminate figures.
D01	185	A small overhang which is enclosed by a semi-circular stone walled structure. Rock art panel contains two antelope one of which is a possible rhebok.
D02		Two rock art panels at site D02. Two human figures are painted within panel A, and red faint painting which is damaged by water is what constitutes panel B.
D03		Two badly faded red paintings.
D04a	246	Located in the centre of the shelter D04a, at a height of +/- 80cm from the shelter floor is a single human figure in red. This figure is unique. The human figure is painted in a squatting/seated position with its elbow bent at sides and forearms raised to head-level. The head of this human figure is 6m high and diamond-shaped. It has only been outlined; the interior remains hollow. However, natural white on the rock face appears to have been used by the painters to divide the face in two. An historical dam-wall on the north side of the site.
D04b		Two human figures that have been flaked and are faded. Indeterminate figures (possibly human based on thinness) also present.
D05		Very faded indeterminate figures.
D08		Indeterminate painting due to water damage.
D09		One red human figure and another indeterminate figure.
D11		Panel A includes 4 rhebok, two of which are painted in white, two in dark red. One of the rhebok in white is painted facing upwards towards the ceiling of the shelter. The group is painted in roughly the centre of the overhang.
D12		Damaged rock art panel, hard to distinguish the contents.
D13		Three panel containing indeterminate figures, some of which have been damaged by salts.
D14		Two panels, one of which is faded and the other exhibits water damage.
D17		Indeterminate faded panel, partially faded and eroded.
D19		One indeterminate figure badly damaged by salts.
D20		This site has not been divided into separate panels. D20 contains little identifiable imagery, as the damage to the rock face has caused it to disappear. There remains a single red human figure. What other remnants there are also in shades of red pigment. The leg of an antelope also remains.
D21		There are three panels on the boulder which has very faded paintings. There is one clear human figure.

D23	NEW	Panel A is the only panel at D23. It contains a single image of a quadruped painted in black. It is approximately 15cm in length and resembles charcoal but is indeed paint. The quadruped has elongated/attenuated legs and horns and appears to be running/leaping. These horns are akin to those of an eland.
D24		Top left, 6 finger stripes in red. These are faded. Left and centre: a single red triangular shape and a dark red running human figure with knee bent. This figure holds a bow and arrow. Right: This section of the panel contains an extremely faded and flaked remnant of a human figure in red. Only leg remains of this figure.
D25	196	Site with 9 panels with an array of rock art. The majority of paintings are faded. D25 is subject to damage by extensive salt washes (causing flaking), animal rubbing damage, fire damage and dust. There are some interesting figures in the site.
D28	206	Site with 7 panels described in great detail as well as stone walling
D29	208/209	There are two panels shelter. Panels consist of indeterminate figures and red human figures. Panel has flaking. Graffiti present within shelter.
E01	248	Rock art site with multiple panels and containing eland, human figures, striding figures, indeterminate figures, and more.
E02		Single indeterminate red figure
E03		Indistinguishable paint, possible finger dots in red.
E08		E08 contains a single image, that of an unidentifiable quadruped with large, fat legs. This image is 1.2m from the shelter floor, on the left-hand side of the back wall of the shelter
E09		One panel of faded rock art. Water damage has led to panel flaking
E13		Rock art faded and has graffiti below panels.
F01		Panels are indeterminate with faded human figures
F03		Indeterminate red marks in amongst natural markings
F06		Stone walling abutting rock face
F07		Indeterminate figures and marks in bright red. Stone walling built with mud as mortar also present.
F08		One faded eland figure in middle of shelter
F11		Indeterminate red smudge
F13		Panel A consists of 10 human figures, 3 bichrome eland. Panel B contains indeterminate figures.
F14		F14 is a site consisting of multiple stone walled structures including semi-circular dwellings, walls, retaining walls and a kraal. There are two human figures painted onto which the structure is attached.
F15	NEW	Indeterminate figure in panel A. While panel B contains human figures and an indeterminate figure. Panel C contains a faded eland and more human figures.
F17		Panel A consists of eland, faded human figures. Panel B consists of several indeterminate pictures, graffiti, and finger dots. Complex stone walling present with a square dwelling and large enclosure surrounding

F18	NEW	F19 is made up of five rock art panels. The site is extremely flaked and faded. Site is exposed to natural elements that continue to damage rock art.
F22	197	Panel with a rhebok painted in red and a light red eland. There is also a light red shaded polychrome eland. Panels show damage from salts and water
F30		Contained in panel A, the only panel found at F30, are very faded dark red indeterminate
G02		Very faded figures. Three huts and large kraal also situated at site G02.
G04		Indeterminate figure located under the overhang
H05a	241	Large dismantled large double wall in shelter. 8 Finger dots painted in red. Faded eland and human figures
H06		Human figure with strange features such as head of a horse. Painted in black. Legs also resemble those of a horse.
H16		Two finger smears are located within shelter A and historical lightening cross is found within shelter B. Collapsed semi-circular stone walled structures within two overhangs.
H18	219	Panel with dark red human figures, top two figures have one arm raised with bow/stick.
H20	228	Site with seven rock art panels. Panel consists of hartebeest, shaded polychrome eland, rhebok and more. There is a semi-circular dwelling abutting the wall of the shelter.
H21		Single panel, containing three human figures one of which has a large head and mouth.
J01	220	Large expansive shelter with multiple rock art panels. Site has large amounts of pecking. Array of different figures that constitute the rock art panels.
J02	221	Site J02 contains five panels with a range of rock art including multiple human figures in different postures, a possible canid, hartebeest and eland.
J04	227	Site J04 contains eleven rock art panels and contains a multitude of different rock art figures. Including human figures with hunting bags, indeterminate figures, red antelope and more. Presence of some lithics.
J05	217/218	Shelter with ten rock art panels that include paintings of eland, human figures, and more. Some of the art has faded. Stone walling also present at site.
J08	224	Rock art and stone walled site. Very well preserved giant polychrome human figure along two walking human figures with hunting equipment, two running figures with antelope eared caps. Some faded paintings are also present.
J09	223	Stone walled dwelling built below overhang. Rock art panel consists of eland and running figures,
J10	222	Panel A consists of red hartebeest, bichrome eland, running human figures with bows. Large human figure about 80 cm in length.
S02	225	Five rock art panels across back wall of shelter
S03	226	6 panels located across back wall of shelter containing dancing figures, polychrome eland, rhebok, and more.
X01		Three faded and faint eland figures, one indeterminate figure.

Z02		Panel comprising of a human figure painted in red which is faded and indeterminate figures that are also faded.
Z04	245	Four to five indeterminate figures all painted in red. Panel b has two indeterminate figures obscured by soot. Panel C has three large human figures with bags, quivers, arrows, tassels; two therianthropes.
Z06		Three rock art panels that are faded. Consisting of faded animal and indeterminate figures.
Z08		Two panels, the first contains seven eland figures, all of which are very faded. The second panel has two larger eland figures faded in red.

Table 9.2: MARA Database.

Site Name	Site Type	Description
Compensation 1	Shelter	Faded eland, rhebok and human figures. Oil paintings on one panel. Sticks and snakes. Red line with white dots. Finger paintings strange figures, feline figure with head covered in patches
Compensation 2	Shelter	Faded monochrome eland, human figures with sticks, three faded bovids, faded white and orange horse
Dikamoreng 1	Rock Face	Numerous buck figures, some upside down or lying on their side, human figure with bow and arrow in between and buck figure with blood coming from the nose (3 sets of pictures, maybe another 2 sites pictures)
Dipaki 1	Overhang	Running figure and four eland
Dipaki 2	Shelter	Five red hartebeest faded red figure (much older than hartebeest). Red human figure with face, figure has stick over its shoulder. Two smaller red figures. Three large eland, of which, one is faded more. Panel with +-17 red human figures: figures have range of different postures namely crouching or walking.
Dipaki 3	Overhang	Faded red eland
Dipaki 4	Boulder	Two red human figures, along with other nondescript markings.
Dipaki 5	Boulder	White figures, possible baboons, a bichrome eland
Dipaki 6	Overhang	Black human figures with antelope
Eliweni La Bantu 1	Overhang	Black figure, two red human figures, precession of eight red human figures, white/cream figures,
Gladstone 1	Overhang	Bending forward figure holding a stick, 2 human figures, 2 running figures with bows, numerous figures with bows and sticks, figures with headdresses and indeterminate animal figure chasing a human figure.
Gladstone 2	Overhang	Eland figure, not usual has black horns, possible feline creature and green dots
Gladstone 3	Overhang	Faded eland and white paintings of therianthropes
Ha Fututsa 1	Overhang	One bending forward figure and one rhebok painted in red
Ha Fututsa 2	Rock Face	Couple of red human figures
Ha Koko 1	Cave	Eland Therianthropes
Ha Koko 2	Shelter	Four red figures bending forward with sticks
Ha Mampoti 1	Shelter	Very expansive shelter with an array of different subjects painted; ranging from eland, mountain reedbuck, human figures, possible horses, nondescript figures.
Ha Maphoi 1	Cave	Mountain Rhebok, human figures and rain animals
Ha Phiri 1	Rock Face	Two white mountain reedbuck.
Ha Poka 1	Overhang	Polychrome baboon, four human figures, one human figure kneeling in, group of human figures sitting/crouching, two figures in red standing, two ladies in dress and possible horse and man
Ha Rawtshweh 1	Shelter	13 small male human figures with kit (bags etc.) in black, 2 or 3 faded polychrome eland, red male figure with dog or small quadruped, several faded human figures in red, 1 dark red antelope superimposed on eland and 3 black human figures on top of eland.

Site Name	Site Type	Description
Ha Seodinyana 1	Rock Face	Ochre/Red smudges with mountain reedbuck
Ha Seodinyana 2	Rock Face	Panel is faded, consists of human figures, eland and red hartebeest
Ha-Tlakanelo 1	Overhang	Lots of miniature antelope
Ha-Tlakanelo 2	Shelter	Man leading an Eland with a line to the nose
Ha-Tlakenelo 3	Rock Face	2 Therianthropes to the right of the shelter, Eland, Hartebeest and Rhebok
Ha-Tlakenelo 4	Overhang	Hind quarters of an Eland
Ha-Tlakenelo 5	Rock Face	Seven figures, one with bow, fine with white face with antelope ear caps
Hilda Heath 1	Overhang	Two human like figures in dancing positions
Hilda Heath 2	Boulder	Bovine figures, 3 running human figures, human figure with bow and red patches, probably a large panel that is very damaged.
Kholokwe 1	Cave	Elongated human figures painted in yellow, antelope on the roof and 4 red human figures with their arms back
Kholokwe 2	Overhang	Very faded red figures
Kinira Poort 1	Shelter	Strange human like figure in posture of a quadruped, indeterminate red markings, 2 black quadrupeds running, human figures in red, one with a black kaross, a line of red human figures holding sticks, an orange quadruped figure and a black human figure rowing a boat.
Kinira Poort 2	Rock Face	Seven human figures, one with kaross, one standing, one running and four squatting.
Kinira Poort 3	Shelter	Finger painted figures, four horses 'chasing' eight eland, Two horses painted in black and red ochre. One with line into rock
Kinirha 1	Overhang	Two badly faded animal figures, red human figures, two polychrome eland, two mountain reedbuck and human figures holding sticks.
Kinirha 10	Overhang	Human figure sitting on a horse, drawn with a black crayon or charcoal.
Kinirha 2	n/a	Requires revisit
Kinirha 3	n/a	Requires revisit
Kinirha 4	Rock Face	Red human figures, eland, black figure which looks like a baboon, therianthropes with antelope or snake head, black human figure and a faded mountain reedbuck
Kinirha 5	n/a	Requires revisit
Krom Ellenboog 1	n/a	Requires revisit
Krom Ellenboog 2	n/a	Requires revisit
Kwa Bhaliwe 1	Shelter	Biggest site in South Africa
Kwa Bhaliwe 2	Overhang	Lots of buck figures, one painted from the rear, one half human half horse figure painted in white, elands figures, human figures sitting and clapping, more eland figures, a buck figure with white substance coming out from nose, therianthropes figure with line from nose and plenty more eland superimposing one another.

Site Name	Site Type	Description
Kwa Chothwe 1	Shelter	Panel 1: Shaded polychrome eland, red flying/floating bucks, rheboks. Panel 2: four white rheboks, two therianthropes
Kwa Lenge 1	Shelter	Large shelter with rock art
Kwa Lenge 2	Shelter	Finger dots and smears in bright red
Kwa Lenge 3	Shelter	Human figures and five shapes in red ochre crayon
Kwa Lenge 4	Rock Face	Scratched horse figure, scratched cow with red outline. Rock art 5m above present soil level.
Kwa Lenge 5	Rock Face	Indeterminate red figures, badly faded, panel with small quadrupeds and elands painted in red and 2 human figures painted with sticks.
Kwa Lenge 6	Shelter	Eland figures and indeterminate red markings.
Kwa Lesesa 2	Shelter	Eland paintings
Kwa Lesesa 3	Shelter	Initiation site, rock face crumbling with rock paintings on the pieces on the floor
KwaMzongwana 1	Shelter	Faded red human figures, red figure with antelope cap holding item shaped like animal head?, eland alongside red human figures, red bovid like creatures, precession of 7 red human figures, black seated figures, white figures below precession, 3 white figures with bows and quivers, followed by white eland, red smudge above quadruped. Two red figures adjacent to quadruped. Red figure, dark red figures above red smudge, small red quadrupeds adjacent to figure with hook face. White antelope, adjacent to two red figures leaning forward. Multiple small orange figures next to bigger red figures. Faded red figure. Faded seated figure, crouching red human figure. Sotho lightning crosses, black human figures. Red human figure with darker torso(could be from graffiti)
KwaNomajuba 1	Overhang	Red pigment unsure of content.
KwaNomajuba 2	Overhang	3 red human figures, one figure with bow leading red antelope in front of large polychrome eland, red human figure with bow and possible shield. human figure lying on back holding white lines with red ends(possible arrows), running red human figure,
KwaNomajuba 3	Overhang	Faded red eland, red human figures, red quadruped with white tips on ears,
KwaPhillipi 1	Overhang	Two eland, two orange human figures, mountain reedbuck, white posterior of quadruped. Orange figure with multiple lines running across its body. Red Eland. Eland in lying down posture with legs tucked in below torso. Panel with about 14 figures painted in red, varying in size and posture some facing out of the rock face and others carrying sticks.
KwaPhillipi 2	Overhang	Faded red figure, precession of red figures. In range of different postures; bending forward, upright, some with arms extended to the side. Figure with kaross. White figure (possible spirit of the dead) adjacent figure with kaross and then a further two figures with white faces to the right.
KwaPhillipi 3	Overhang	Most likely faded eland. Photos lack detail.
Lekitchening 1	Overhang	Possible human figures and black finger painted human figures

Site Name	Site Type	Description
Maboloka 1	Rock Face	Large site, many eland and human figures and orange finger painting (Revisit: White bending forward figures, eland, red running figures, figure with kaross, red antelope and figures with dancing sticks)
Maboloka 5	Open	Engravings, deepest grooves are 1cm deep, grid like patterns and other geometric shapes.
Mafube Mission 1	Rock Face	Very scratched buck figures, 4 red human figures, one holding a bow, running human figure in red, 4 human figures in white and a Basotho lightening cross.
Mafube Mission 2	Rock Face	Just one red mark
Mafube Mission 3	Shelter	Multiple polychrome Eland (1 looking out of rock face)
Mafusing 1	Shelter	Polychrome eland figure, a line of legs (bodies missing), numerous large black elands and 5 human figures with "tassels" and lines.
Mafusing 2	Overhang	Small marks only
Mafusing 3	Overhang	Eland figure and human figures with bad damage to paintings
Mafusing 4	Overhang	Two horses with reigns drawn with charcoal crayon
Mafusing 5	Rock Face	Two human figures in black
Mafusing 6	Overhang	Red finger dots
Makhulong 1	Overhang	Running figures and finger painted figure with kaross
Makhulong 2	Overhang	Clear shaded polychrome Eland figures
Makhulong 3	Shelter	Large Eland, flaked red figure with white hooves and white Eland on the roof of shelter
Makhulong 4	Overhang	Flaked human figure, Eland and Rhebok
Makhulong 5	Open	None
Malithethana 1	Overhang	Panel 1: Sotho lightening crosses, black marks, red marks, Eland, Hartebeest, Rhebok and human running figures. Panel 2: Unidentified antelope
Malithethana 2	Overhang	Eland and two kaross
Malithethana Source 1	Overhang	Three red human figures sitting, one facing into the rock
Malithethana Source 2	Shelter	Human figure with animal head painted in red, indeterminate red markings and lots of red lines painted.
Malithethana Source 3	Overhang	Four very large human like figures with animal heads, one sitting and clapping, one sitting painted in rear view with a little human figure next to it, one standing with arms up, one sitting holding a line that is about 30cm long, small strange quadruped type figure and another human figure painted in red.
Malithethana Source 4	Shelter	Shelter, 50+m long, 10m deep, 20m high, Basotho lightening symbols, 5 eland 1 large eland, red finger smears and numerals, multiple red fine line humans with head dressers and sticks, 1 superimposed in white.
Maplankeng 1	Shelter Rock Face	Small quadruped figure painted in white and small figure with triangular dress on.

Site Name	Site Type	Description
Maplankeng 2	Shelter	Finger painted and cuttings into the rock.
Masupa 1	Overhang	Eland, human figures in various postures, one bent over with sticks, therianthropes, natural holes in panel circled with orange paint and a strangely painted eland figure
Masupa 2	Overhang	Very faded rock art
Masupa 3	Overhang	Many human figures faded on small panel, large flat rock with engravings of morabarabo.
Military Hill 1	Boulder	Faded white human figure possibly carrying a shield with 3 protruding spears.
Military Hill 10	Shelter	Single horse, black upper half and legs, white under. (16cm long, 7cm high).
Military Hill 11	Boulder	2 red human figures, one holding a stick, 1 faded red patch maybe a human figure, 2 bending forward large red figures, distinct figures, maybe a bag?
Military Hill 2	Boulder	3 animals on left hand side looking at wall, 1 very faded dark red figure probably a buck, 1 very faded dark red figure probably a hartebeest, 1 very faded orange/red figure probably a feline and 1 polychrome buck.
Military Hill 3	Shelter	Red antelope (looks alcephaline), white human figure, very indistinct red quadruped, 3 bichrome eland in a line, red human figure, faded red buck and another faded bichrome eland with red dot above.
Military Hill 4	Shelter	Quadruped, blotches on ceiling, 2 humans one with hands on hips, 10 human figures with 7 having their arms extended, a row of dots at least 11 and numerous "flecks" around these dots extending to the ceiling.
Military Hill 5	Boulder	3 red dots in a row, 2 large orange/red dots
Military Hill 6	Boulder	1 human figure in white (12cm high)
Military Hill 8	Boulder	Requires revisit
Morumotsho 1	Overhang	Very clear but flaked images
Morumotsho 2	Shelter	Very faded but visible images
Morumotsho 3	Shelter	Very flaked human figures
Morumotsho 4	Overhang	10 plus figures
Motijaneng 2	Rock Face	A single faded eland painted. Can still see red ochre but lighter colours like white have faded
Motseng 1	Overhang	Many human figures and eland figures, some with strange attributes more legs etc., possible feline and bird creatures, many antelope type images and very faded red dots.
Mount Jumbla 1	Shelter	Human figures with sticks and shields, orange human figures upside down, orange/red eland, human figures in a line wearing black aprons (trance dance) and holding bored stones
Mount Jumbla 2	Shelter	Traditional eland and rhebok underneath five horses with bridals and riders, 7 eland, one classic style eland painting
New Stands 2	Boulder	Small buck in white (head and legs inside the "wall"), faded red eland, and another white buck painted on top of faded eland, on the other side of the "wall" white legs of buck.
New Stands 3	Overhang	3 red and white eland (15cm long), 1 human figure, 2 faded red quadrupeds, 5 red and white eland, 3 faded buck, 2 human figures in red, small therianthrope in with and red, decoration on top of sitting human figure.

Site Name	Site Type	Description
New Stands 4	Boulder	Pale white figure, 2 faded white figures possibly an antelope, red line, 2 faded white figures, possible rhebok, possible human figure in black, yellow dot and yellow figure not clear though.
New Stands 5	Boulder	Indeterminate red markings
New Stands 6	Overhang	2 small quadruped figures painted in red and orange
New Stands 7	Boulder	Small scratching, 1 white animal figure, 1 red and white eland well preserved body but faded head, 3 faded white figures and an unclear animal figure with white dots on the front of the body.
New Stands 8	Boulder	5 small buck in white, 8 tall human figures in white overlaying a small buck, at least 2 polychrome eland (26cm long), 2 white buck, 3 red human figures bent legs and arm posture, 5 human figures 4 in red and 7 spindly white figure running.
New Stands 9	Open	Example of yellow paint as found in a modern kraal
Nkwediarora 1	Shelter	5+ Large, shaded polychrome eland outlined in charcoal, possible horse figure and human figure with line from head
Nokhohloko 1	Shelter	Panel 1: Monochrome Rhebok head. Panel 2: Shaded polychrome figures 2+ Rhebok, faded monochrome therianthropes
Otterspoort 1	Overhang	Requires revisit
Phephela 1	Shelter	San paintings with graffiti overlaying them. Removals maybe for muthi.
Phuting 1	Boulder	Site with multiple painted figures. Rhebok, eland and human figures
Phuting 10	Shelter	Possible contact scene done in black and red with multiple human figures. Sotho shields
Phuting 11	Shelter	Hartebeest, eland, large array of human figures with rhebok heads. Snake with rhebok head. Feline with yellow belly. Yellow human figure. Figures with bows and arrows. Tusked serpent. Human figure with claw feet. Running figures.
Phuting 12	Boulder	Two red eland, faded antelope, black human figures, white eland with an arrow pointed at it, feline creature, red dots, black painted antelope.
Phuting 13	Overhang	White handprint and 5 scratched white elands
Phuting 14	Overhang	White antelope, red feline, red lines and dots, eland painted with man behind, the man has black dots around his head and human figures painted in white
Phuting 15	Shelter	White and red human figures standing in a line, red flying figure, three red standing figures and a feline creature
Phuting 16	Shelter	White human figures and eland, thin red lines running across which are very faded
Phuting 17	Shelter	One yellow hand print, antelope figures and a recent image of a cow
Phuting 18	Shelter	Group of figures painted in white with sticks and one has a hat, eland, small red dot, crudely painted white figures, yellow object, and antelope in white and red human figures. Poorly preserved rock art, red and white human figures with a polychrome eland.

Site Name	Site Type	Description
Phuting 19	Shelter	Charcoal marks, charcoal horses, 3 charcoal human figures one with hands on hips and Basotho hat, charcoal grids, number 180 written, Basotho lightening crosses, orange finger dots, panel with 5 horses (5x7cm), black eland, horse possibly pulling a plough and a large horse in charcoal.
Phuting 2	Shelter	Eland and human figures
Phuting 3	Rock Face	Very faint human figure
Phuting 4	Shelter	Indeterminate red markings
Phuting 5	Shelter	Multiple running figures
Phuting 6	Shelter	Eland, black figures, human figures, painted lines
Phuting 7	Shelter	Eland figures
Phuting 8	Shelter	Shelter with array of well-preserved figures. Consisting of eland hartebeest and a likely serpentine creature
Phuting 9	Shelter	Red human figures
Qachasnek 1	Overhang	Very faded bovine figure, human like figure with enlarged head and other very flaked images painted in red.
Qachasnek 2	Overhang	Human figure with elongated legs, Black figure "floating", black human figure with animal head and arms extended upwards, red lines, numerous red human figures bending forward holding bows and arrows, dog type figure chasing a human figure, 3 human figures in sitting positions and other red human figures and buck figures.
Qachasnek 3	n/a	Requires revisit
Qachasnek 4	Overhang	3 very flaked human figures and 4 red human figures.
Qachasnek 5	Overhang	Couple of patches of very faded and flaked red images.
Ramaqela 1	Rock Face	Small red dot on fallen rock
Sekwate	Overhang	Bichrome eland with superimposed paler figure with antelope head. Red human figure walking behind the eland. More red human figures with bows and spears. Straight line with smaller lines painted perpendicularly to it.
Seqhobong 1	Shelter	Red hartebeest and red lines. Most paintings covered by vegetation
Seqhobong 2	Overhang	Human figures, rheboks and sticks
Seqhobong 3	Rock Face	Running human figures. Strange monochrome figure, rain animal, sticks with medicine on them and bows and arrows
Seqhobong 4	Overhang	Running monochrome human figures, bows and arrows, bovine like figure, upside down figure, feline figure with long tail, three leopards
Seqhobong 5	Rock Face	Red monochrome human figures, faded red line
Seqhobong 6	Shelter	Red ochre paintings, sticks, running and squatting human figures, Rhebok and eland figures and beasty figure possible juvenile eland
Sethotseleng 1	Overhang	2 Eland, one with white face

Site Name	Site Type	Description
Sethotseleng 2	Shelter	Flying figures, figures with lines from head 'exploding' at top of line, quadrupeds, Therianthropes and figure with spear
Thaba Chitja 1	Overhang	Painted horses and engravings
Thaba Chitja 2	Shelter	Large panel consisting of polychrome eland, humans and buck, one half human half buck polychrome figure holding a stick, human figure with animal head and other human figures with sticks, bows and arrows.
Thaba Chitja 3	Shelter	3 rhebok and charcoal graffiti
Thaba Chitja 4	Shelter	Huge panel, lots of rhebok, finger painted rain animal, sealed kaross group with kit, rhebok with lines and a large rain animal.
Thaba Chitja 5	Shelter	Badly damaged ochre markings on the roof of the shelter
Thaba Chitja 6	Overhang Shelter	Badly faded bovine like figure, a buck figure lying down and 2 badly scratched buck figures.
Truant 1	Shelter	Bovine figures, strange images on the roof, possible rain animal with human figures around it, eland and human figures around the panel.
Vleedraai 1	Overhang	2 red human figures, very faded eland figure, 4 very faded red human figures, white finger smears, little red human figure, couple of black human figures, some running and more buck figures, some polychrome.
Vrymani 1		Faded red human figure
York 1	Overhang	Four human figures with sticks, one bending forward, 3 antelope figures, black human figure with antelope ears holding a spear and shield and four black human figures.
Zwart Modderfontein 1	n/a	Requires revisit

.

9.2 Data Used

9.2.1.1 SRTM

USGS (2014), Shuttle Radar Topography Mission, 1 Arc Second scene SRTM1S30E029V3, Unfilled Unfinished 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland, Feb 2000.

USGS (2014), Shuttle Radar Topography Mission, 1 Arc Second scene SRTM1S30E029V3, Unfilled Unfinished 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland, Feb 2000.

USGS (2014), Shuttle Radar Topography Mission, 1 Arc Second scene SRTM1S30E028V3, Unfilled Unfinished 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland, Feb 2000.

9.2.1.2 SPOT 6

Astrium 2013, SPOT6/7 Satellite imagery for global solutions, Astrium EADS Company, http://www.astrium.eads.net/en/programme/spot-603.html. Airbus Defence and Space

9.3 Figures

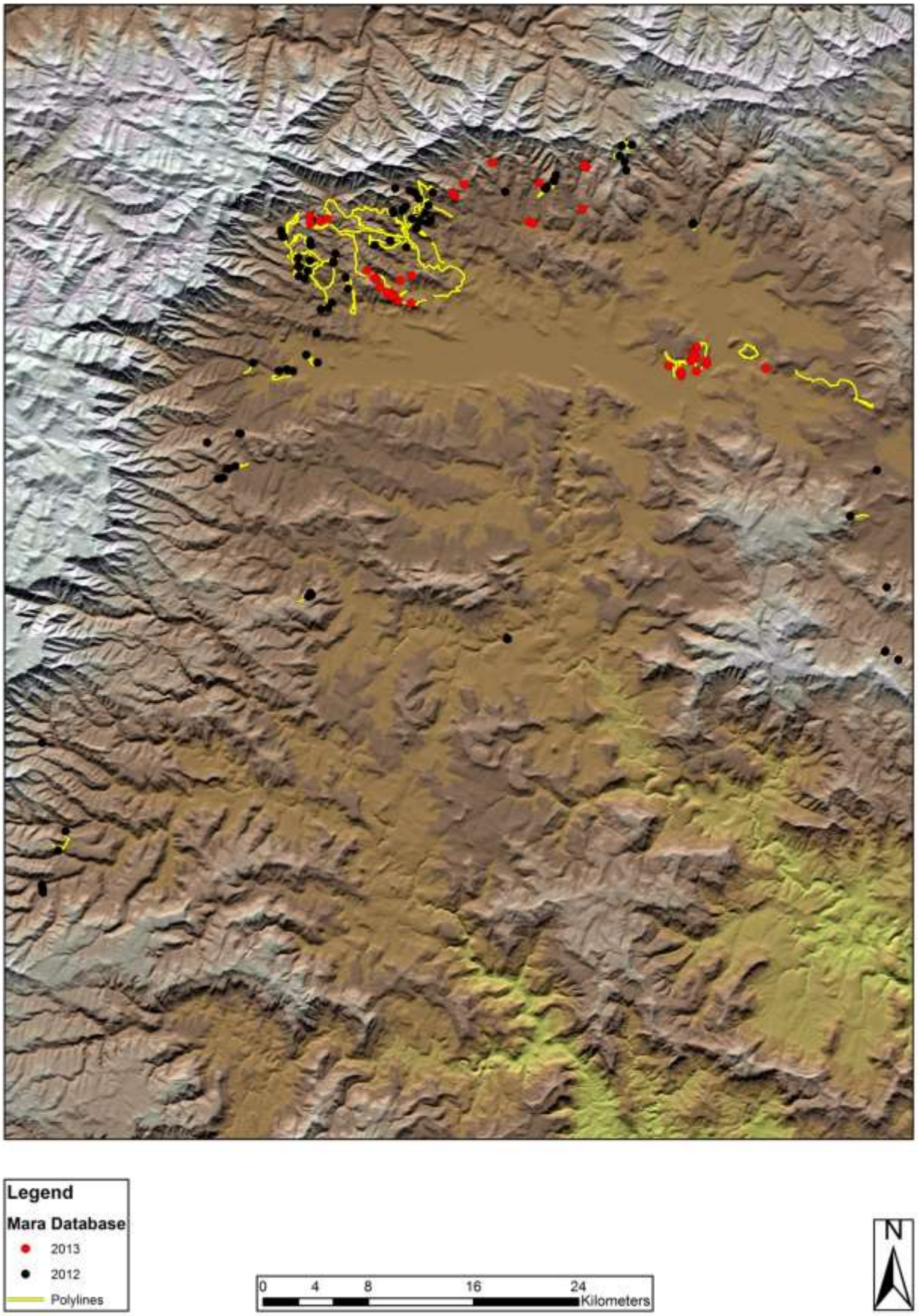


Figure 9.1: MARA survey tracks, areas without tracks depict areas where tracks were overwritten.

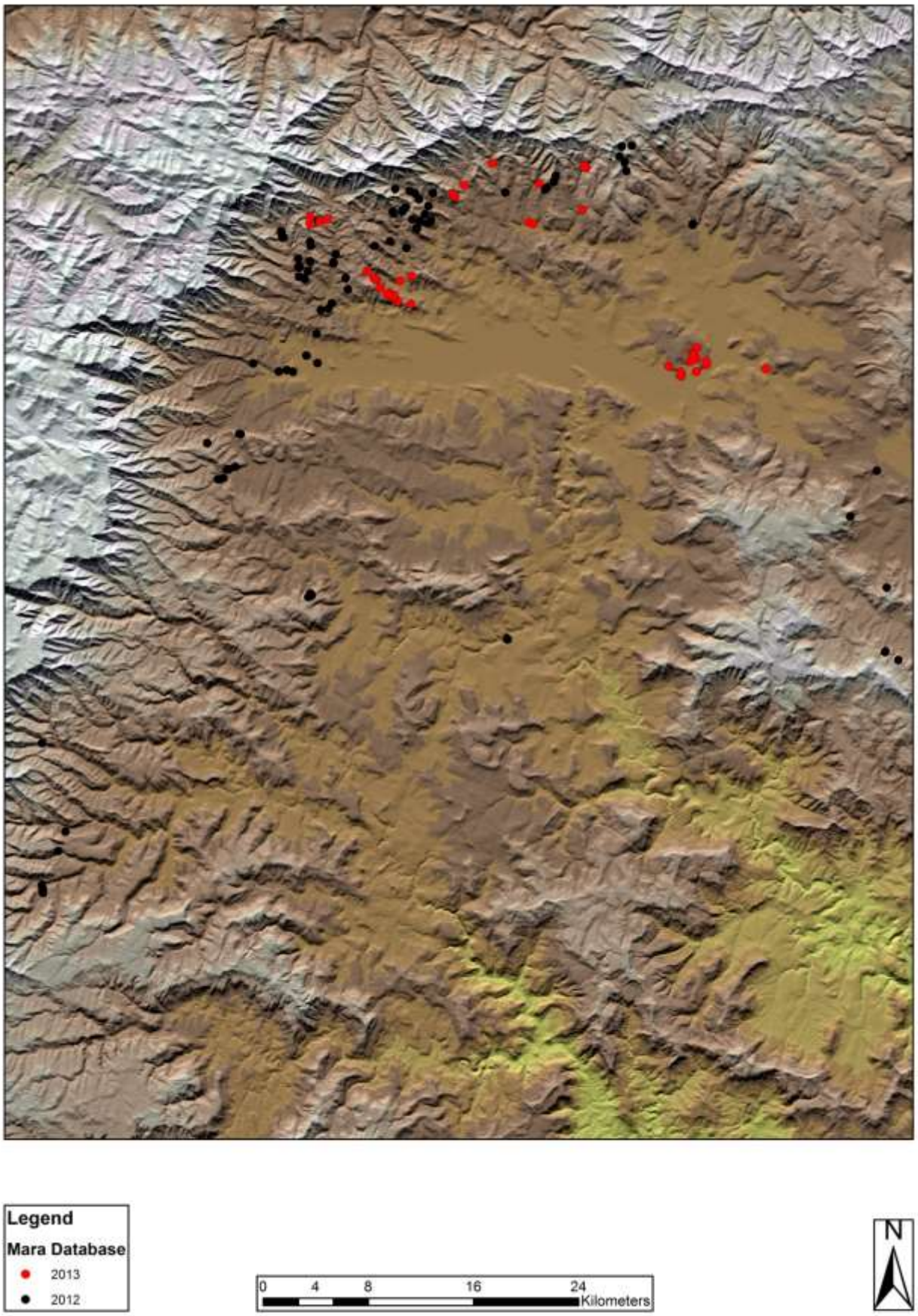


Figure 9.2: Painted Relief for the Alfred Nzo and Joe Gqabi Districts with MARA Sites as of 2012.

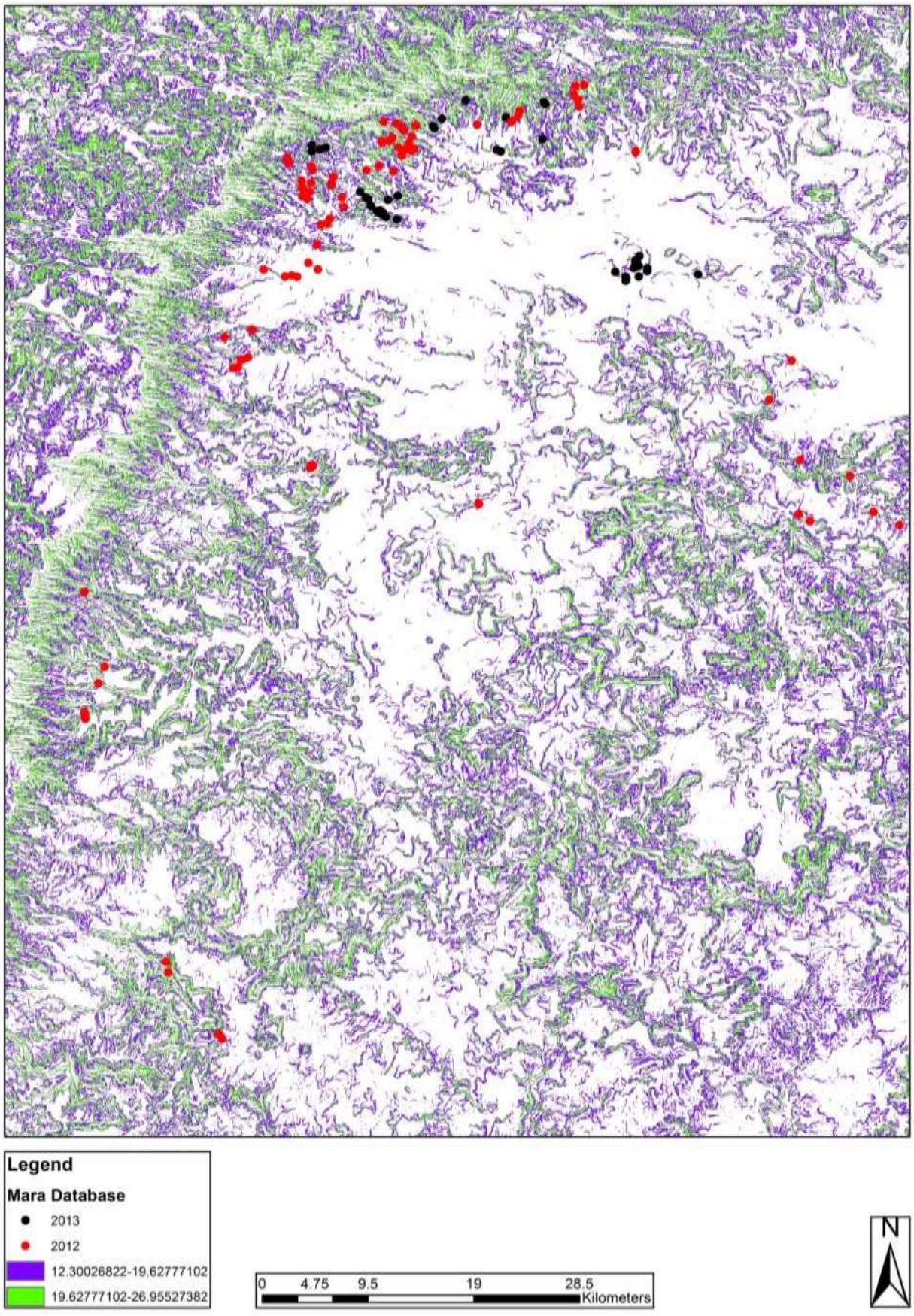


Figure 9.3: Slope slice for the Alfred Nzo and Joe Gqabi Districts, white background reflects areas with null values.

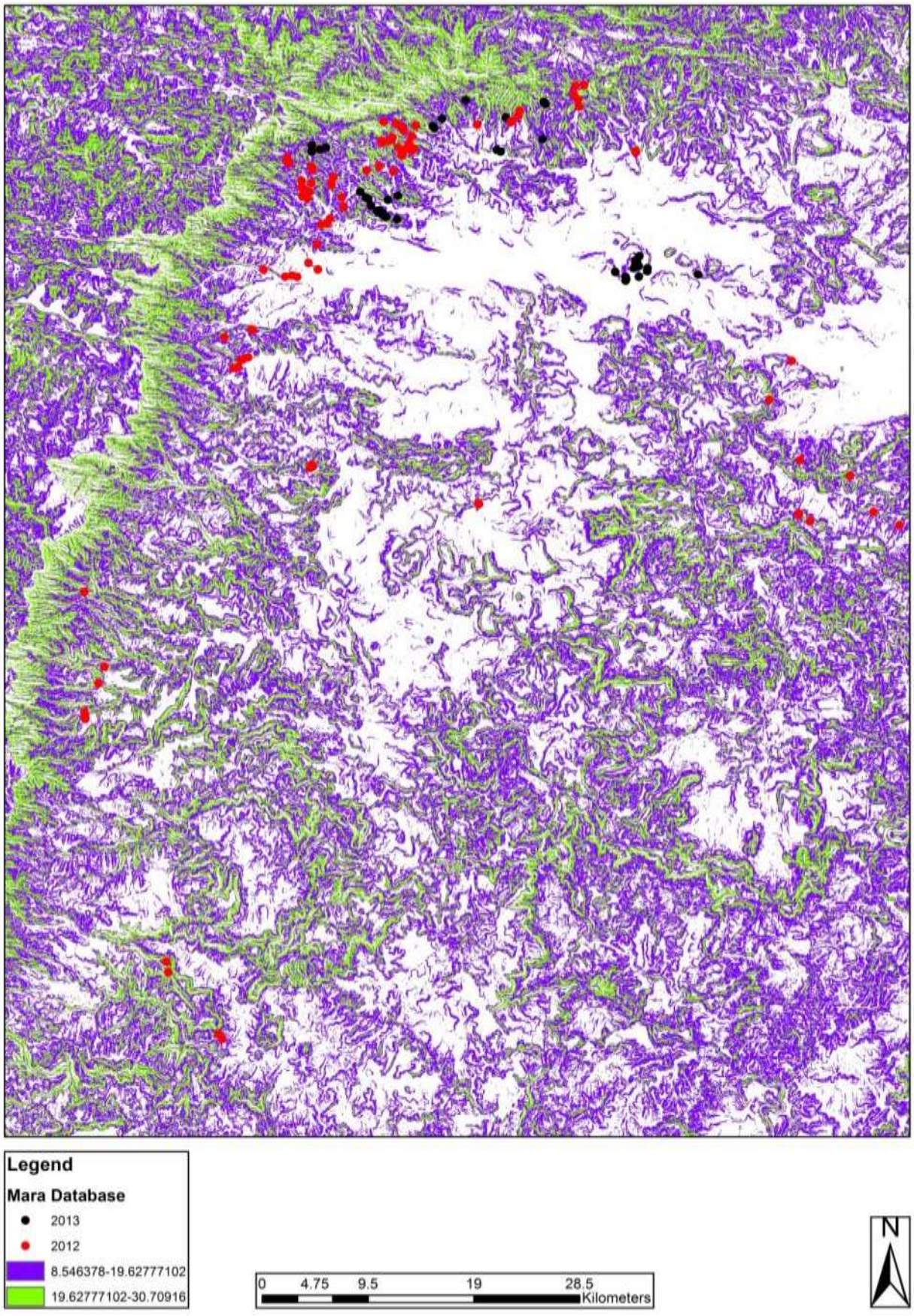


Figure 9.4: 150% extension of the slope slice, white background reflects areas with null values. Large white area depicts the alluvium as discussed earlier.

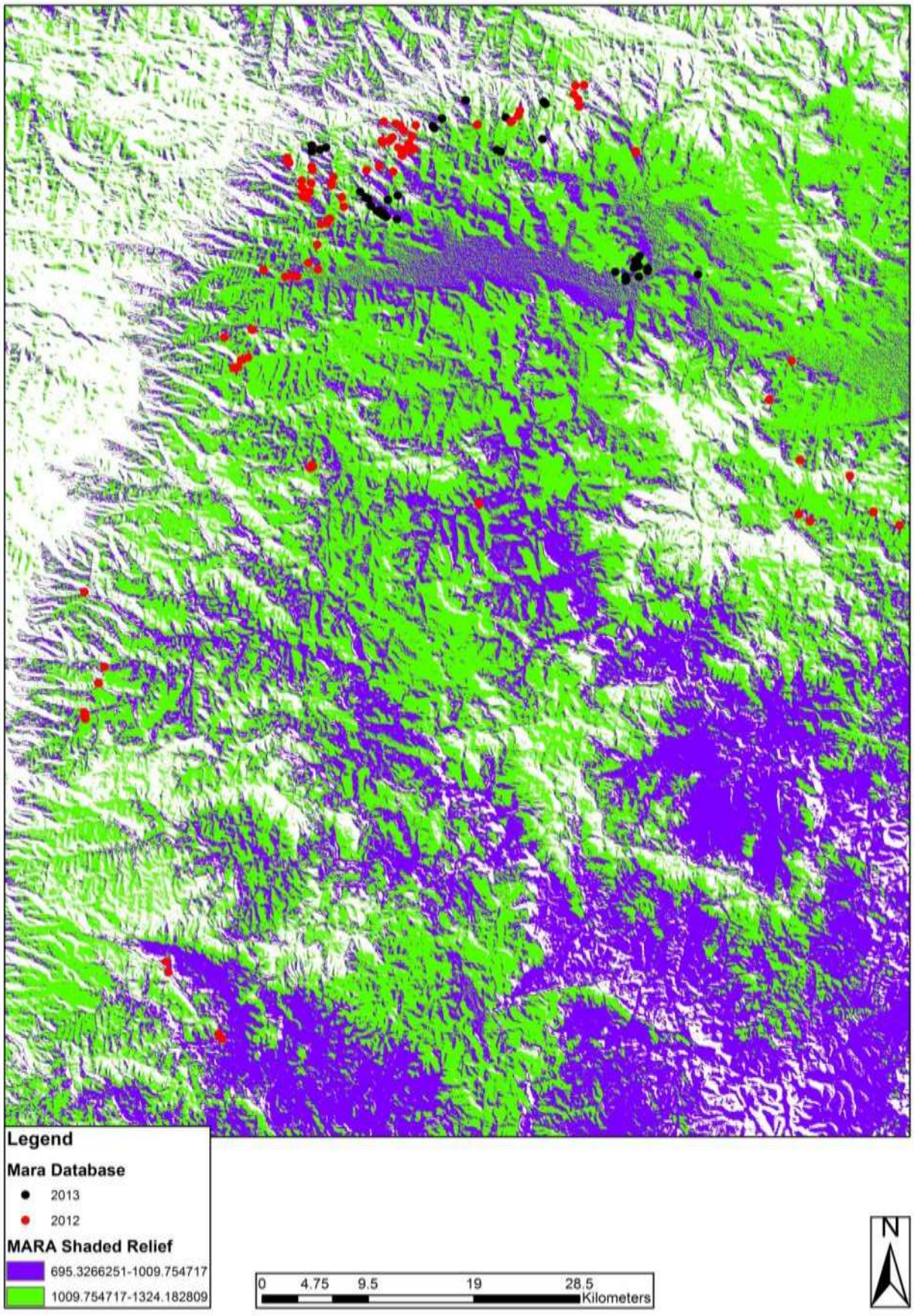


Figure 9.5: MARA shaded relief, white background reflects areas with null values.

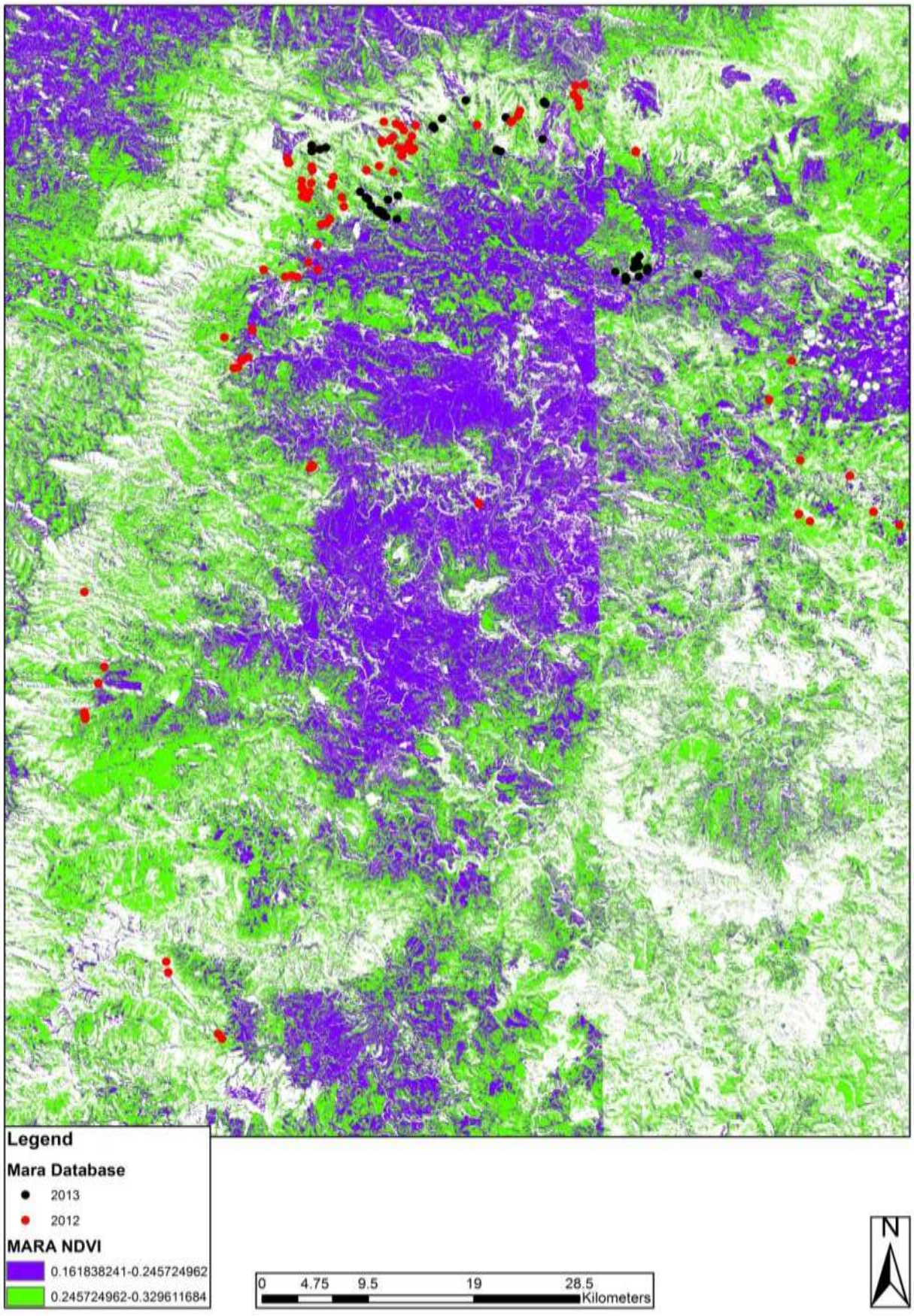


Figure 9.6: MARA NDVI, white background reflects areas with null values.

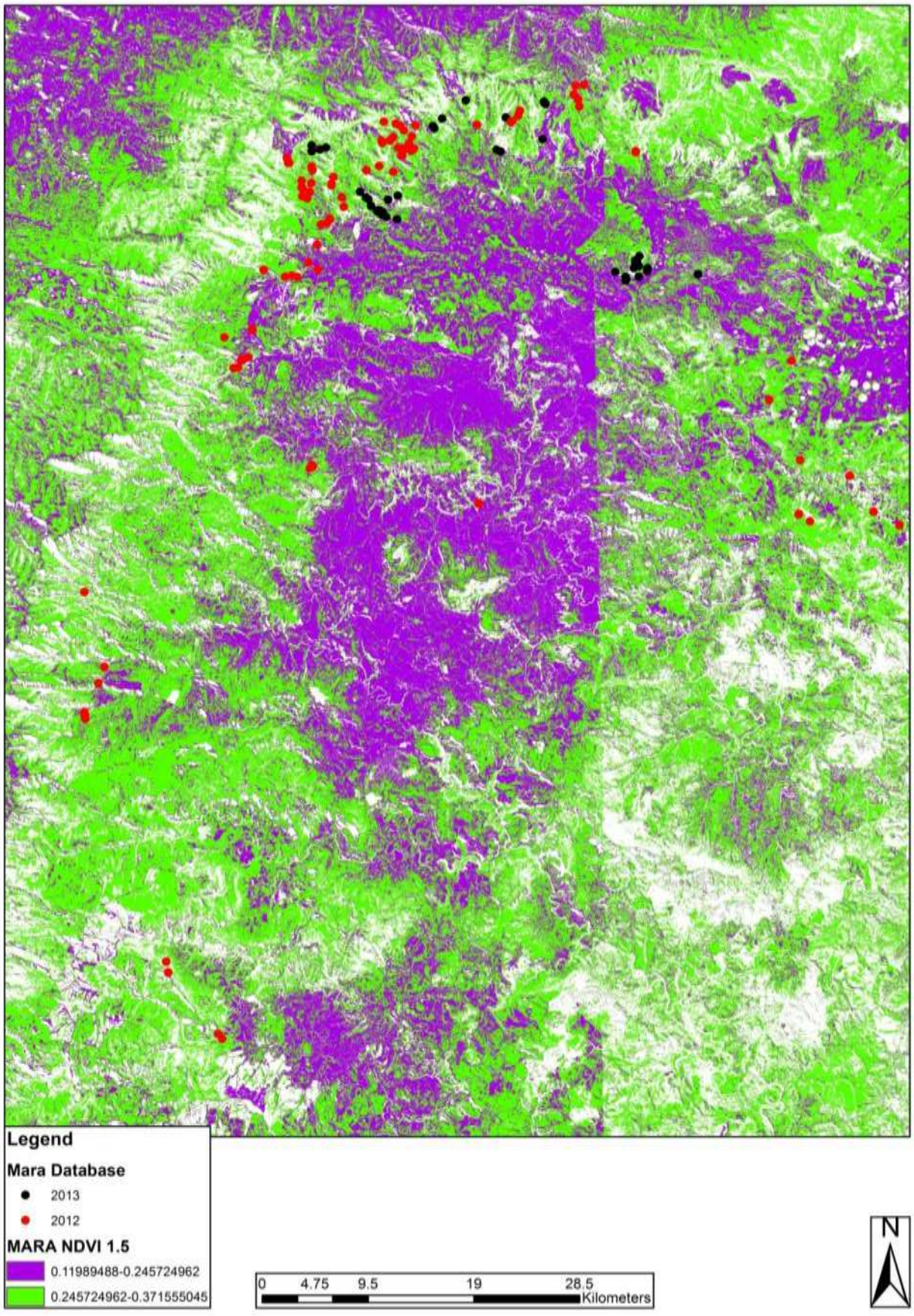


Figure 9.7: MARA NDVI with thresholds expanded by 150%, white background reflects areas with null values.

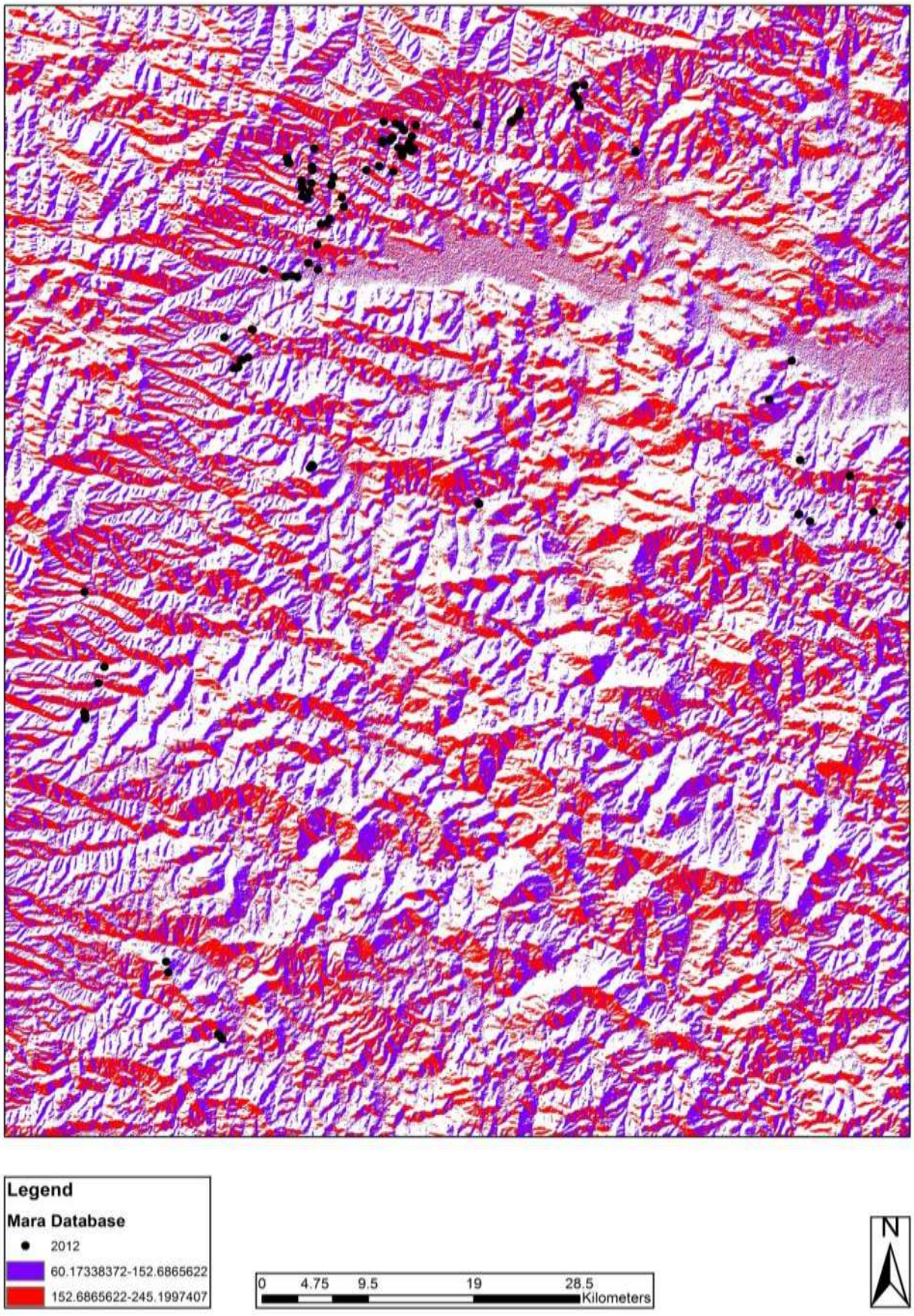


Figure 9.8: MARA aspect slice, derived from SRTM, white background reflects areas with null values.

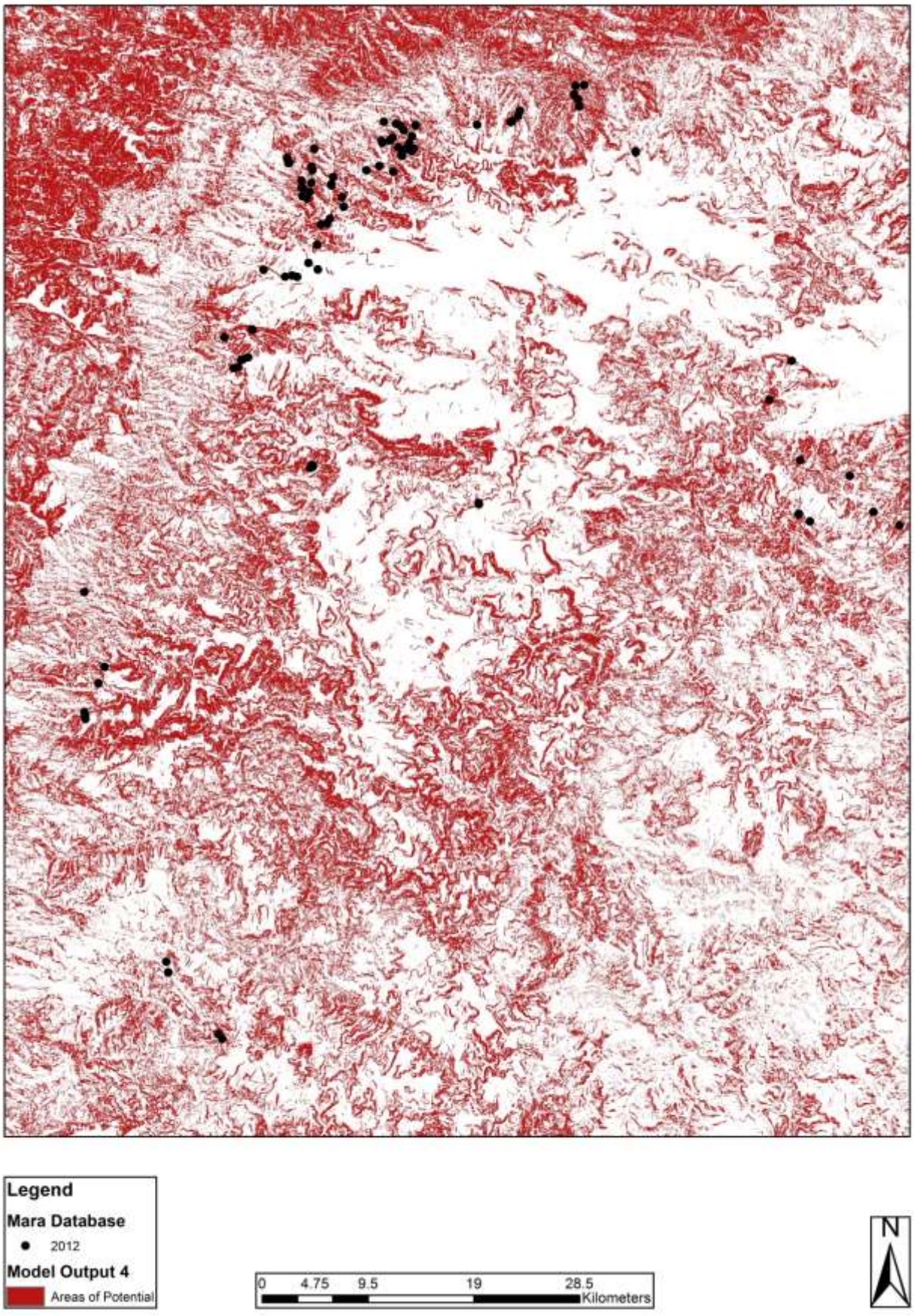


Figure 9.9: Model Output 4, white background reflects areas with null values.

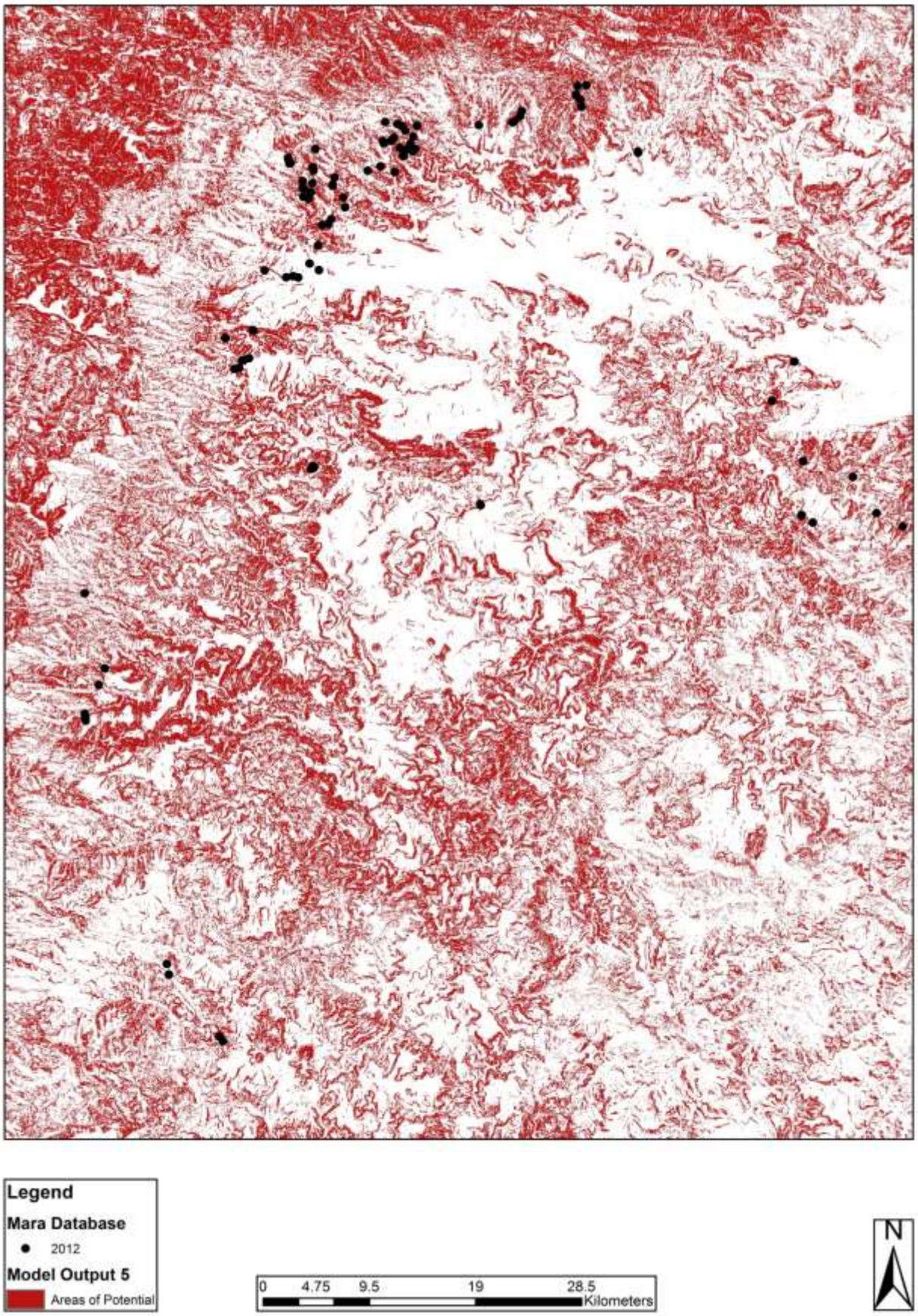


Figure 9.10: Model Output 5, white background reflects areas with null values.

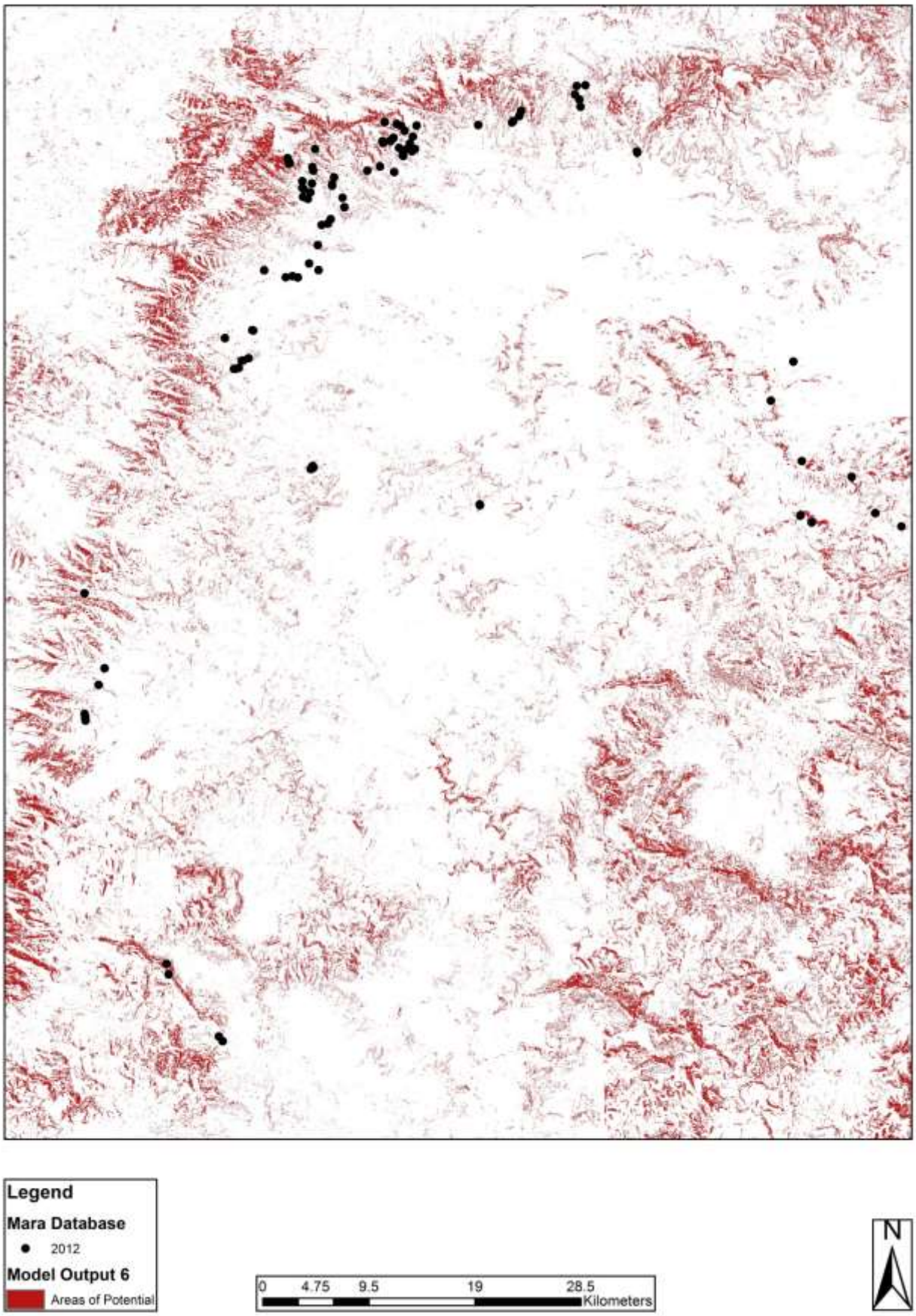


Figure 9.11: Model Output 6, white background reflects areas with null values.

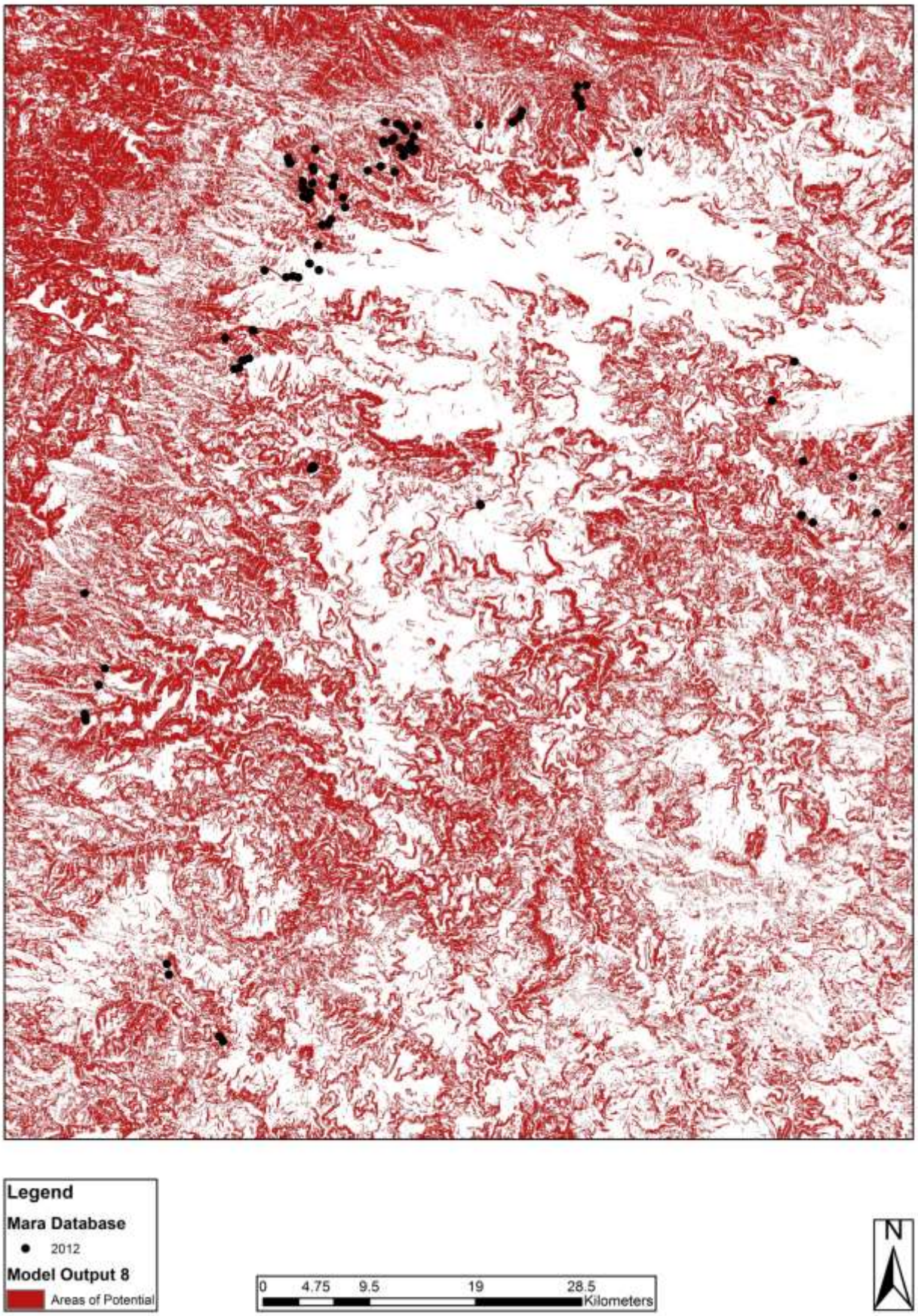


Figure 9.12: Model Output 8, white background reflects areas with null values.

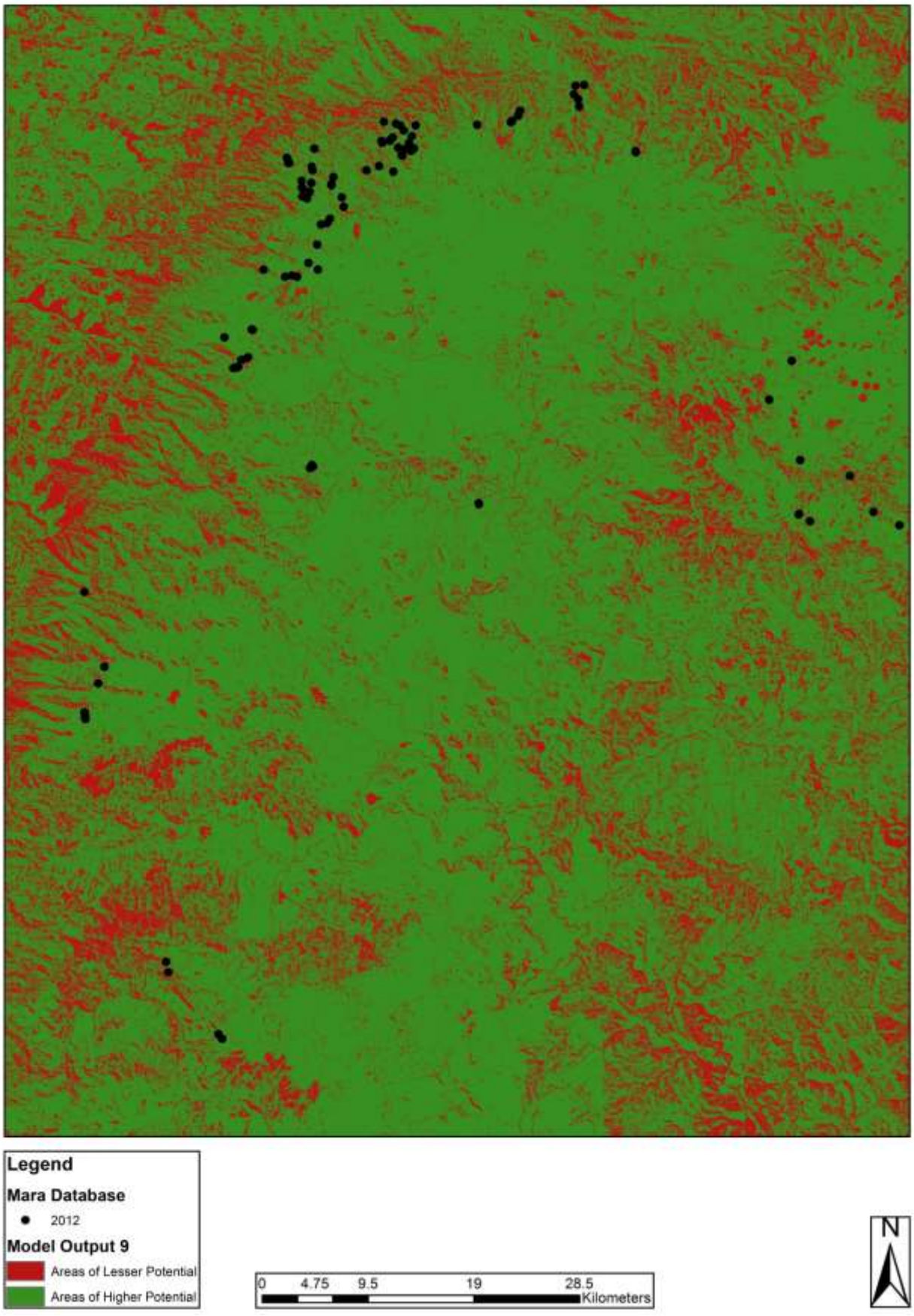


Figure 9.13: Model Output 9

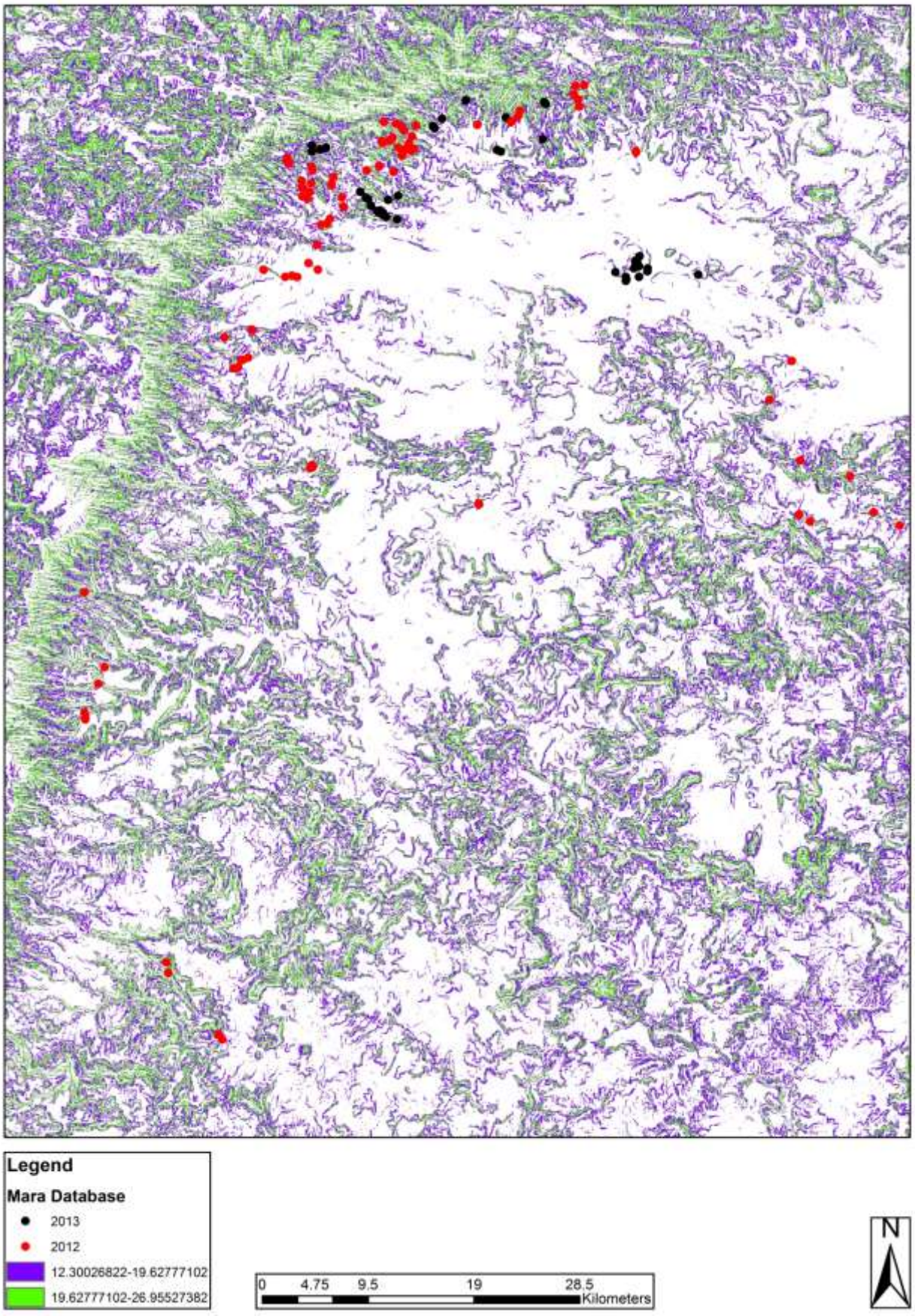


Figure 9.14: Slope slice for the Alfred Nzo and Joe Gqabi Districts, white background reflects areas with null values.

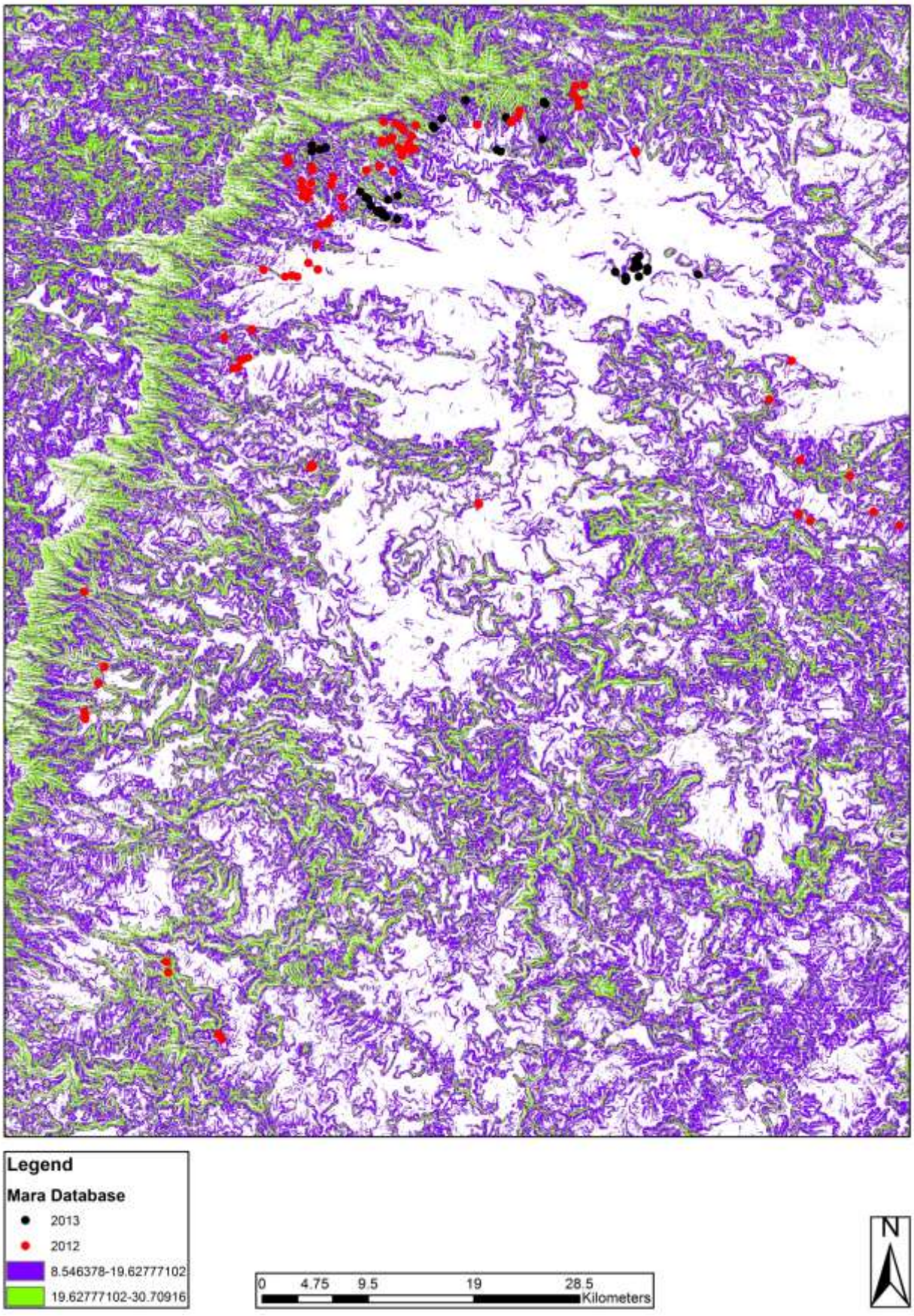


Figure 9.15: 150% extension of the slope slice, white background reflects areas with null values. Large white area depicts the alluvial plain discussed earlier.

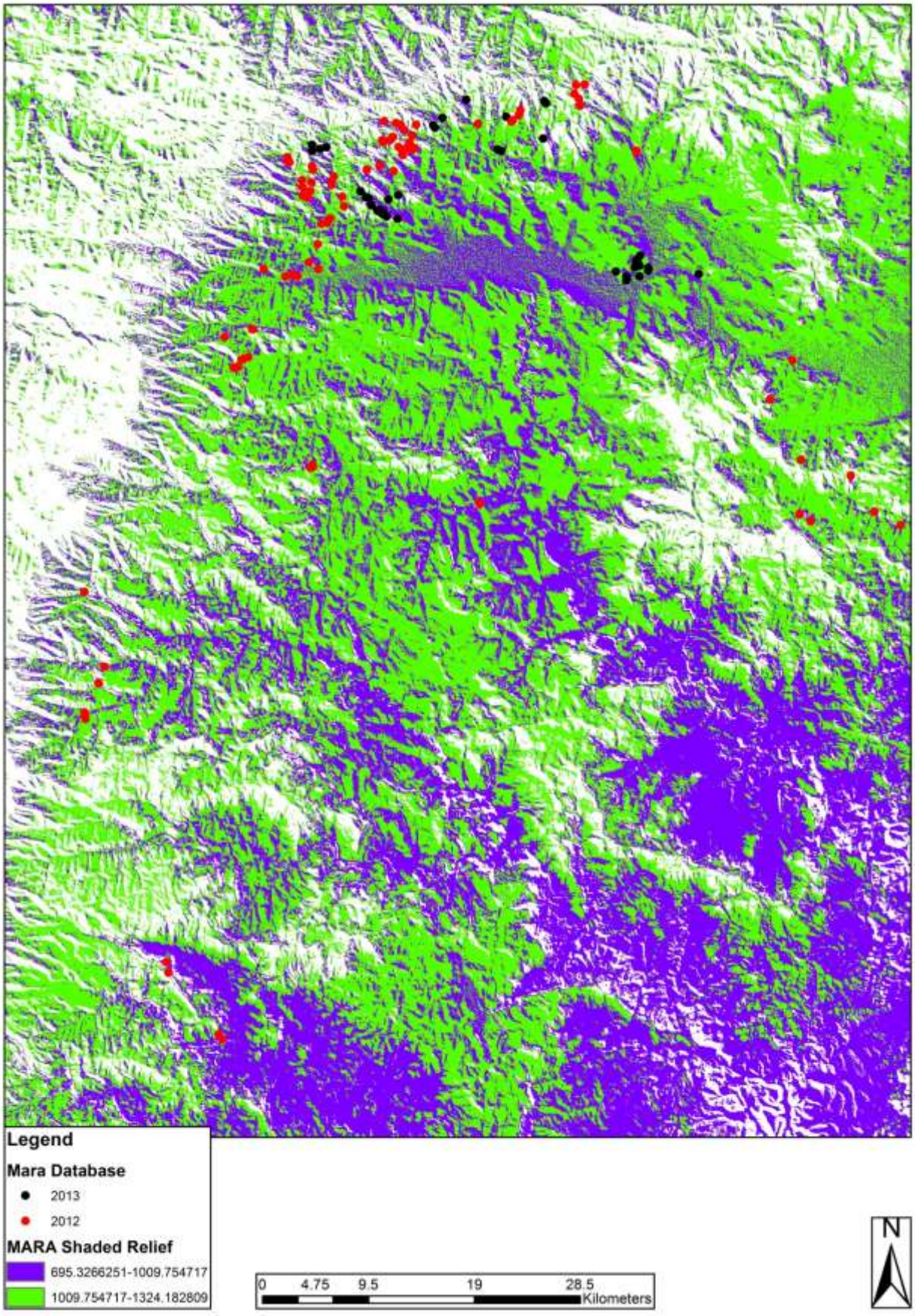


Figure 9.16: MARA shaded relief, white background reflects areas with null values.

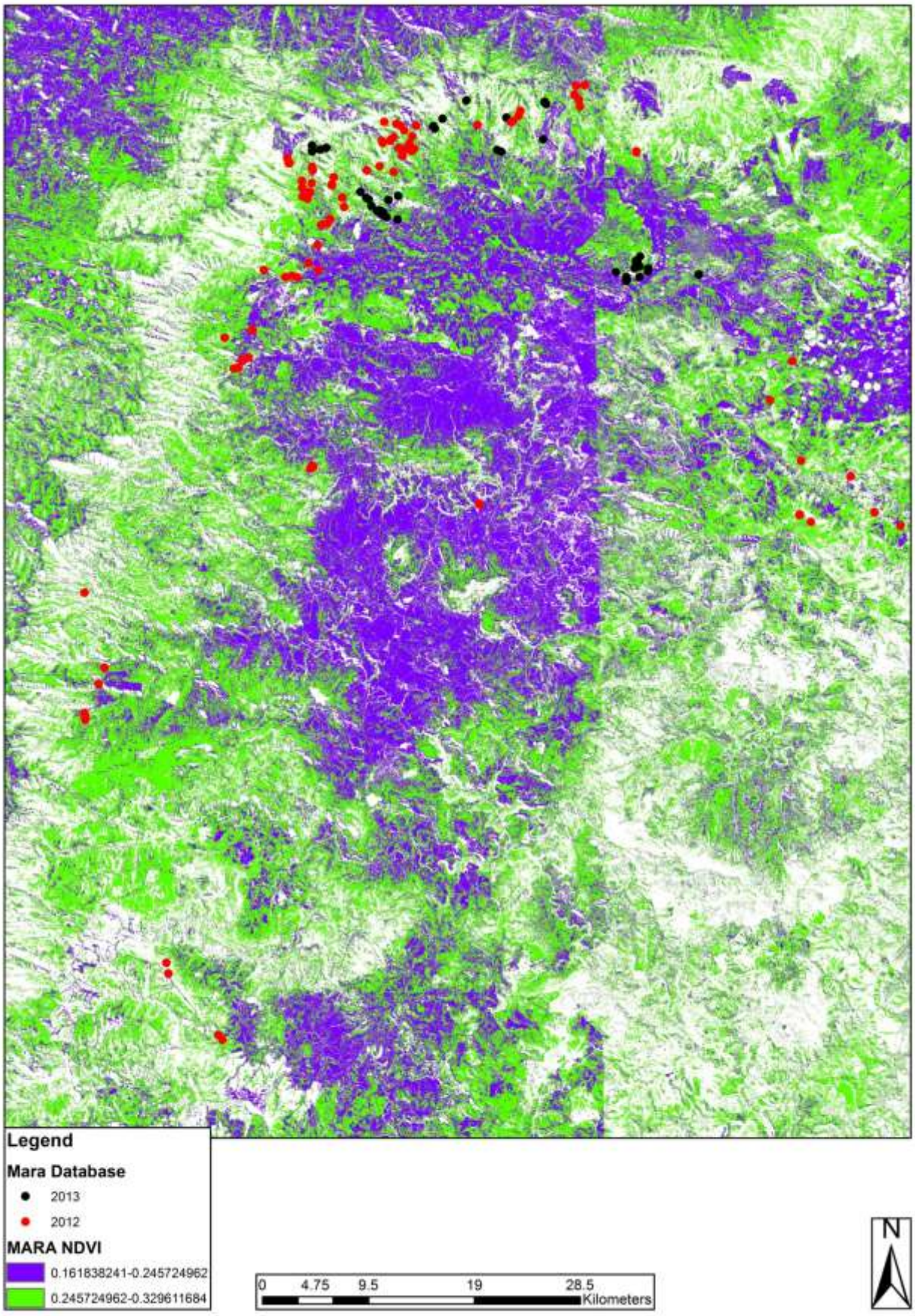


Figure 9.17: MARA NDVI, white background reflects areas with null values.

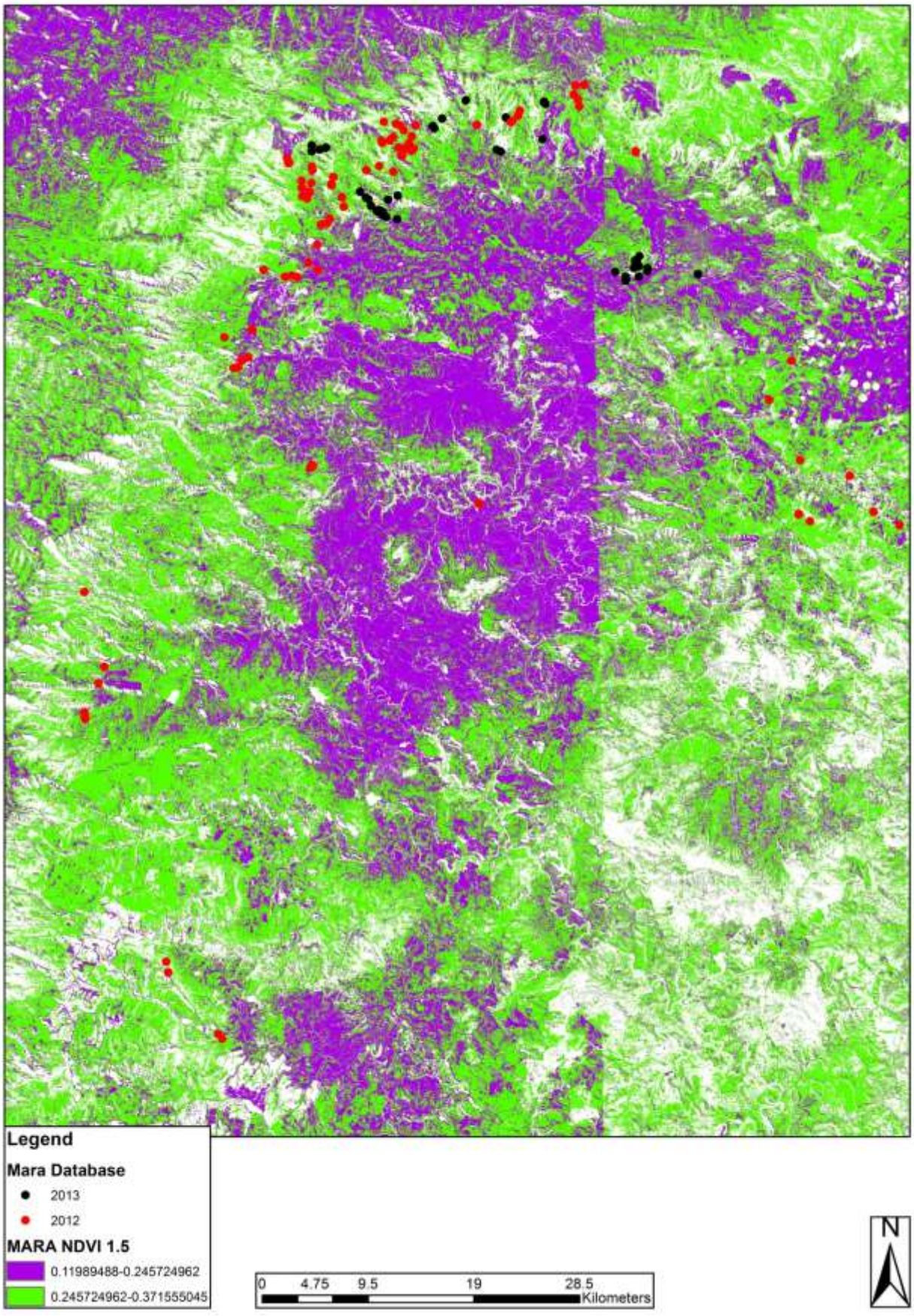


Figure 9.18: MARA NDVI with thresholds expanded by 150%, white background reflects areas with null values.

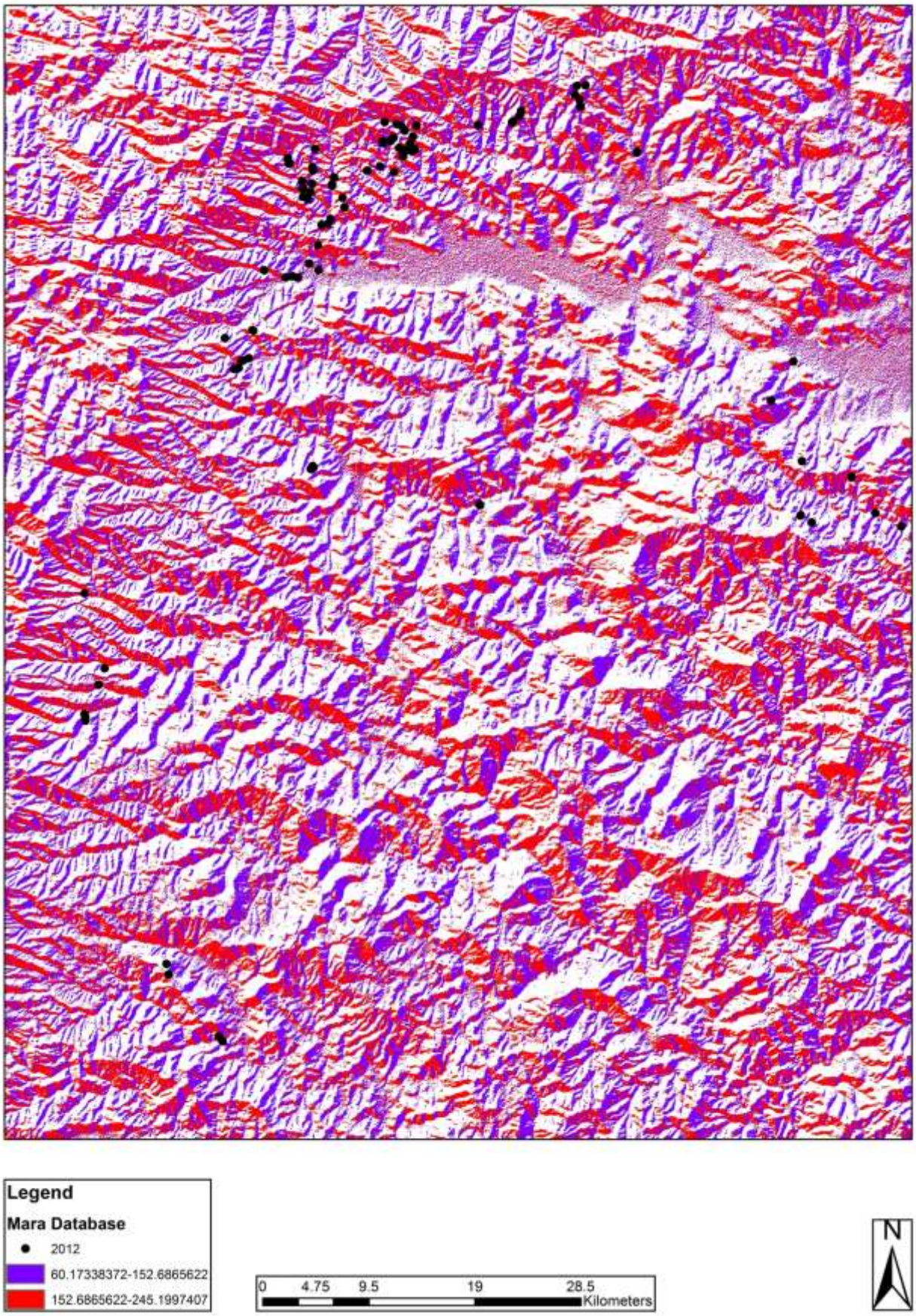


Figure 9.19: MARA aspect slice, derived from SRTM, white background reflects areas with null values. Red and purple depicts areas that are preferential based on the mean aspect.

9.4 Site List

Table 9.3: List of known sites in the surrounding areas of Matatiele. Abbreviations included for Natal Museum Records (NMR), East London Museum Records (ELMR), Archaeological Data Recording Centre (ADRC), and Van Riet Lowe (VRL)

Site Name	MARA	Derricourt	Carter	Vinnicombe	VRL	NMR	Willcox	Goodwin	ADRC	ELMR	Malan	Batiss
Belleview				Vinnicombe								
Berridale				Vinnicombe								
Bertvale Farm			Carter									
Bittern 1		Derricourt	Carter		Lowe							
Bittern 2			Carter									
Bon Accord		Derricourt			Lowe							
Chevy		Derricourt			Lowe							
Dengwane		Derricourt			Lowe							
Donald Drift		Derricourt			Lowe							
Esilindini		Derricourt			Lowe							
Etchellberg		Derricourt			Lowe							
Ethelsale		Derricourt							ADRC			
Fiectcherville		Derricourt			Lowe							
George Moshesh	MARA	Derricourt			Lowe					ELMR		
Gladstone	MARA	Derricourt	Carter			NMR	Willcox					
Gxaku		Derricourt			Lowe							
Harmony		Derricourt										
Hilda Heath	MARA	Derricourt	Carter		Lowe							
Hlankomo		Derricourt			Lowe							
Joubert Farm			Carter									
Ketelete		Derricourt			Lowe							
Kinira (Kenegha) Poort	MARA	Derricourt	Carter				Willcox	Goodwin				
Kirk			Carter									
Koningskroon				Vinnicombe								
Koppies Kraal				Vinnicombe								
Krom Elboog	MARA	Derricourt					Willcox					
Kruiskoop				Vinnicombe								
Kueberg		Derricourt			Lowe							
Likhetlane		Derricourt			Lowe							
Loyalty Shelter			Carter									
Luzie		Derricourt			Lowe							
Madanagala	MARA	Derricourt			Lowe					ELMR		
Mafivake		Derricourt			Lowe							
Malan's Near Ramaselitso Gate			Carter								Malan	
Maria Zell	MARA	Derricourt	Carter									
Matandela		Derricourt					Willcox					
Matube (Mafube) Mission	MARA	Derricourt			Lowe							
Middle Valley				Vinnicombe								
Mohobotsana		Derricourt			Lowe							
Mont Plesir		Derricourt			Lowe							
Moshebi's (Multiple Sites)	MARA		Carter									
Mzongwana		Derricourt					Willcox		ADRC			
Nene Gate	MARA	Derricourt			Lowe					ELMR		
Ngolloe		Derricourt			Lowe							
Nkasole		Derricourt			Lowe							
Nooitgedacht				Vinnicombe								
Paballong		Derricourt			Lowe							
Pigeon Rocks	MARA	Derricourt							ADRC		Malan	
Qacha's Nek	MARA	Derricourt			Lowe							
Ramaohlakona			Carter									
Rheebok's Rust		Derricourt										Batiss
Seghobong	MARA	Derricourt			Lowe							
Shepperds Mission			Carter									
Thaba Chitja	MARA	Derricourt				NMR						
The Meads		Derricourt		Vinnicombe					ADRC			
Tinana		Derricourt			Lowe							
Tsoloberg		Derricourt			Lowe							
Upper Tsitane		Derricourt			Lowe							
Upper Umtai River		Derricourt							ADRC			
Vaalbank				Vinnicombe								
York	MARA		Carter									
Zwartmodder Fontein	MARA	Derricourt		Vinnicombe		NMR			ADRC			

9.5 Site usage

Without performing excavations, it is difficult to determine what the activities may have been at any given site and, in any event, site use signatures may be regionally or locally specific. In each research area (MARA and SNP) localised trends were identified with some certainty. These included the Mofoqoi valley in the SNP, Phuting, New Stands and Military Hill in Matatiele.

9.5.1 Aspect

The notion of sites occurring in similar aspects may be a coincidence, however, such a notion needs to take certain components into consideration: are other sites with alternate aspects painted elsewhere, is the presence of these sites based on the occurrence of potential rock art locations in easterly aspects or is there a conscious choice to paint in east facing sites. Assessing the distribution of the aspect threshold, it can show the dynamic range of aspects that can be painted and the threshold covers the majority of this range. Is it still acceptable to state that there is a preference to paint in these sites? The aspect threshold covers 79% of the possible values, showing the broad range of aspects that contain rock art sites, although the mean is south easterly, this can be seen as either a preference for sites to be painted or the predominant aspect of the majority of potential rock art locations.

9.5.2 Environmental Determinism

Are human choices influenced by the environment? This age old question is one that has been asked and debated thoroughly within archaeology. Making correlations to site type is problematic as there is limited evidence to support why a specific rock shelter has rock art housed in it while a similar shelter has no rock art at all. Researchers have tried to make similarities between the rock art content and environment, but this is also problematic for a number of reasons; no record of environmental change from time of rock painting until today, some content within the rock art does not and may not have appeared in specific areas in the past.

Archaeological uses of predictive models, as a means of explanation, are problematic as they seek to correlate the environment to archaeological contents. The problem with this is that these predictive models focus on environmental traits/characteristics (the characteristics that are of relevance to predictive models and GIS), hence these models are inherently trying to identify parcels of the environment that show similarities to known archaeological sites (Wheatley 2004: 5).

However, Wheatley (2004: 6) shows that the use of identifying sites based on the environment de-humanises the people responsible for the archaeology. This statement is valid as the suggesting that decisions made by humans were simple, straightforward and often governed by the environment is limiting and harms the theoretical aspects of archaeology.

This assumption is valid because in some cases, the actual models are used to model human behaviour, which is problematic as site locations may not have been decided based just on environmental characteristics. Furthermore, Wheatley suggests that any assumptions made using correlations assume that actions or agency of the people of interest is disregarded as they are making decisions based on the immediate surroundings (Wheatley 2004: 5).

Rock art site locations are largely dependent on the availability of a rock face that could be painted and therefore many sites share similarities such as geology, aspect, and elevation. Without a rock face, the paintings would not occur. However the problem that exists relates to why some shelters have rock art and why others do not some sites may have had rock art present and it has since faded and, or flaked. However, specific site selection may be influenced by factors that researchers are not aware of today such as spiritual or religious influences. So the question relates more to site selection than that of environmental determinism.

9.6 Case Studies

Areas with high densities of rock art sites such as Phuting, Military Hill and New Stands were identified by the predictive model as areas with high potential that required surveying. Although all of these areas, namely particularly the Phuting Valley, would have been surveyed at some point, the model was able to identify it as an area that would probably have contained rock art sites. Therefore, it was surveyed sooner than it would have if the research continued in a systematic fashion. Two of these areas are discussed as case studies and are assessed based on archaeological content, environmental characteristics and the possible reasoning behind the high density occurrences.

The initial MARA area and the percentage of sites that fall into areas classified as areas with the potential for containing rock art sites, this will be followed by the assessment of sites that were located in Sehlabathebe National Park. The analysis of areas that are identified as archaeological hotspots will be discussed whilst paying particular attention to two areas identified during this research, first the Phuting Valley and then the Mofoqoi River Valley of Sehlabathebe. The final component that will be included in this results chapter is the inclusion of a few well known sites and whether they fall into areas with the potential for containing rock art sites.

9.6.1 Phuting Valley Case Study

The Phuting valley occurs within the MARA research area and is one of the denser concentrations of rock art sites within the MARA research area, let alone the greater region. The valley contains 21 rock art sites of which 20 occur on the north east facing slope of the valley. A scatter of Later Stone Age tools was also located within the Phuting Valley. The valley houses five high significance rock art sites with major potential for future research. This valley can also be used to study possible movement passages throughout the region as it could have provided a thoroughfare between areas above and below the Maloti-Drakensberg Mountains. Prior to the discovery of the sites within this valley, sites were located in less nucleated areas.

The valley provides some questions to the researchers: first why are twenty rock art sites located on one side of the valley and only one site located on the opposite side. Is this evidence of site choice or a distinct preference in aspect? Why does this valley contain this many rock art sites and what could contribute to this valleys high site density? Why do other areas not contain as many sites as this? Are these sites possible occupation sites? Was the area occupied or was it just used for the purpose of painting?

The presence of twenty rock art sites located on the north east facing side of the valley is based on a few characteristics; the presence of sandstone rock shelters which is boosted by the amount of large boulders providing overhangs (Boulders contain four of the twenty rock art sites), the north east side of the valley is more accessible and less steep than the other, whereas the south west facing slope is inhabited by black wattle today – although not a characteristic that would have affected accessibility during the time of painting – it affects access today.

9.6.2 *Mofoqoi Valley Case Study*

The Mofoqoi river valley of SNP is a similar in nature to the Phuting Valley of MARA, as the majority of rock art sites occur on one side of the river valley. The Mofoqoi valley has seven high significance rock art sites on the north and east facing side of the valley whereas the west facing side of the valley contains one high significance rock art site and two low significance sites. The valley contains a substantial amount of potential rock art site locations that occur on the side of the valley with the higher concentration of rock art sites. The presence of these sites could be based on a preferential aspect or could be based on the availability of more sites on one side of the valley and not the other.

The presence of sites on one side of the valley might point towards a local preference to paint in north east facing sites but the density of potential sites on the one side of the valley could obscure

this. Therefore, a preference towards a specific aspect might exist however this trend could be biased by the lack of sites on the other side of the valley. In this example, would the occurrence of potential rock art sites result in a similar distribution if these potential rock art sites occurred on the opposite side of the valley?

9.7 Predictive Modelling Process

1. Create individual components for research area from obtained imagery

2. Obtain the relevant statistics for the research area, such as the distribution of sites against the individual components

3. Export the remote sensing components into ERDAS Imagine for data slicing.

4. Slice data using 'Level Slice' located under the Terrain Menu of ERDAS Imagine and create thresholds (Terrain Menu → Level Slice)

5. Export data and then reimport to ArcGIS (Ref.)

6. Add all the components to the Weighted Overlay, located within the Spatial Analyst submenu of the ArcToolbox (ArcToolbox → Spatial Analyst → Overlay → Weighted Overlay)

7. Assign values to the individual components prior to computing the Weighted Overlay

8. Resultant image from Weighted Output shows the areas of rock art potential

9. Test resultant image against known sites to determine if the rock art sites correlate to areas of rock art potential

10. Conduct a field survey of the MARA region using initial predictions

11. Use results from field survey to strengthen initial model and then apply it to Sehlabathebe National Park.

12. Use results from Sehlabathebe to try strengthen model further

9.8 Rock Art Sites



Rock Art Site 1: Dipaki 2



Rock Art Site 2: Ha Phiri 1



Rock Art Site 3: Hekeng Ya Tshepe 1



Rock Art Site 4: Malithethana Source 6



Rock Art Site 5: Mambhele 1



Rock Art Site 6: Phuting 5



Rock Art Site 7: Phuting 6



Rock Art Site 8: Phuting 8



Rock Art Site 9: Phuting 11



Rock Art Site 10: Phuting 15