GIS for Low-cost Housing Development: *A Case Study for the Evaluation of Vacant Land in North Western Windhoek*

By

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This Report is dedicated to my best GIS Lecturer and my special GIS classmates. You all made GIS much more fun despite all the stresses we have all gone through!

Acknowledgements

This paper was completed with the efforts of my two best Supervisors and without them; I would not have managed to complete this course study.

Primarily, I would like to give special thanks to my first supervisor, Dr. Martin Hipondoka who has been there when I needed advices on my whole research paper, especially during the period of data analysis.

Secondly, I would like to send gratitude to my second supervisor, Ms. Hilia Hitula who gave me an idea of what to research on and also for helping me with my research proposal.

Lastly, thanks to everybody such as students and lecturers who assisted me in matters I had difficulties solving alone.

Thank you all!

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List of Abbreviations

CoW   City of Windhoek

CBD   Central Business District

CBS   Central Bureau of Statistics

DEM   Digital Elevation Model

DX   Height difference in X direction

DY   Height difference in Y direction

GIS   Geographic Information System

ILWIS   Integrated Land and Water Information System

NGOs   Non Governmental Organizations

UTM   Universal Transverse Mercator

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Abstract

This paper deals with the use of GIS in determining suitable vacant land for low-cost housing development in north-western Windhoek. The land is meant for accommodating the economically-struggling families in the city, where approximately 19,000 families are currently in such a need. Two GIS software, namely, ILWIS and Arcview, were jointly used to analyse the vacant land in the area. Several terrain characteristics, such as flat, gently sloping and sloping were considered for the identification of suitable vacant land where it would be cheaper to develop such houses. Results show that 14.19 km^2 of suitable land is available in the area for such purpose. Of this land, 13.81 km^2 can accommodate approximately 46 035 erfs, each having an average size of 300 m^2, while the remainder can be reserved for servicing infrastructure such as access roads and power stations. However, with the current annual growth rate of 9.5% in this area, it is predicted in other studies that in general, vacant land would be fully occupied by the year 2016. Thus, future studies should look into alternatives ways in which housing development, especially for the low and middle income families in Windhoek, could be advanced.

Keywords: *GIS, low-cost, housing, development, economically, struggling, families, north-western, Windhoek*

CHAPTER 1

1.1 Introduction

Windhoek's human carrying capacity is limited and at some point in future the land that is still vacant at present will be fully occupied. According to Katomba (2009), the land available for development in Windhoek is expected to be fully occupied by 2016. Windhoek lies in a valley and covers only an area of about 20 kilometres long and 10 kilometres wide or 200 km^2. The area is surrounded by mountainous landscapes such as the Khomas Hochland to the west and the Auas Mountains to the south (City of Windhoek (COW), 1996), extending northwards and eastwards, respectively. Today, about 300 000 individuals are residents of Windhoek, with the current annual growth rate of 5.4% and an average household size of 4.0 persons (Katomba, 2009; Central Bureau of Statistics, 2006).

Furthermore, vacant land in Windhoek's suburbs is auctioned to the highest bidder. This has created a situation where most suburbs are socio-economically homogeneous (Gold et al, 2001). As a result, economically-struggling families tend to purchase land and built low-cost housing in suburbs located mainly in the north-west of the city. It is also in this area where informal settlements are situated and where about 60 000 to 75 000 individuals have settled in informal houses on land that is still legally owned by the Municipality. The annual growth rate in these areas is approximated to be 9.4% (CoW, 2005; Pendleton, 2005; Katomba, 2009).

A number of studies on low-cost housing have been carried out over the years. However, the application of GIS to low-cost housing assessment has been insufficient. The application of Geographic Information System (GIS) is significant to housing development. As according to Can (1998), GIS for spatial analysis offers a best research environment for processing, analyzing, and modeling housing and mortgage data sets since housing is fixed in geographical space. The purpose of this study is therefore to analyse land vacant in north western Windhoek, under a GIS environment.

1.2 Research Aims and Objectives

1.2.1 Aims

The main aim of this research study is to evaluate and identify vacant land for low-cost housing development in north-western Windhoek. The identified land is meant to accommodate the economically struggling families within the city limit, especially those living in north-western areas.

1.2.2 Objectives

Objectives of this study are as follows:

1. Evaluate the landscape of north-western Windhoek in terms of topography for its suitability for low-cost housing.

2. Identify suitable vacant land for low-cost housing development using a Digital Elevation Model.
3. Quantify the carrying capacity of the identified area in (2) above for low-cost housing.

CHAPTER 2

2.1 Literature Review

Urbanization is the main and rapid process currently taking place in cities all over the world. High urban growth rate has a negative impact on housing as houses become unaffordable to people earning below the median wage for their respective areas. In many cases, these people are driven to live in informal settlements, in slum houses. According to Yu & Xiaolong (2007), the majorities (more than 60%) of the world's low and middle income classes have urgent housing needs and are unable to solve their own housing problems. The main goal that governments all around the world have is to solve the problem of housing security by eliminating slums and provide a suitable housing and living environment for all societies.

In a study done in Malaysia, Idrus & Siong (2008) define low cost houses according to their selling price, averaging about US$8 000 (N$59 353.60). Such houses were first aimed for individuals earning monthly income not exceeding US$225 (N$1 669.32) (Bank Windhoek, 2010). However, today the Malaysian government is dedicated to provide adequate, affordable and quality housing to all Malaysian of all income levels, particularly the low income group.

Closer to Namibia, Adebayo & Adebayo (2000) pointed out that one of the most important aspects of the South African housing policy is to ensure that low cost housing is located close to areas of economic opportunities. The importance of accessibility to employment and services in housing planning is universally recognized. Furthermore, Burgess Model explains that low-cost housing should mainly be built nearby industrial areas where low income people are likely to be employed; they need to live close to industrial areas to reduce travelling and rent (Waugh, 2000).

Thomson and Hardin (2000) quoted Mesev (1997) that Remote Sensing and GIS contributes to spatial analysis by providing different types of information. Remote Sensing provides continuous data on physical surface variations while GIS principally provides physical land cover data with aspatial attributes of population, building activities and characteristics. Each of these data formats are inherently different in their purpose and structure; for example, vector vs. raster, land use vs. land cover, object oriented vs. field oriented. Thomson & Hardin (2000) further demonstrated how GIS was used in Bangkok's potential identification of low-cost housing site. Using Landsat Thematic Mapper image with broad general land cover, land was analyzed and suitable vacant land for low-cost housing development was extracted and georeferenced to UTM coordinate system. Furthermore, several GIS coverage that could be derived from the Landsat image were derived with input from related maps such as land use, land parcel, roads and drainage and then classified using appropriate classifications, namely: supervised classification and unsupervised clustering.

In Namibia, rights to land have commonly been assigned to four categories, namely: the state land, which is used for nature conservation, game parks and military base; town land, where standard concepts of state, municipal and private ownership apply within proclaimed boundaries under statute law; commercial farmland, which refers to all freehold agricultural

land, and communal land, which is a collection of all land reserved by the German and South African colonial administrations exclusively for the use of indigenous Namibian communities, owned by the government (Bruce, 1998). Windhoek is allocated to the category of town land owned by the municipality. The municipal land covers about 47 821 hectares or 478.21 km² (Gold, et al, 2001).

Windhoek is a town with the highest topography in Namibia. Gold et al (2001) stated that Windhoek is situated some 1, 800 meters above sea level with hilly and steep slope landscapes. Apart from the already occupied little flat land in the southern part and some vacant land that is currently being developed on the western part, most flat and cheapest land is in the north-western part of the city. Presently, formal and informal development is mainly taking place on the edge of north and north-western part of Windhoek. Frayne & Pendleton (2002) explained that population growth is mainly taking place in Katutura, the large township located to the north of the city, where about 60% of the city's population live on about 20% of the city's land. Central Katutura is the older and the more established part of the township while the north-western area is where most of the informal housing is located and much of the growth is taking place.

According to Gold et al (2001), Windhoek still illustrates divisions between 'First World' and the 'Third World' sectors. There are visible distinctions between suburbs located in different parts of the city. According to Gold et al (2001), the Central Business District (CBD) at the centre, is modern, has the tallest buildings in the city, and has a variety of goods and services on offer. To the east, there are elite suburbs with large mansions; to the south and south-west, one mainly finds the middle-class group; while to the north and north-west, there is mainly low-class group. Furthermore, there is still legacy of segregating people. After independence, the government tried to reduce the injustice created by apartheid by linking the Khomasdal and the Katutura areas and by improving the services in Katutura areas. This did not however, eliminate the gap between the advantaged and disadvantaged areas, because at the same time, new low income areas grew outside Katutura, and new high income areas grew in the southern part of Windhoek. The differences between the income groups became even wider than before (Selenius & Joas, 2004).

The World Bank & AFTU 1 & 2, (2002) states that during the period of 1991 until 1999 Windhoek developed a number of formal low-cost housing schemes. However, the serviced plots provided were unaffordable to the vast majority of the city's poor. Furthermore, in response to the influx of poor urban migrants, the city developed three Reception Areas that were intended to be temporal homes for these migrants. The idea was that people would be resettled in accordance with City of Windhoek's (CoW) squatter policy of the time. Unsurprisingly, this did not happen because the areas attracted additional settlers even before the sites had been laid out or could be provided with basic services. This kind of shortcomings of Reception Area approach led CoW to develop new policies and strategies for dealing with urban low-income residents, and projects were being planned and designed in accordance with the new policies.

In 2005, the CoW anticipated that by 2009, it would have upgraded Greenfield sites (600 erven) in Otjomuise Extensions 10-11 and informal settlement (approximately 1000 households) in One Nation Extensions 1 & 2. Furthermore, the Municipality estimated that it would continue until 2010, to develop Otjomuise Extensions 12-13 and upgrade the smaller informal settlements (City of Windhoek, 2005). However, as far as it can be ascertained by the author, no significant improvement or development took place in these areas as they remain almost the same as before 2005.

According to Katomba (2009), land invasion continues to increase in most informal settlements in Windhoek. In 2008, for example, illegal structures were put up in Havana, Otjomuise, and 7 de Laan. However, CoW is doing its best to demolish all illegal structures on occupied land, with the help of the City police. The latest example took place in June 2009, when the City Police destroyed illegal shacks at Agste Laan in Otjomuise (Katomba, 2009).

2.2 Study Area

Windhoek is the capital city of Namibia and generally, the city is situated at the centre of the country (*figure 1*). According to Stols (1994), Windhoek's geographical location is: 22° 31 S and 17°1 E.
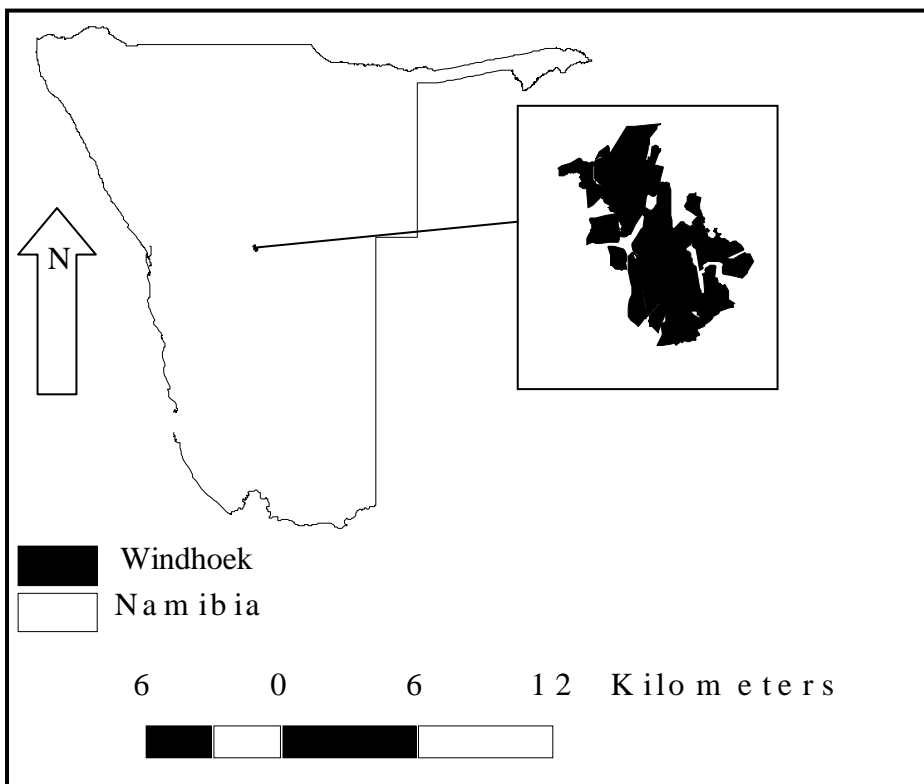

Figure 1: Location of Windhoek in relation to the layout of Namibia

The focal point of this study is the north-western part of Windhoek. North-western Windhoek is chosen to be the focus of the study because of its main legally vacant land, which is currently occupied by informal settlers who have no legal claim to this land. Moreover, north-western Windhoek is found near Northern Industrial, where the financially struggling families who are going to live in these low-cost houses could be employed.
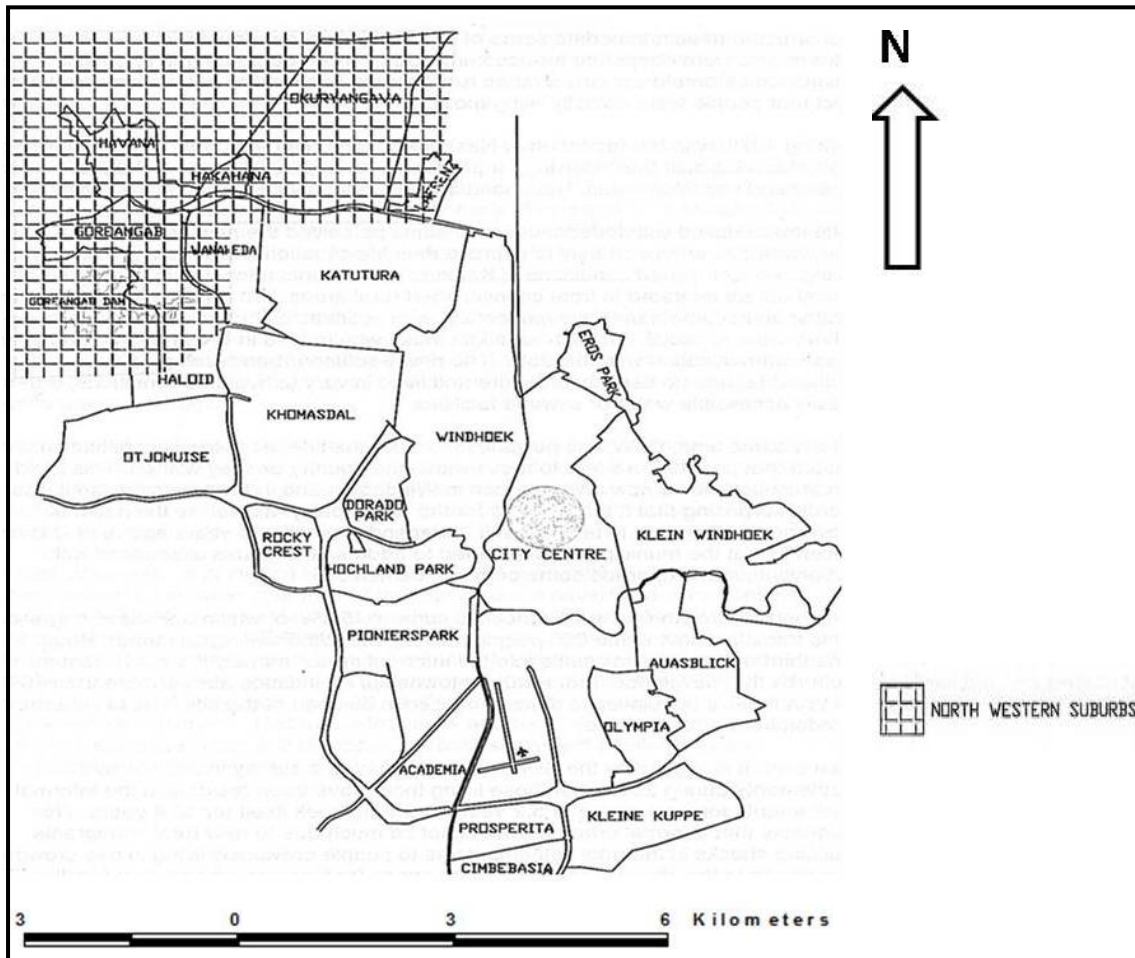

Figure 2: Location of north-western Windhoek's suburbs in relation to the layout of the Windhoek (Source: Gold, et al 2001).

Figure 3: Aerial photo showing topography of north-western Windhoek, Goreangab suburb (Source: Becker et al, 2003).

3. Methodology

A contour map representing Windhoek and surrounding areas was used. This map was entered into ArcView, georeferenced to Universal Transverse Mercator (UTM) coordinate system and then imported into ILWIS because ILWIS can create raster data from vector data, which was relevant for Digital Elevation Model (DEM) calculation, something that ArcView cannot do.

In ILWIS, for the imported vector map to only cover the study area (the north western part of Windhoek), a sub-map was created from the contour data set using a tailor-made georeference file. DEM from segment was then calculated using the formula:

DEM=*MapInterpolContour (E_WHK.mps, WHK_EL.grf)*...........................Equation 1

Where:

DEM   is the output name of raster map (DEM map)

MapInterpolContour   is used to start the contour in interpolation operation

E_WHK.mps   is the input name of the segment map

WHK_EL.grf   is the input name of the existing georeference to be used by the output DEM map
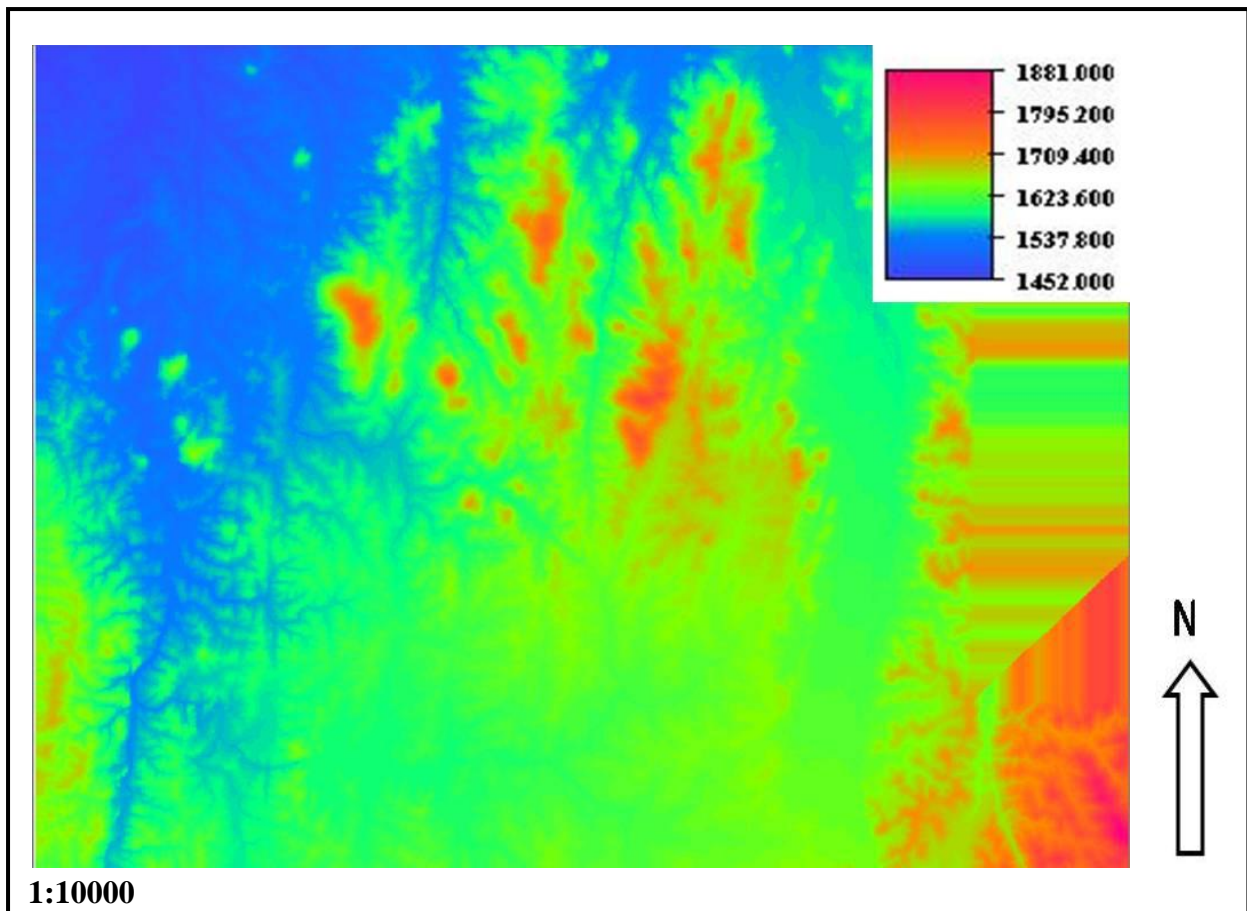
Figure 4: DEM of north western Windhoek.

The DEM was used to calculate height differences in both X and Y directions (DY and DY). The differences were linear filtered, and a slope in percentages was calculated from these maps (DX and DY) by typing on the command line of the Main window the following:

SLOPEPCT = *100 * HYP (DX, DY)/ PIXSIZE (DEM)*...........................Equation 2

Where:

Slopepct	is the output name of the slope map in percentages
Hyp	is used to calculate slope values in percentages from two input maps which contain heigth differences in x-direction (DX) and in y-direction (DY).
Pixsize	is used to return the pixel size of the DEM map, and
DEM	is the input name of the DEM map

The percentage values were then converted to degrees values by typing the following on the command line:

SLOPEDEG=*RADDEG (ATAN (SLOPEPCT/100))*...........................Equation 3

 Where:

Slopedeg   is the output map name of the slope map in degrees.

Raddeg   is used to convert radians to degrees

Atan   is used to return the arc tangent, and

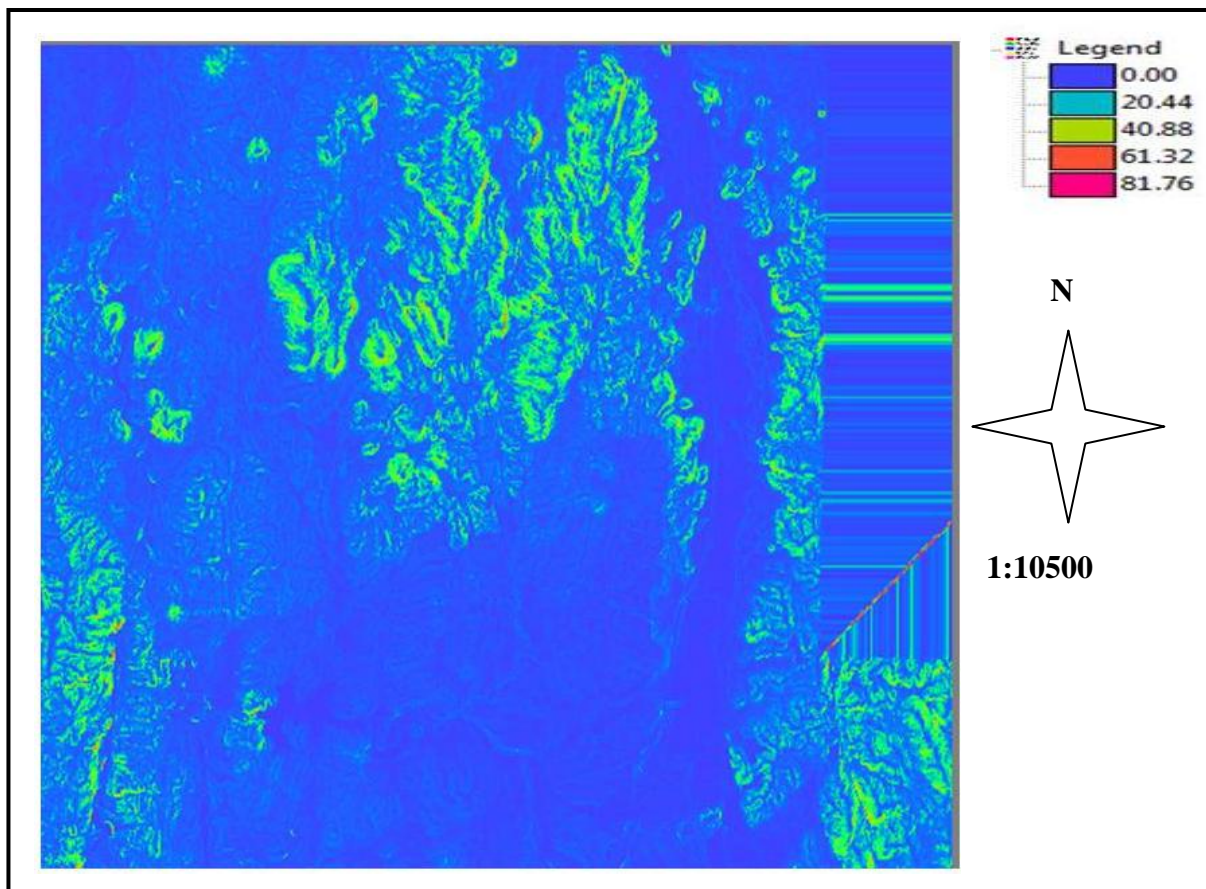*Slopepct*   is the input name of the slope map in percentages (*equation 2*)

Figure 5: Slopedeg map of north-western Windhoek**.**

Terrain map was then analysed and mapped according to analyses recommended by van Zuidam (1986): 0°-2° - flat or almost flat; 2°-4° - gently sloping; 4°-8° - sloping; 8°-16° - moderately slope; 16°-35°, steep; 35°-55°, very steep and >55° extremely steep. Only flat to sloping areas (0°-16°) were considered suitable for low-cost housing development. The rationale is: it is cheaper to build houses and establish services like water and electricity on a flat area than on a steep area. As a result, flat, gently slope and sloping land in north-western

Windhoek is the suitable for low-cost housing development for the economically-struggling families in this area.
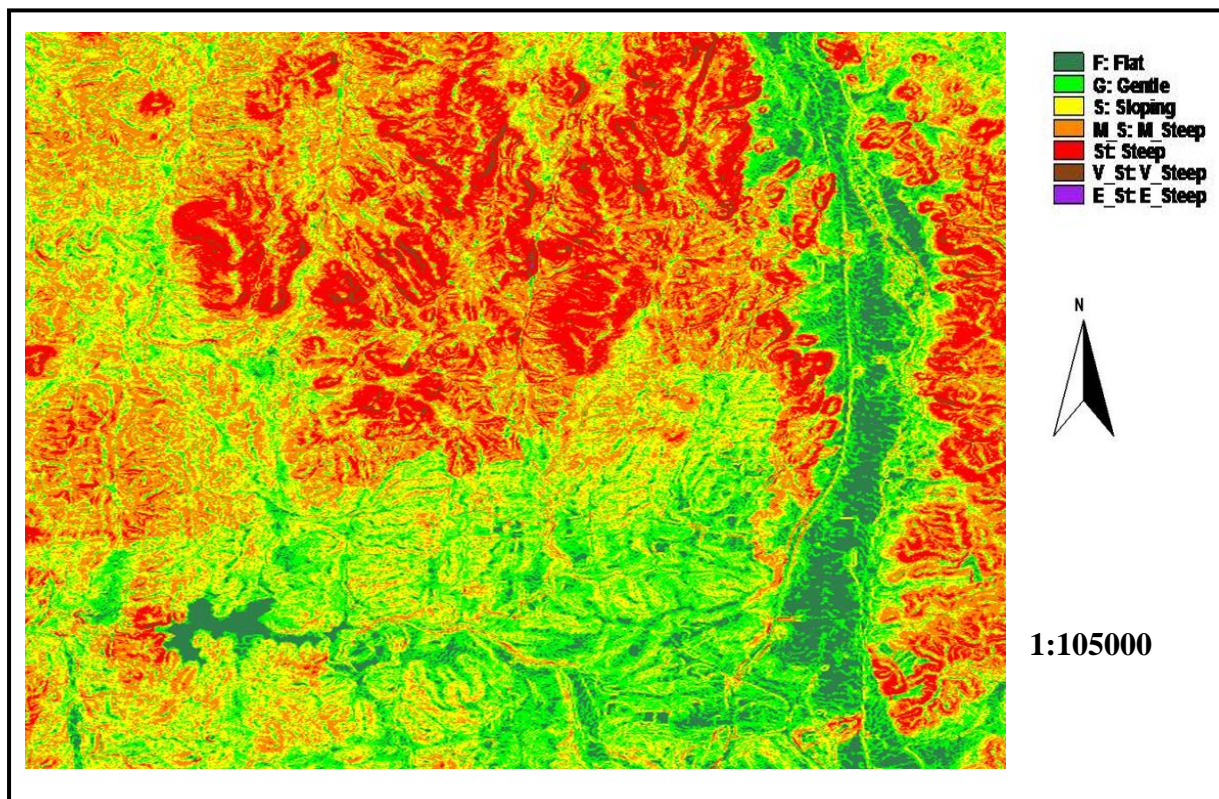

Figure 6: Terrain analysis of north western Windhoek.

To make sure that other unnecessary terrain classes (from moderately sloping to extremely steep) are not considered as suitable, the "*IFF*" function was used to only retrieve all the flat and gently slope lands with other classes being identified as undefined, using the following formula:

Suit_Char =*IFF ((S_WHK="Flat) or (S_WHK="Gentle") or (S_WHK="Sloping"), S_WHK, "?")*.................................equation 4

Where:

Suit_Char   is the output name of the suitable terrain characteristics map

IFF   is used to return: if S_WHK is flat or S_WHK is gentle or S_WHK is sloping; the rest of S_WHK characteristics should be returned as "?"

S_WHK   is the input name of the terrain characteristic map (*figure 6*)

"?"   is used to represent undefined values

Furthermore, to make sure that flat and gently slope land which is already occupied by existing suburbs, roads and dams are not shown as suitable vacant land, the "*IFUNDEF*" function was used to eliminate these occupied flat and gently slope land, using the following formulas:

Vac_Land =*Ifundef (Suburb, Suit_Char, "?")*.................................Equation 5

Where:

Vac_Land	is the output name of the map
Ifundef	is used to return suburbs within suitable characteristics as undefined
Suburb	is the input name of the suburb map
Suit_Char	is the input name of the suitable terrain characteristics map

V_Land =*Ifundef (G_Dam, Vac_Land, "?")*...................................Equation 6

Where:

V_Land	is the output name of the map
Ifundef	is used to return the land covered by G_Dam within Vac_Land as undefined
G_Dam	is the input name of the Goreangab Dam map
Vac_Land	is the input name of the vacant land map (*equation 5*)

S_Vac_Land =*Ifundef (Arterial, V_Land, "?")*...................................Equation 7

Where:

S_Vac_Land	is the output name of the suitable vacant land map
Arterial	is the input name of roads map
V_Land	is the input name of vacant land map
Ifundef	is used to return land covered by roads within the V_Land map as undefined

The derived suitable vacant land was polygonized using 8-connected pixels. This was done in order to eliminate pockets of lands that could not accommodate at least 5 low-cost houses.
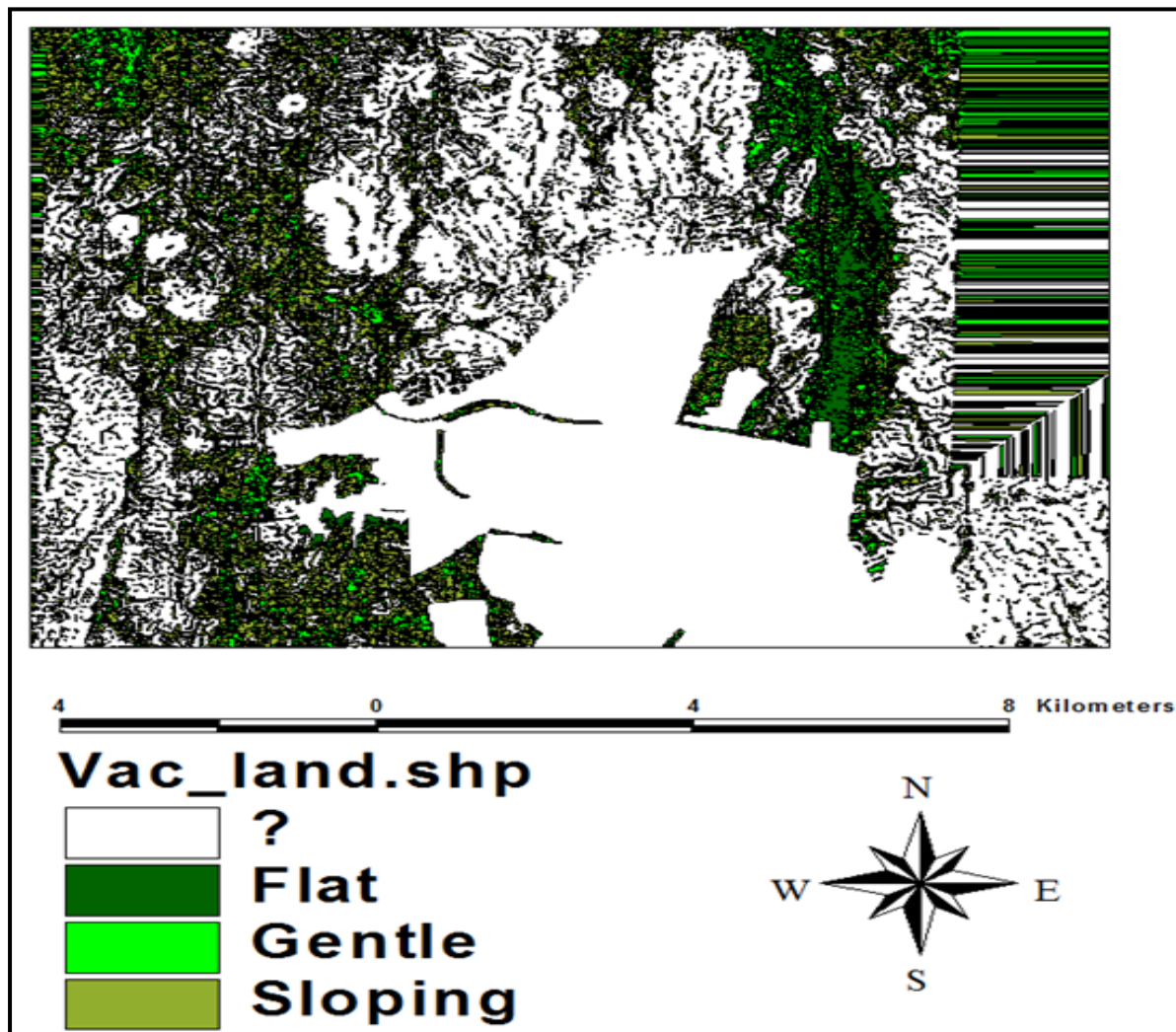

Figure 7: 8-connected polygonized map, showing vacant land suitable for low-cost housing development.

However, there were still some areas appearing to be available for housing development while in reality they are not, such as: the river and industrial area. Therefore literature review and author's knowledge on the area was used to determine what exactly these areas are and why are they not suitable for housing development. Vector data, a polygon map was then exported to ArcView for calculating the area (m²) of the studied site by using the following steps:

1. Activate the theme of the suitable vacant land map (S_Vac_Land)
2. Open the attribute table
3. Table > start edit
4. Edit > add field (name: area, type: number, width: 16, and decimal: 3)
5. Highlight the new added field
6. Field > calculate
7. Type in the field calculator the following: [Shape].ReturnArea

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8. Table > stop edits
9. Save edits

Furthermore, ArcView was used for querying where the suitable vacant land with the size of at least 1500 m² is found, where at least 5 low-cost houses could be developed. This was done for editing and deleting land that had area less than 1500 m². The total area of suitable vacant land was then calculated.
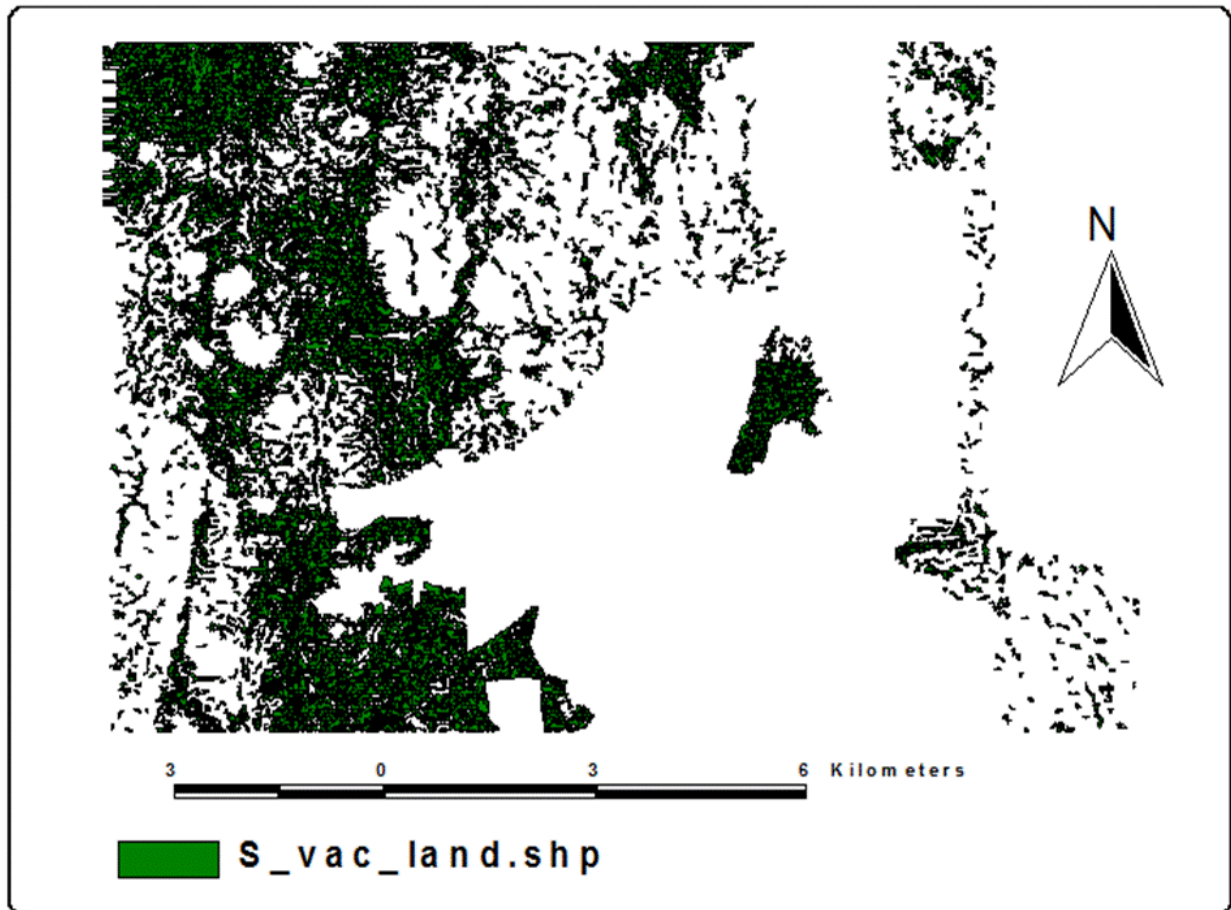

Figure 8: Suitable vacant land for low cost housing development

Lastly, an existing erven map of approximately same size as the size of the suitable vacant land covered by houses and roads was used to calculate the area (m²) of the total area used for the construction of roads. The same area (m²) of these roads was used as the area to be used for the construction of new roads on the vacant land. The carrying capacity of the total suitable vacant land was then calculated using the following formula: *Carrying capacity = (total area of suitable vacant land-area to be covered by roads)/minimum area of a single house).* This was done to determine how much of the total suitable vacant land would be used construct roads and how many low-cost houses or families would be accommodated on the available land. According to Gold et al 2001, the minimum erf size in Namibia is 300 m².

4. Results

Out of a total 188.47 km² area of the studied site in North Western Windhoek, 147.01 km² is vacant while 41.46 km² is already occupied by suburbs such as Goreangab, Hakahana, Havana, Okuryangava and Lafrenz and the Goreangab dam located in the north western Windhoek. However, for the reason that low-cost houses should be developed on flat, gently sloping and sloping terrain, only 14.19 km² (10%) of total vacant land (147.01 km²) or 8% of studied site (188.47 km²) is suitable for such a purpose. These are flat, gently sloping and sloping contiguous areas covering at least 1500 m² (*figures 2, 9 & 10*).

Additionally, a total area of 132.82 km² (70%) of vacant land is unsuitable for low-cost housing development. These are flat, gently sloping and sloping areas occupied by the Swakop River, closer to the northern industrial areas, those with the area less than 1500 m², and land with the slope aspect higher than 16° (*figure 9*).
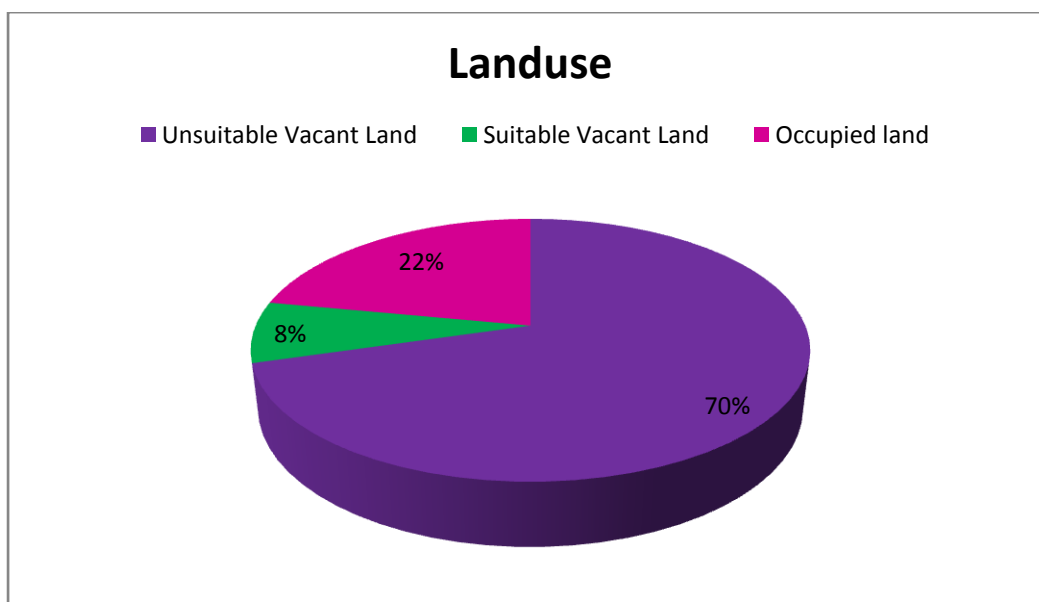

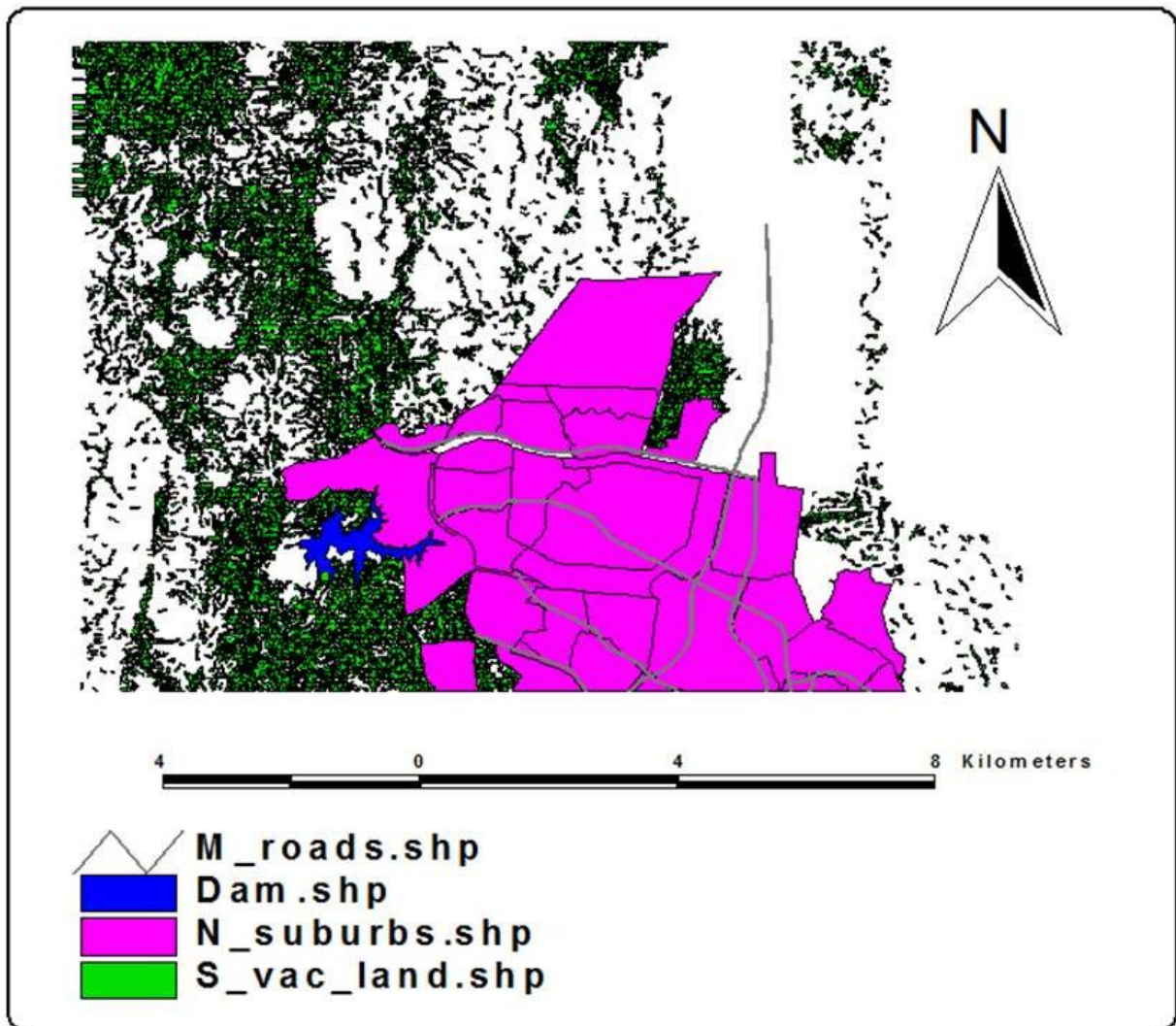**Figure 9:** Landuse of the studied north-western areas of Windhoek

Figure 10: Suitable vacant land for low-cost housing development in north-western Windhoek and the land which is already developed and occupied by the dam and suburbs.

The identified suitable vacant land is sufficient to develop low-cost houses for at least 46 035 economically struggling families, with enough roads covering 375 071 m^2. This is more than enough for the known current number of families approximated to be 18 750 who live in informal settlement in north-western Windhoek and have formal housing need. Once these families are accommodated, the vacant land left would still accomodate at least another 27 285 low-cost houses.

5.1 Discussions

The use of GIS was significant during this research study. GIS made it easier to analyse landscape and land use in north-western Windhoek to determine suitable vacant land for low-cost housing development without visiting the study area to capture primary data, which is time consuming, expensive and less accurate. GIS software used, namely: Arcview and ILWIS could use secondary data to generate useful data regarding land vacancy in north-western Windhoek.

The objectives of this research study (*Chapter 1*) were all covered in the research methodology and results presented. The evaluation of DEM and analyses of terrain characteristics produced a reasonable proposal of which vacant land is to be used as suitable for low-cost housing development. The size of the identified suitable vacant land (14.19 km² or 14 190 000 m²) divided by the minimum erf size of a single house (300 m²) presented the carrying capacity of the vacant land, which is 47 300 houses or families.

The results showed that only 8% of the total studied site is vacant. This available land is currently more than enough for low-cost housing development for the families currently living in informal settlements and in need of low-cost housing. According to Katomba (2009), Windhoek's population is about 300 000, of this population about 75 000 individuals or 18 750 families live in north-western Windhoek and are in need of better housing. Due to high population influx in this area, land is expected to be fully occupied by 2016 (Katomba, 2009). The population trend of 1985 to 2009 however predicts that after 15 years, Windhoek's population will be over 410 000, if population growth remains constant (Figure 11). Of this total population, about 110 000 will be living in north-western Windhoek by then (Figure 11). It can then be assumed that about 35 000 individuals or certain number of families (depending on the size of household by then, the current one is 4.0) would certainly be in need of land to develop low-cost housing. These families could still be accommodated on the suitable vacant land that has been identified, because there is still sufficient land available. However, the projection of total number of individuals who move to other parts of Windhoek apart from north-western Windhoek who might need low-cost houses later is unknown. Consequently, it would be very difficult to assume what the total land demand and when the vacant land would be fully occupied.
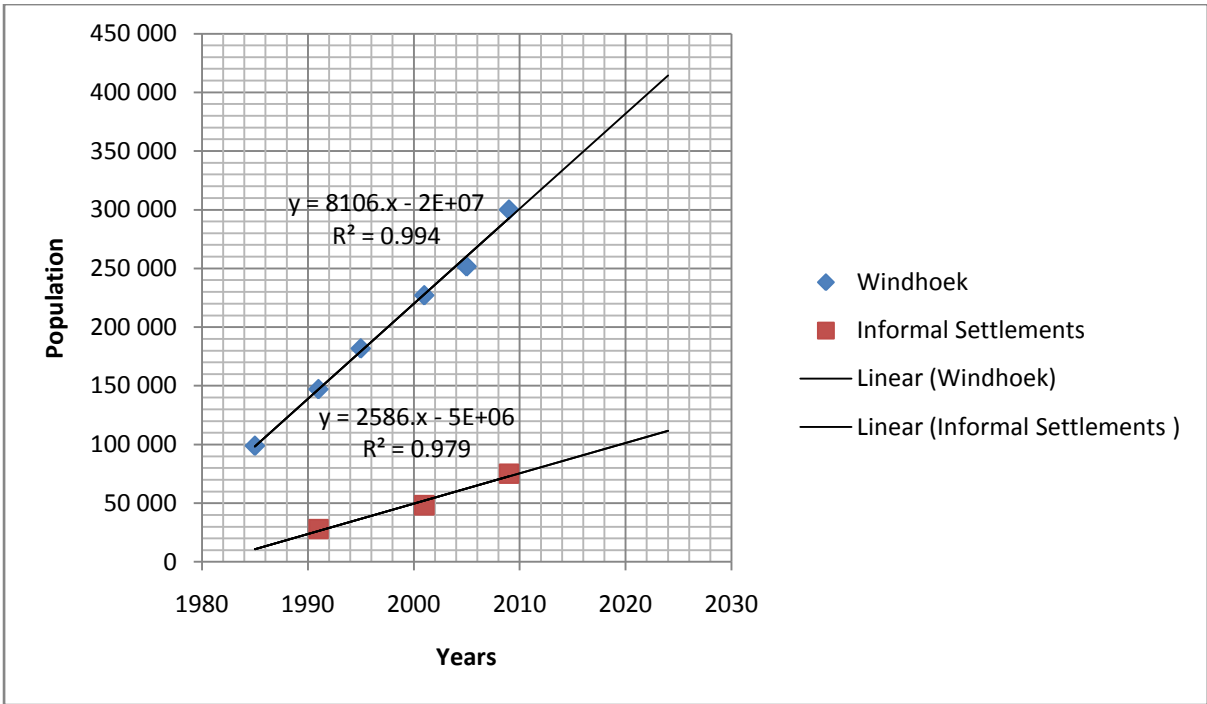
Figure 11: Population trends of Windhoek as a whole and of Windhoek's informal settlements

5.2 Conclusion

There is vacant land in north western Windhoek. Eight % of the total 188.4 km² area is suitable for low-cost housing development. This land could be used to develop approximately 46 035 low-cost houses in which same number of families could be accommodated. A number of new settlers settle in Windhoek each day, especially in north-western Windhoek where the population is approximated to be 20-25% of the total Windhoek's population of 300 000, and the annual growth rate 9.4% (Katomba,2009). North-western Windhoek's settlers are the main settlers in need of low-cost housing and before the year 2016, these settlers shall fully occupy the suitable vacant land. Consequently, future researchers on land vacancy in Windhoek, the government, private sectors and non-government organization should try to find alternatives/recommendations to land shortage for low-cost housing development for the low and middle income families in Windhoek.

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