Words of thanks

My thanks to the people of Kavango and especially my former colleagues in the MLR for their kind hosting.

"Ich versichere, diese Master Thesis ohne fremde Hilfe und ohne Verwendung anderer als der angeführten Quellen angefertigt zu haben, und dass die Arbeit in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegen hat. Alle Ausführungen der Arbeit die wörtlich oder sinngemäß übernommen wurden sind entsprechend gekennzeichnet."

Ibadan, 26.02.2015 Martin Mueller

Abstract

This text deals with the increasing shortage of land for settlement for the 'average' Kavango settler who practices small scale crop farming and is dependend on natural resources and a communal water supply in the rural areas of Kavango Region. It tries to answer the question „When will the land reserves be depleted?“ by identifying deterministic weight factors for the main influencing factors of settlement in the remote rural areas: water access, road network, soil suitability, local availability of land. As a result it shall be possible to quantify the attractivity of a not yet occupied plot in order to facilitate planning.
Fragile data qualities and quantities are usual challenges and require to find pragmatic answers in this interdisciplinary analysis. Under a scenario in which current trends of land allocation continue „business as usual“, an overall answer is that the area of land might not limit settlement. The urbanization factor carries the most vague factor. In the last census decade, it absorbed in numbers the entire rural population growth. That shows a new trend towards expansion of cropland while supplying the townlands with food which again requires logistics.

Table of Contents

Table of figures

Table of Tables

Abbreviations

RSA	Republic of South Africa
VCF	Veterinary Cordon fence
AoI	Area of Interest
NNF	Namibia Nature Foundation
UNITA	União Nacional para a Independência Total de Angola (one of the three movements involved in the civil war in Angola after independence 1975)
HH	Household
AEZ	Agro-ecological zones
ALD	Average land demand

Introduction

„Population growth results in a increase of demand of land for settlement“. Most people might intuitively agree with this simple and fairly general hypotheses. When it comes to concretization, that means parameterization, quantification, localization, embedding in a historical situation, political and cultural „real-world“-context, the verification of that statement becomes difficult. Especially when data of various sources, methodologies and decades must be used, the outcome of any trial to correlate population growth and land demand is highly dependend on stable conditions and relatively non-dynamic influence factors. This seems to be given in the area of interest, the Kavango Region in Northeastern Namibia.

Assuming that virtually all produced food in the region is also consumpted in the region, and therefore a strong to very strong correlation between population size and crop land demand is given and each of them is well predictable, one can use the above statement deterministically under certain scenarios. A certain population unit, such as a household, has got a certain land demand. The demand's concretization can be measured. If the number of people increases, the increase of land under cultivation should also be noticed. Is this verifiable? Land demand varies according to (agroecological) suitabilities and other options to make a living. Can those be quantified for using them as weighting factors? How do these factors develop in time?

The phrase „When will the Kavango land reserves be depleted?“ emphasizes a planning aspect. In fact the idea of this question was born in connection with a land use planning campaign for the Kavango Region in 2012. By nature, population growth show an exponential growth while the amount of land to feed the people remain the same and is even with intensification measures finally a limited resource. This essence of the Malthus' debate will come one day to this Region.

Today one can perceive a general „land hunger“, especially in the previously disadvantaged areas of Namibia. Landless people apply to benefit from the Governments resettlement efforts to get a piece of land somewhere in the central and southern parts of Namibia of which most are unsuitable for crop farming. Land grabbing and illegal fencing is taken place on communal land. And a „run“ on the „virgin“ hinterland areas in the Kavango, but also other northern Regions (previously „homelands“) can be observed. This „run“ is driven not so much by those who are dependend on land (the poor) but by wealthier people, mainly from the Region itself, interested in hugh plots to keep their cattle in farms leased from (and often equipped by) the state. Traditional land allocation practices also favor certain settlers and land use types. At the same time the current Land Reform tries to overcome the historical disadvantage of black people through the Apartheid regime especially in access to land. Its against this background that equal chances to access land for settlement enjoys a high level of attention.

This thesis aims to answer the question applying a methodology that uses aerial photo interpretation to identify land demand in order to correlate the findings with census data about the population growth. In addition, it should be analysed where the settlement takes place first. It is assumed that the proximity to roads and waterpoints are the most effectiv factors influencing new settlement. How do they correlate to the household density? GIS-technology seems to have the appropriate toolset to implement this methodology. The outcome shall be a map that shows the settlement likelihood (approx. speed of being settled) of a site.

Definitions

Settlement land	Land that is used for settlement in the meaning of rural Kavango households. It includes crop fields, household plots, livestock kraals, horticulturaly used areas, minor tracks or roads and other lands frequently used by the households, if not declared other (such as school plots and other public properties). It does not include the grazing area of the households livestock and the area used to collect forest resources (firewood) despite both are essential necessities to settle.
Cleared land	Land that has been visibily cleared of vegetation for the purpose of being used for settlement, mainly crop fields. Livestock ranching does not require clearing. „Visible“ refers to the identification in the aerial orthophotos used to delineate. Since this is an interpretation, the actual delineation might vary slightly according to the interpreter and the orthophoto's time taken, quality and resolution. The latter metadata are not available for the data extracted of the orthophotos of 1943 and 1972.
Reserve lands	Lands without a) an obvious and mostly longterm purpose (i.e. National

	Parks, irrigation schemes or cattle farms), b) any other already existing occupation or c) planned occupation even without an official land utilization title.
Depletion of reserve lands	The total amount of ungiven and unused land became 0% of all land.
Hinterlands	Undefined term for land behind the densly populated ribbon approx. 5km from the Kavango river towards the South.
Household	„... defined as a person or group of persons, related and unrelated, living together in the same house and having the same catering arrangements“ (Central Bureau of Statistics, 1991. Population and Housing Census. Windhoek). A household size is given as the number of people belonging to the household. One person can only belong to one household.
Locality	„... defined as any nucleated and physically distinct settlement which had a name or locally recognised status“ (Central Bureau of Statistics, 1991. Population and Housing Census. Windhoek)
Migration	With respect to the Kavango Region as the Area of Interest (AoI) this study understands the term 'migration' as the movement of settlers from outside the AoI or out of the AoI. The migration inside the AoI will be called 'internal migration'.
VCF	The Veterinary cordon fence is a fence to keep cattle and buffalo epidemics, mainly the foot-and-mouth-disease, out of the southern parts of the country. It runs along most southern borders of the Kavango Region.
Omuramba	Local name for dry valleys which had been formed in previous climates.
„given“ land	Means all land that is occupied by state bodies (such as MET in National Parks) or private individual leaseholders.

Literature review

Thematical literature

First data and literature ressources dated back to the early 1900ies with some textual descriptions and estimation of the population. Population census' started in 1950 (Mendelsohn, J., 2003). More detailed interest in the Region came in with the 1960ies, a time when the „Odendaal-Plan“ was implemented, the Namibian version of the Apartheid administrative structure of these days „Southwest Africa“. For example the „Reconnaissance Soil Survey of Okavangoland“ (SWA Administration, 1967) with special respect on irrigation potentials was initiated.

Milestones in systematic, modern resource assessments for planning were conducted in the late 1990ies with the Agro-Ecological Zoning Project of the Ministry of Agriculture, Water and Forestry (MAWF), the Natural Resource Mapping edited by the Ministry of Environment and Tourism (MET) and the 1:50,000 mapping Project by the Ministry of Land, Rehabilitation and Resettlement (that time MLRR, today MLR). Also the Agricultural Census' 1996, Demographic and Health Survey 2006 and the population and housing census' from 1991, 2001, 2011 revealed a thorough base of detailed and quantified information for spatial planning and, through numerous spatial data, in GIS processing. Population growth simulations have been applied to the Region by the National Statistics Agency (NSA) (Central Bureau of Statistics ed., 2010) as well as the US Bureau of Statistics.

Literature that refers to the specific topic of this study could not be found. Several authors throw a glance at the future limitations of land and see especially the severity to manage the increase in clearance of land: Mendelsohn discusses the general prospects for future development under traditional farming methods on the background of physiographic and socioeconomic studies (Mendelsohn, J., 2001), GTZ analysed the economics of different alternative land uses (GTZ ed., 2006) while the Namibia Nature Foundation handed in a comparative synopsis of all of them in its „Land use planning framework“ (NNF ed., 2010) that sheds a light on the driving factors of settlement in the Region.

Land use modeling

Land use models are numerous and vary in their central objective (Koomen et al., 2008). A land use modeling approach called LUMOS was developed by Eric Koomen, Hilferink, Rietveld and others with respect to support spatial planning. Unfortunately, LUMOS works by simulating the land market. A land market as such is not in place in the Communal lands of Namibia. Communal land vests in the state and Traditional leaders act as custodians of it in their areas, not private individuals (Republic of Namibia, 2002). Nevertheless, the grid based approach of LUMOS is useful to make locations comparable in numeric ways.

Description of the Area of Interest (AoI)

Delineation

The **area of interest** is described by the entire Kavango Region of Namibia of 2012. In 2013 it was split into two Regions „Kavango East“ and „Kavango West“. The term „Kavango Region“ is used throughout this document and means both parts as if there is no split.

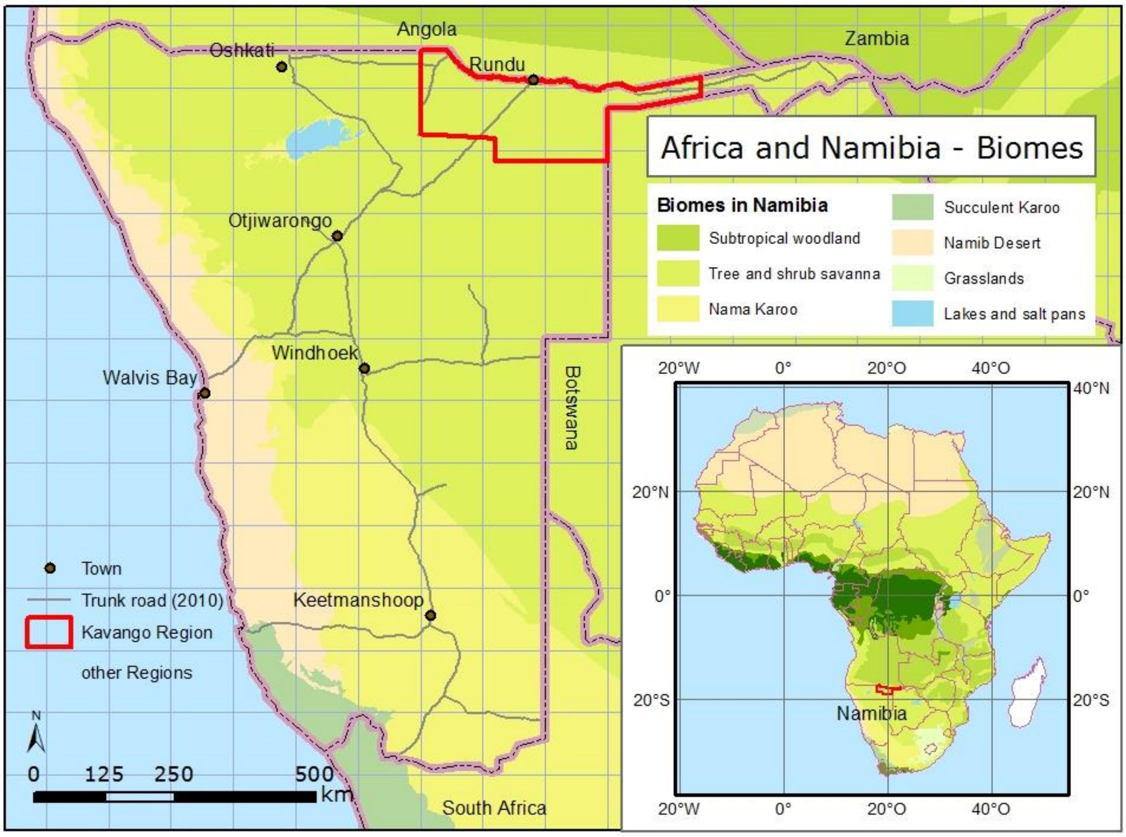


Figure 1Kavango Region in Africa and Namibia (data from www.the-eis.com, 28.05.2013)

The Kavango Region of 2012, one of thirteen Regions in Namibia, is located in the Northeast of Namibia and borders Angola along the middle line of the Kavango River in the north. It stretches fingerlike to 22°30' East far inside the so called Caprivi strip. To the Southeast it borders Botswana along the 21° East Longitude. This meets the latitudinal oriented Veterinary Cordon Fence at 19°10' S from where the fence runs between Tsumkwe and Kavango Region 189km westwards and with an 40km offset to the north another 127km westwards to Kavango's southwestern Corner at 18°00'E, 18°45' S. A straight line connects this point with the Northwest-Corner (18°00'E, 17°23'20''S) neighboring the Regions Oshikoto and Ohangewena. This longitude means again the Angolan border and has to be followed to the Kavango River eastwards.

Special focus in this area lies on those lands without a) an obvious and mostly longterm purpose (i.e. National Parks, irrigation schemes or cattle farms), b) already existing or c) planned occupation even without an official land utilization title.

In this meaning, this „**focus area**" shrinks to about 48607 km² (2012). In the following, the term „**reserve lands**" is used to describe this particular part of Kavango Region. Most maps in this document also show the Kavango Region without the very eastern areas (land east of Kavango River), because no reserve lands are to be found there.

Geography

The region is a flat area throughout with a very slight slope gradient to the north-northeast: -0.08% from Grootfontein to Rundu.

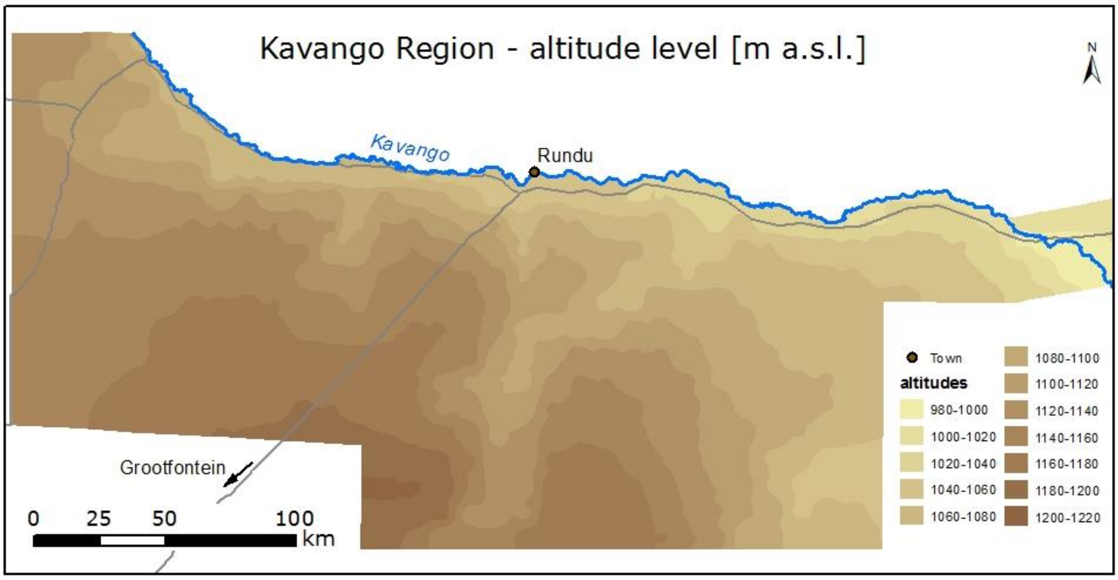


Figure 2 Kavango Region - Altitude level (meter above sea level)

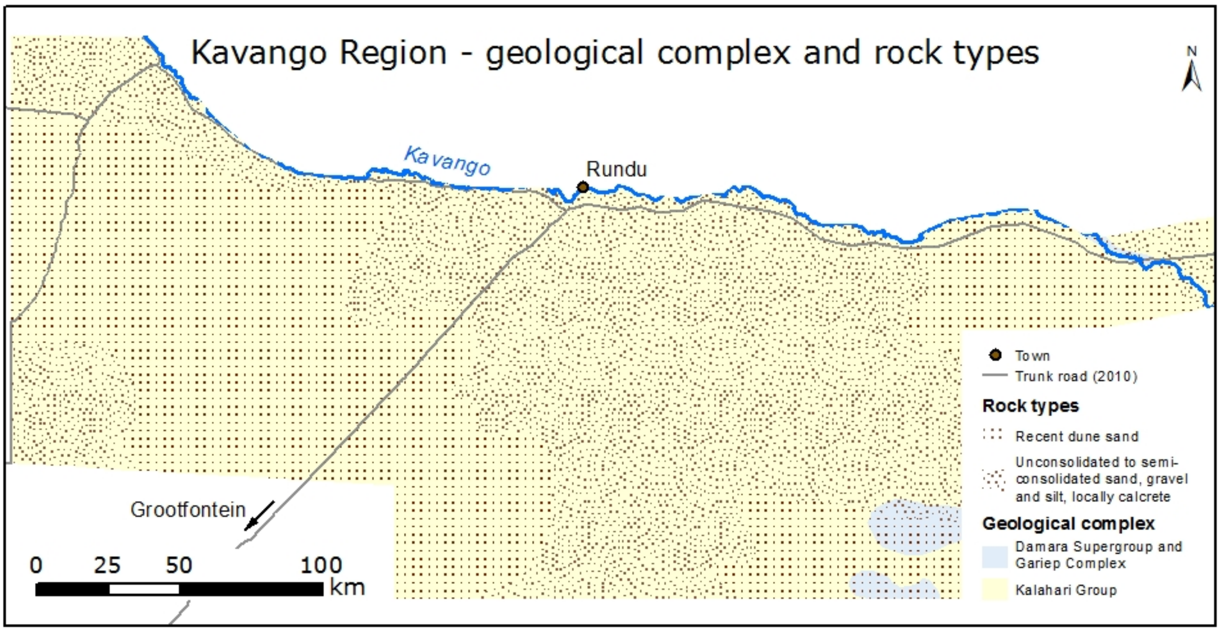


Figure 3 Kavango Region - Geological complex and rock types

Nearly the entire Region is covered by a thick mantle of aeolian Kalahari Sands, generally poor in nutrients and without major mineral resources (RSA, Dept. Of Bantu Administration and Development, 1967).

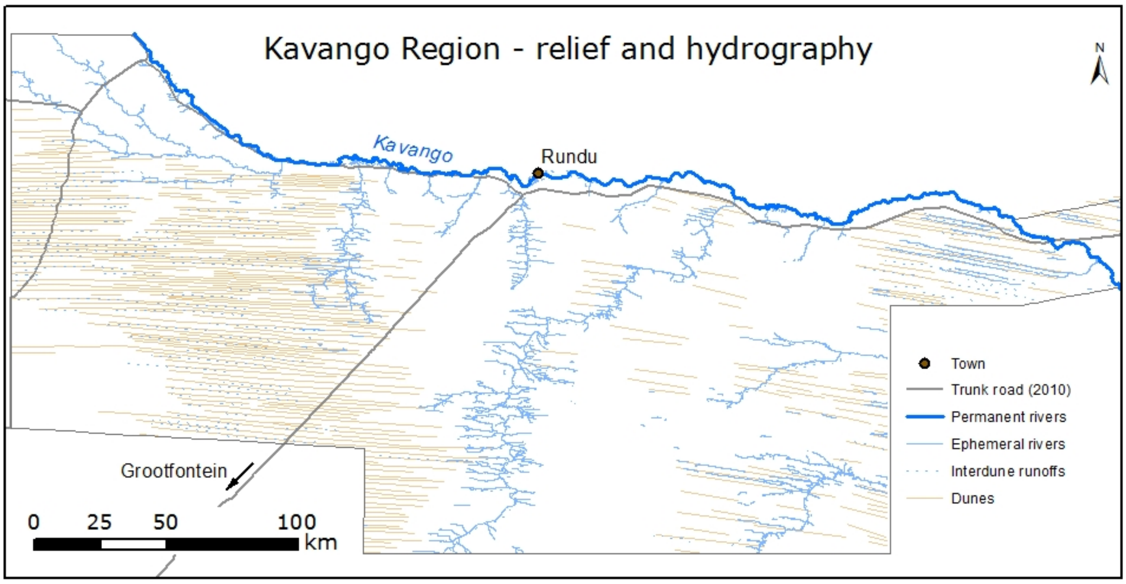


Figure 4 Kavango Region - Relief and hydrography

Wide areas in the West and the first 60km of the Caprivi strip show this origin with the presence of fossil dunes (West-East) up to 30m high. These landforms control to a big extend the clay content in the soil, the settlement patterns, population concentration and the road network (RSA, Dept. Of Bantu Administration and Development, 1967).

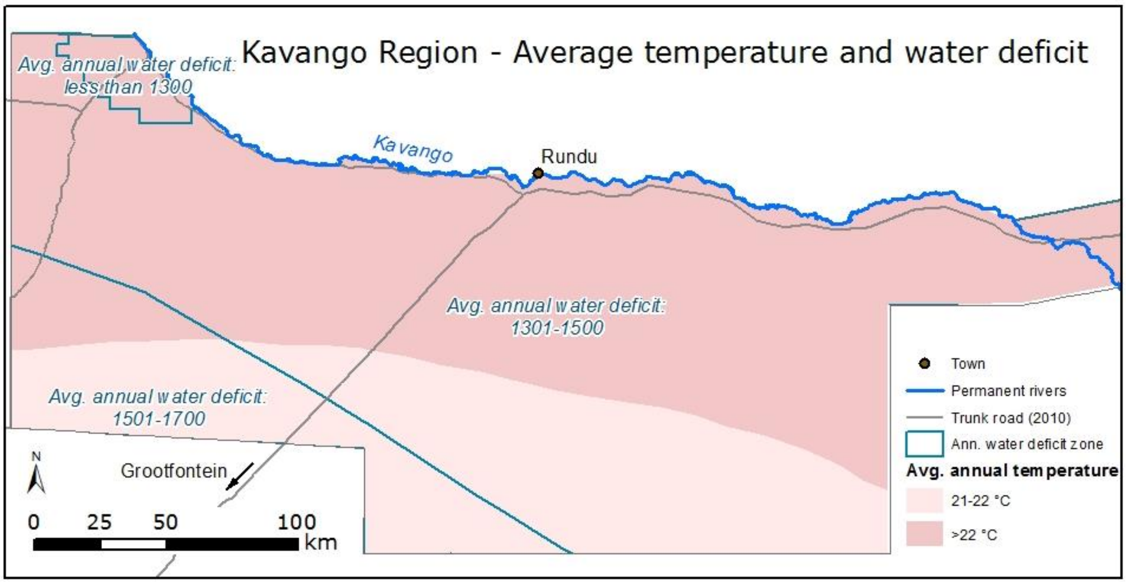


Figure 5 Kavango Region - Average temperature and water deficit

Average temperature (23°-21°C) and median precipitation values (annually 450-550mm) show again a very slight decrease from North-Northeast to South-Southwest (van der Merwe, J., 1983).

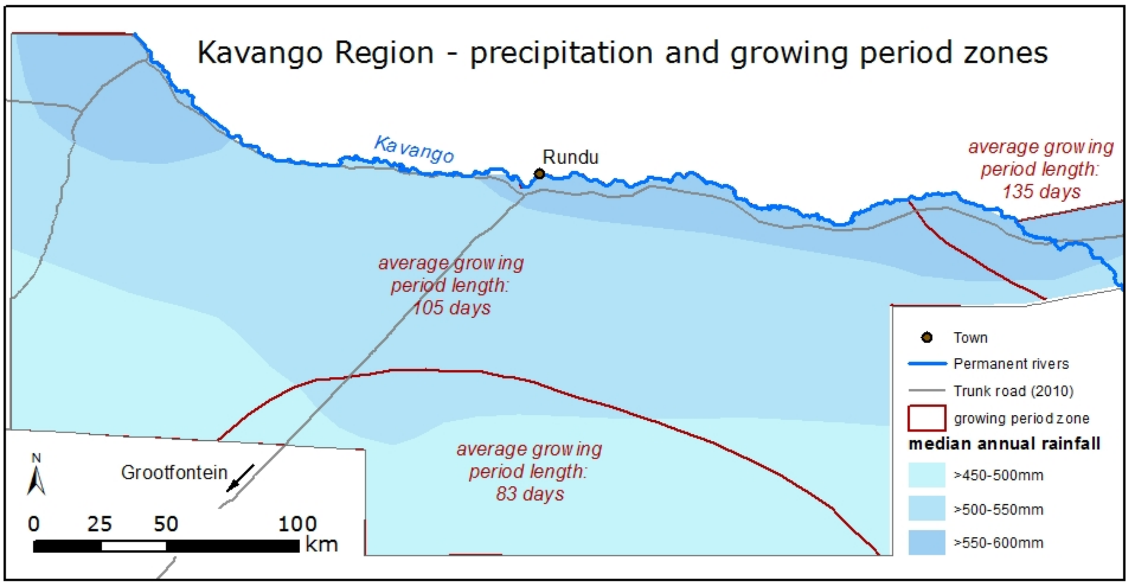


Figure 6 Kavango Region - precipitation and growing period zones (own mapping)

While the median annual amount of precipitation and the average growing period length seems to be enough for farming adapted crops, the high interannual, innerseasonal and spatial variability of rainfalls result in the fact the cropping becomes a high risk the more south it is undertaken (Hines, C., 1998). This risk is pushed again through unfavorable soil water retention conditions: Due to the porosity of the sandy surface, the few rainfall waters also tends not to be kept in the rooting zone of staple crops as long as it should which causes water stress or crop failure. Another hugh loss of soil moisture is that water evaporates quickly after an adhesion driven uptake (see the hugh water deficit in the map figure 5). Both factors reduce the length of the actual growing period and so the diversity of potential cropping seeds. Hines (Hines, C., 1998) noted that 90% of rain falls within the period November to March. This temporal rainfall pattern determines to a hugh extend the crop calendar (see figure 7).

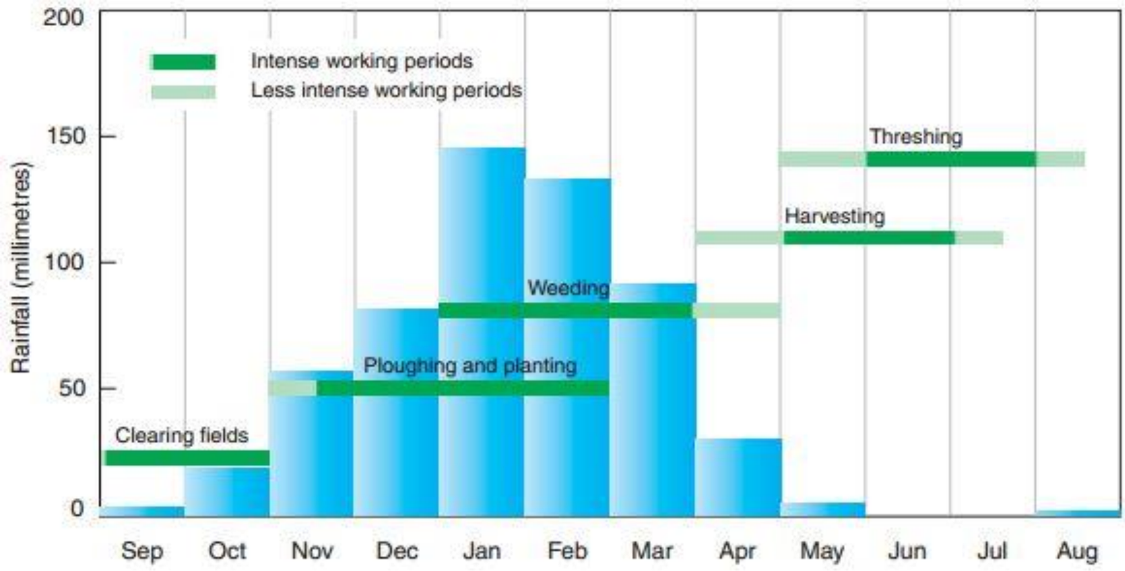


Figure 7 Kavango Crop Calendar (Mendelsohn, J., 2001)

Biogeography: the entire Region is part of the broad leafed Tree & Shrub Savannah Biome of medium plant diversity. Vast areas of Kavango Region are protected. Bwabwata National Park, Khaudum National Parkand the small Mangetti National Park make together 7547 km² (own calculation) of which most but not all are restricted and/or unsuitable for settlement. Therefore they are not part of the „reserve lands" of this study. Moreover with every hectare that is cleared for cropping the protected area gain higher value as 'reserve' lands for the high plant biodiversity (Hines, C., 1998) and wildlife of the Region.

Physiogeographic zones

From a regionwide perspective there are no remarkable heterogenities in the natural conditions for settlement with one important exception: the Kavango valley with its floodplanes, river terraces and the moderately fertile soils, the nearly pristine water and fish resources and biodiversity hot spots.

Zooming closer to the natural resource inventory, more differentiation can be observed caused by landforms (dune valleys and omurambas as major intersections), drainage and soil conditions. In 2001, the MET published an integrated view on natural resources that illustrates their variation both by a map of vegetation formations/soil groups and by catenas which explain differentation along the slope line (Simmonds, E. and Burke, A., 2000). An example is the following schematic drawing of a South-North Catena for the Western Stabilised Dunes-Zone, which is in terms of vegetation mapping identical with the Baikiaea plurijuga-Schinziophyton rautanenii woodland.

Figure 8 Soil and vegetation catena (North-South) in the land region "Western Stabilised Dunes" (Simmonds, E. and Burke, A., 2000)

The catena picture illustrates that there are locally cropping potentials (on the petric and haplic calcisols) and that they can be identified by their relief topological position. This assessment is taken as the primary source for deriving potential. Simmonds and Burke described seven Land Regions, a total of 19 Land Systems (such as „sand plain incised by short omirambas") and associated land units (such as „Terraces crests") and their catena, based on survey flights in 1999 and previous field studies (Simmonds, E., 2000).

Table 1 Land Regions, Vegetation units and households in 2011

Land Region / *Vegetation unit*	Sqkm	Households in 2011[1]
Eastern Flowing Palaeo-Drainage	6841.5	358

[1] Own calculation

Eastern palaeo drainage vegetation	6841.5	358
Ephemeral Catchment Divide	1526.7	16
Catchment divide vegetation	1526.7	16
Karst Pediplain	2052.7	104
Camelthorn - Silver Terminalia shrubland mosaic	2052.7	104
Northern Sandplain	18014.0	36230
Baikiaea forest	3.1	0
Floodplains and open water vegetation	1396.3	26498
Kalahari woodlands of Caprivi	2877.9	773
Riverine forests & Impalili Island	109.0	1009
Woodlands of northern sand plain	13627.7	7950
Omatako Drainage	1644.3	760
Omatako drainage vegetation	1644.3	760
Southern / Eastern Panveld	1482.2	1
Shrublands of southern panveld	1482.2	1
Western Stabilised Dunes	16841.1	2019
Burkea - Baikiaea woodlands	11568.3	1938
Burkea woodland and shrubland	5272.8	81

The low catenary positions play a major role in the land regions: Western stabilized dunes, Northern Sandplain and Omatako Drainage. The major part of reserve land for settlement is expected in these regions especially in the interdune and omuramba valleys.

Demography and settlement patterns

Following this preference in the natural conditions and historical presettings, settlements concentrate (outside Rundu, the dominating urban centre) a) along the Kavango river valley and b) additionally along the major roads, especially those ones with interregional (B10) and international (B8, B15) importance. Settlement outside these corridors occurs in form of small disperse villages only along omurambas (dry valley) and dune valleys with a some content of clay soil and waterpoints as well as singular farm households or cattle posts. Mendelsohn classified the Kavango Region by population density into three zones (Mendelsohn, J., 2001):

Table 1Table of population density zones according to Mendelsohn, J., 2001

People/ sqkm	Description
>10	Densely populated
1-10	Sparesly populated
<1	Not populated2

Looking of the spatial distribution of these zones (outside the urban center Rundu), the spatial relationship between settlement on the one hand and water availibility, road network and somewhat suitable soils on the other hand becomes obvious.

In terms of spatial size, Kavango Region ranks in the middle of all Namibian Regions. Hence the population, that means the five 'Kavango tribes' (Kwangali, Mbunza, Shambyu, Gciriku, HaMbukushu) plus San people (approx. 4800 in 1998), plus approx. 15% Angolians, 223352 people acc. to the 2011 Census, contributes with around 10% to the total Namibian population. Compared with the other 13 Regions, this declares Kavango as a high populated Region in Namibia.

Settlement directions

Directions of consecutive settlement on a micro level can be regarded as identical with the average radius of individuals follow a) convergent point features: water points and public infrastructure (good school and health facilities) and b) line features: roads, interdunal valleys (mostly east-west), omurambas (mostly southwest-northeast). On a meso level, parallel, occasionally divergent southern directions dominate since reserve lands are located south of the river zone, the tribal areas stretch in this direction and roads respectively 4-wheel-drive traffic moves towards the farms in the south. On macro level, employment opportunities in urban areas in and outside Kavango and

[2] the „reserve lands“ can be regarded as approximately identical with this third zone minus cattle farms and National Parks

political factors, such as tribal settlement areas, political (in)stability, development focal areas, planned major roads, have a significant concentration impact and a speed which is not bound to the extension of crop land.

Urbanization

Urbanization played the major role of settlement and lifestyle change in the past decades. In 1971, Rundu town counted approx. 1000 inhabitants (Mendelssohn, J., 2001), while in 2011 it is inhabited by already 65000. This impressive and ongoing growth might be influenced positively by refugees from Angola during the Angolian civil war after 1975 and with a special peak before the end of the last fights with UNITA at 2002. Negative influences on fertility rates are due to employment opportunities for women in town and the rise of the HIV-AIDS epidemic in the 1990ies. Both might cause to come back to a more balanced growth rate percentage as the census data indicate: from 2001 to 2011 the percentage of urban to rural population remained the nearly same (28%+1%) (National Statistics Agency, ed., 2013). In the future this percentage might increase just formally/statistically because Nkurenkuru and Divundu (each of them with approx. 10000 inhabitants in its sphere) have just been declared townlands. Other bigger villages might follow.

Settlement history

Pre-colonial and colonial times until 1910

With respect to the oasis-like favourable natural conditions in the Kavango valley, it is not surprisingly that archeological findings (early middle stone age) showed that the valley was already inhabited by crop farmers, long before the five „Kavango-tribes“ moved into the area. Bushmen, the indigenious hunters and gatherers, and maybe other unknown tribes with an interregional trade settled near the river until they were displaced to the harsh hinterland by the newcomers. Around 1500 the Kwangali and Mbunza tribes settled on both sides of the Western Kavango valley. Shambyu and Gciriku's arrived some 200 years later and the HaMbukushu tribe again another 50 years later in the very eastern part. Exact numbers are unknown (Mendelsohn, J., 2004). All tribes originated most likely from the upper Zambezi area from where they inherited the shifting cultivation which is in itself a quite mobile form of farming and settlement.

From 1886-1915 the German colonial power ruled officially the Region south of the river and shaped the boundaries of the nowadays „Namibia“. The northern bank fell to the portuguese colony of Angola as agreed one year after the so called „Berlin Congo conference“ early 1885 which divided Africa in spheres of colonial interests. However, the German's (and also the Portuguese) permanent presence in the Kavango Region existed „on paper only“ until 1910, when the first and only police station was built in Nkurenkuru. In the same year the first Mission was founded. Before 1910, only a few German expeditions and patrols were conducted, most times to explore settlement suitabilities. (Eckl, A.,2004). Likewise today, the lack of water in combination with the absence of a weather proof road network to overcome the 120km respectively 180km long „Durststrecke“ („thirst distance“ through the hinterland) between the central parts of the colony and the fertile Kavango valley in the far Northeast were assessed as the hampering factors for opening the area up for investments in public infrastructure, settlement, civic services and general economic exploitation (Eckl, A., 2004). The mentioned isolation of Kavango Region has one political root in this negligance of the obvious development potential. The aquisition of a Region east of Kavango, the so called Caprivi Strip in 1890, did not really this. The first world war interrupted any German plans and in the succeeding apartheid decades, Caprivi Region (today Zambezi Region) wasn't under the direct rule of Windhoek.

The first reliable estimation of the population in Kavango dates back to the year 1903. One of the Expeditors, Volkmann, spoke about 7000-8000 people, all living along the river (Volkmann, R., 1904). Eight years later, von Zastrow and Streitwolf (see data for HaMbukushu) localised the population as follows:

Table 2population estimation at the end of the German colonial period (von Zastrow and Streitwolf in Eckl, A., 2004)

	Kwangali	**Mbunza**	**Shambyu**	**Gciriku**	**HaMbukushu**	**Total**
Total population	1500	1000	0[3]	1300	4000-5000	7800-8800
German bank	400	940		800	ca. 1500	ca. 3640
- villages	15	31		23		69+50=119
Angolan bank	1100	60		500	ca. 3000	ca. 4660
- villages	35	2		14		51+100=151

10000 people is a remarkably low number for such a fertile valley of roundabout 430km length (and even less than the total number of German settlers in those days „German South-West-Africa“). Evenly distributed along a theoretical settlement at the river bank, it means that every village of 30 people only is 2500m apart from the next one. Assuming a crop field demand of 3 ha per household, this density means that the crop fields evenly placed along the river would stretch only 58m from the shore inside the hinterland. The river terraces with the better soils range from 2 to 5km from the banks.

Mendelsohn and others collected a number of possible reasons for the low population density.

1) Slavery. The inner Angola was known for centuries to be the source of slaves for the „new world“. Birmingham reported about approx. two million Angolan slaves between 1493 and 1910 (Birmingham, D., 1966). It is likely that the Kavango river formed a slavery trade route into the dry Kalahari basin. Volkmann reported 1904 on continuous slavery along the Kavango (Volkmann, R., 1904). To which extent slavery had a reducing effect on population growth in the late 19th century is hard to assess, also because slavery was a standard argument for justifying colonial interventions in these times and might therefore be overestimated (Eckl, A., 2004).

[3]The entire Shambyu tribe escaped rapidly in 1909 into an area 500km to the north. This was due to an expected punishment by the portuguese powers on a (stated) murder of three Germans on Angolan ground by Shambyu people. It can be assumed that (essential parts of) the Shambyu tribe had come back latest in 1919 (Eckl, A., 2004). The land which was left empty by the Shambyu people reached from the Fontein Omuramba (just west of Rundu) to the Omatako Omuramba (Seiner, F., 1912) led to the estimation that the tribe had a similar number of people than the Gciriku, if the same population density can be assumed (own estimation). If so, the total population left and right of the river amounted not more than 10000 people.

2) Tribal conflicts/wars and theft. In the middle of the 19th century, the troups of Kolololo people as well as the raids of Jonker Afrikaner (southern Namibia) made the people escaping to the northern banks of Kavango (Mendelsohn, J., 2004). Later, the Botswana Tawana tribe killed 80% of able-bodied men of Gciriku in 1893. As a reaction to it, Gciriku's did not kept cattle in fear of loosing them in tribute payments. Object of theft has also been women from other tribes for slavery. With the presence of colonial troups and missions, those practices stopped (Mendelsohn, J., 2004). That makes the year 1910 a remarkable cesura for the settlement history of Kavango Region.

3) Health. The absence of health facilities and the presence of numerous diseases such as malaria, diarrhoe, bilarzia, relapsing fever, hook worm, tubercolosis, pneumonia, epidemics (records about influenza in: 1918, 1925, 1928, 1932, 1940; measles: 1928, 1948, 1953, 1959) and malnutrition kept the death rate high (Mendelsohn, J., 2004) and do so on a lower level still in recent days especially in the remote areas of the AoI.

4) Dangerous Animals (Lions, Leopards, Crocodile, Hippopotamus, Elephants, snakes etc.), much more present in the past, resulted in loss of human life, health and productivity (Mendelsohn, J., 2004).

5) Agricultural production failures (droughts, low productive seeds, missing plant protection against pests and diseases, lack of soil preparation, unsuitable storages) could have caused severe hunger. Cattle and buffalo epidemics occured (foot and mouth disease, sleeping sickness, lung sickness). The great rinderpest outbreak of 1897 killed the majority of cattle and buffalo of the region and even far south in Southern Africa (NNF, ed., 2010)

6) The German administration created a „red line“, the northern border of the „police zone“ also in 1911. But even in these times it was thought also to be used as a veterinary fence.

In summary, in 1910 the population of the Region, concentrated exclusively along the river, counted even less heads as the natural conditions could feed under those times historical living conditions.

Slow population growth between 1910 and 1964

After the first World War, the Republic South Africa was internationally mandated to administrate Southwest Africa. It proclaimed the Region in 1937 as the „Okavango Native Reserve“. Just one year before, Rundu had become the new location of the regional administration. The South African apartheid regime was mainly interested in getting cheap labourers from the so called „homelands“, as the Region was, rather than to develop the non-white parts of the country. The five missions remained for decades the only permanent contact of ordinary small-scale farmers with the 'civilized' world. An ongoing positive effect on both population growth and settlement cores have had the foundation of the Kavango missions because of their health facilities and schools: Nyangana in1910, followed by Andara 1913, Nkurenkuru 1926, Tondoro 1927, Bunya 1929, Shambyu 1930, Mpungu (the only mission not near the river!) in 1951.

Still in 1942, almost nobody settled in other areas else than the ribbon close to the river (Mendelsohn, J., 2003).

The liberation period 1964 - 1990

The Veterinary cordon fence (VCF), running along most parts of the reshaped Kavango Region's southern border since 1964, was created – based on the mentioned former German police zone border - to defend the southern parts of Namibia against the foot and mouth disease which has not occured since 30 years in the Region (NNF, ed., 2010). In the mindset of the apartheid regime, the „positive“ side effect was the easy control of people's migration in and out of the „white“ parts of the country (Mendelsohn, J., 2003).

The Region's trafficwise isolation persists until 1964. A straight „arterial“ gravel (later tarred) road was constructed directly from Grootfontein to Rundu (Mendelsohn, J., 2003) – a „breakthrough“ in multiple meanings. It broke suddenly the transport- and so the trade barrier with the southern Regions, their economic centers, harbours, their products (heavy equipment and materials), health and education standards. And it paved the way to the first and only urbanization of the endpoint of that road: Rundu. It also facilitiated the labour migration (as desired by the apartheid regime). There were certainly also strategic military reasons in the Angolian independence war which began in the early 1970ies and lasted until the death of Jon Savimbi, UNITA rebel leader, in 2002. This war inclusive the last fightings with UNITA influenced population numbers of the Region significantly (Mendelsohn, J., 2004).

Development since Namibians independance (1990 – 2014)

Even in 1986, Kavango's paved roads network remained with these 137km. After independence, the road network in all former „homelands“ developed comparatively rapidly. A tarred road to the eastern neighboring Region Caprivi were constructed with some distance to the river (approx. 5 km), just outside the valuable terrace soil area.

The existence of the Veterinary cordon fence has still serious consequences for the

Region and in particularly for the reserve lands because the European Union only buys meat south of the fence which makes a significant better price. These prices might make the difference if a commercial cattle farm like the 512 of the governmental „Small-scale commercial farming unit“-scheme can become operational or not (Schuh, C., Werner, W., 2006). The competition on land in Kavango's reserve lands would be much higher between cattle ranchers and usual small-scale farming households. Therefore it is the hope of many Kavango citizen since independance that the fence will be removed or shifted to the Angolian border (The Namibian, 10.09.2013, „The Red Line And The Goose“ <http://www.namibian.com.na/indexx.php?archive_id=113888&page_type=archive_story_detail&page=1 >, accessed 05.12.2014). This helps explaining the massive growth of cattle farms since the 1980ies. Even before independance, hugh (>5000ha) farms (the 44 farms of the „Mangetti Block“, the 10 drought rwere installed starting from the Region's South.

Just within two and a half decades, approx. 18000sqkm of communal land or 37% of the area of the Region were given to private individuals (own calculation). In 2000, the establishment of the nowadays called „Small Scale Commercial Farm Units“ was decided. It means another GRN surveyed and partially equipped farm scheme of 2500ha-farms, 512 of them in total. At the same time, Irrigation farms were built next to the river and increased the land scarcity there.

In demographic terms, two factors manipulated the population data: the Angolan war with refugee influx until 2003 and the HIV-AIDS epidemic. The first started already in the 70ies but reached its peak period in the late 1990ies. These Angolian's settled mainly in Rundu, but also with a preference along the B8, the Rundu-Grootfontein-Road (Mendelsohn, J. 2004). The first incidence of HIV-AIDS in Namibia was reported in 1986. From the1990ies on it significantly contributed to the average life expectancy rate (Central Bureau of Statistics, 2010).

Socio-economics

The hugh majority of the Kavango people in rural areas practice a small scale low input low output crop production for mainly direct own consumption as the dominating part of the livelihood, and small numbers of cattle, goats and chicken, mainly for meat production (Namibia Nature Foundation, ed., 2010). Oxen were used as draught animals. The staple crop which copes with the described semiarid conditions is the local pearl millet (Pennisetum glaucum) variety called „mahango“. Next to mahango, drought resistant maize varieties are also popular and if successfully harvested consumed by the household members itself. In order to minimize further the risk of crop failure by diversivication, farmers cultivate also some groundnuts, sorghum and to a much lesser degree vegetables (Mendelsohn, J., 2001)

Natural capitals

The Census 2011 revealed that 14 688 out of 25 518 rural households (58%) stated „farming“ as their main source of income. This activity binds the settlement behaviour of most but not all of them in spatial terms since settlers rely on suitable soils, water and forest ressources. Water sources can be boreholes, little dams, pumpstations, hand dug wells but also natural pans that have water in the rainy season, some of them even in the dry season.

The **crop field** (cropping plot) lies for the majority of people immediately next to the household area (residential plot) or within a walking distance (max. 5km) which results in general disperse settlement patterns. Surveys like the one of Hentze (Hentze, K., 2011) speak about 2.6 crop fields per household and an area of 4-7ha (Mendelsohn, J, 2001: 3-6ha, Yaron et al., 1992: 4ha).

Wealthier people with a higher number of **livestock** (>40cattle) might own a cattle post deep in the hinterland or even a farm accessible only with a four-wheel-drive car. They „recruit family members and other people to live at the posts“, Mendelsohn explains (Mendelsohn, J., 2001). If this cattle post respectively the cattle farm sustains, if it grows or shrink is then mainly dependend on the investments done, predominantely in water infrastructure.

Financial capitals

3 out of 5 rural households in the total Kavango Region (including the weathier areas between the highway and the river) are classified as „poor“, defined as a monthly expenditure of N$262 or less per adult equivalent (Barnes, J. Wamunyima, D, 2009) and the number in the remote reserve lands might be significantly higher.

This level of poverty emphasizes the importance of natural ressources in the coping strategies of settlers in the hinterland. Yaron explains the more poor a household is the more important becomes the crop field harvest, because the livestock and cash income dissappear (Yaron, 1992). Despite many household have other means of income (pension fund, wages, salary), they are vulnerable to change in natural capital (Permanent Okavango River Basin Water Commission, 2011). Cattle are also kept as a store of value. Bank loans based on land ownership are not possible because all communal land vests in the state.

Transport

Transportation is a challenge in the rural areas. In terms of the road network it is often not at all existing. If so, then the sandy ground of the existing ways require expensive 4-wheel-drive cars. Maintenance of bushroads are up to the users.

Since the majority of households are poor, own transport capacities are scarce (only 15% of the total population own a car; NSA, 2011) and payment for transport services is saved for incidential emergencies. Marketing of any product is therefore limited by the road network. Access to any other property, including building materials is a challenge as well. The majority of rural household in Kavango Region is built on free forest resources (wooden poles, sticks, mud, thatch grass). The availibility is assumed to be given everywhere in the reserve lands even if temporal shortages due to bushfires may occur on a local scale.

Forest resources play an important role in the livelihood of rural household as they are sources of medicinal plants, construction poles, some commercial timber (Kiaat and Zambezi Teak). But foremost they are used as firewood. Nearly all rural households are used to collect dry (and free of charge) firewood in the near bush: out of 25 518 households for 23 959 it is the main energy for cooking and 21 494 for heating (NSA, 2011a). In Kavango's rural areas, firewood is without an alternative since electric power grid and parafin or gas suppliers are far away: along the river and the B8 highway. The firewood collection (next to commercial logging) causes severe deforestation around densely populated areas (Namibia Nature Foundation, ed., 2010). It also reduces the time and energy of the wood collectors: predominantly the women which are at the same time responsible for water, most of the agricultural field work and the care for children.

Legal framework of settlement and land utilization

Land ownership and land allocation process

There are three different types of land in Namibia: „state land“, "commercial" land and "communal land".

In Kavango Region, there is no commercial land.

Land type	land purpose	ownership	land titles
State land	State functions	State only	occupational land right (planned)
Commercial land	Residential + business	private or GRN	Freehold title
Communal land	Residential + business + commonage	State as custodian	Customary land right

The Communal Land Reform Act (CLRA) of 2002 describes the way how a land right title can be achieved in the Communal areas (land allocation). The Kavango Region is part of the Communal area. Rundu is currently the only part of the Region with a „townland“ status, meaning that the CLRA is not applicable. Within townland, a plot can be treated just like freehold land, meaning that one can own, buy and sell land. The land administration inside a town is with the magistrate of that town, not the Ministry of Land and Resettlement (MLR), which is the administrator for all rural communal and commercial land (Republic of Namibia, 2003).

All Communal land vests in the state. Communal land can not be bought or sold. But inhabitans can apply for a land right that allows them to undertake a certain utilization of the given plot for a certain time (Republic of Namibia, 2003).

Land allocation starts with a consultation of the interested person with the respective Traditional Authority ("T.A."), the custodian of communal land. If the T.A. gives "green light" the application will be checked by the Regional "Communal Land Board" ("CLB"), a non-public committee established according to the CLRA. Traditional Authorities, line ministries and organizations of the civil society are represented in there. The Communal Land Board uses the logistical and IT-support (GIS) of the Ministry of Lands to undertake their investigations and the registration processes. In case the CLB is convinced, it will handover a certificate of the respective land right (Republic of Namibia, 2003).

There are currently two types of land titles in the rural areas of Communal land as the Kavango Region:

1. Customary Land Rights (for residential and crop farming purposes and hence usually below 20ha per household) and
2. Leasehold rights (for business purposes, including agricultural business). The Government gets a lease fee which is determinated by land valuers of the Ministry of Lands and Resettlement.

Ungiven land is by default part of the communal land resource "commonage" which can be used for example for grazing by everybody's livestock. Customary Land Rights as described in the Act need to be registered in cadastral register and documented with a sketch map including the Coordinates of the cornerpoints of the plot (Republic of Namibia, 2003).

Land allocation practice

Land for settlement purposes is not a ressource like any other: a) it is incomparable with other resources of minor size or temporal availability. Access to land has got b) a cultural and c) a historical d) a political and e) even an emotional dimension.

Leasehold titles are given for business plots. The act lacks a clear definition or setup of criteria what can be regarded as a "business". One should not read this with a "western" understanding. In reality, there is a grayzone between usual settlement that takes place on a leased land and a highly organized agribusiness plot for clearly and entirely profit making purposes (own observation based on interviews in connection with a participatory mapping exercise in 2011).

For various reasons, the chiefs of the five Traditional Authorities of Kavango (from West to East: Ukwangali, Mbunza, Shambyu, Gciriku, HaMbukushu) refuse to accept Customary land right registration and refused to cooperate with the Government in this registration process. They are the only one in Namibia doing so and it is unforeseeable whether they might change their opinion in the future. The Central Government continues to promote the idea of the act, but respect the current decision of the local leaders. Registration of customary land rights is therefore still on hold (verbal information by Dep. Director A. Kanyinga, MLR, 2012).

The more favored is the idea of large farms in the hand of leaseholders by the Traditional leaders. There is an immense growth of non-communal land, mainly farmland, in the last decades and this trend continues. While the farmland „moves“ closer to the more dense populated areas from South to North, the settlement direction of small scale farmers is the opposite. The shape of the tribal lands also look like stripes running north-south, which matters because in the usual practice, settlers of one tribe remain in the same tribal area to search for new land. In some cases, the rush for farmland results in illegal fencing of large plots (verbal information by Dep. Director A. Kanyinga, MLR, 2012) very near or inside communities‘ cropland. Numbers of conflicting situations are increasing as noted by the Land Board (own observation between 2009-2012).

Materials and methods

Data and data sources

Tabular overview

Data	Description	Source	Date publ.	Date refer-ence	Spatial cover
Population census: population density map	Map of areas of equal population density derived from the population census data 1970	Central Bureau of Statistics	1979	1970	Kavango
Population census: population distribution map	Map of household clusters derived from the population census data 1970	Central Bureau of Statistics	1980	1971	Kavango
Population census: Household count data per enumeration area	Household count data per enumeration area; shapefile	Central Bureau of Statistics	1991	1991	Kavango
Population census: HH count data	Household count data per enumeration area; shapefile	Central Bureau of Statistics	2001	2001	Kavango
Population census: HH count data	Household count data; tabular format	National Statistics Agency	2011	2011	Kavango
Top. Map 1:50k dwelling unit locations	dwelling unit locations as derived from the 1996 ortho-photo	MLR	2001	1996	Kavango
Top. Map 1:50k Villages	village locations, same source	MLR	2001	1996	Kavango
Population census: population count data	Total, and projected, population of Namibia from 1921 to 2021	Total, and projected, population of Namibia from 1921 to 2021	2000	1921-2011	Namibia
Population census: population count data	Household location, Population estimate, derived avg. HH size. The point data, household points, from various sources (numbers refer to Kavango only): - 533 pts. in "Caprivi Profile" (Mendelsohn, JM & Roberts, CS. 1997. An environmental profile and atlas of Caprivi. Directorate of Environmental Affairs, Windhoek) for the HaMbukushu area: one dot covers more than one HH! - 21 pts. in "1:250k mapping project", presumably from	Atlas of Namibia	2000	1996-2000?	Namibia

	1996 orthophoto, MLR - 18377 pts "preliminary profile of Kavango”: Population densities were estimated by linking to each household the average number of people per household in each enumeration area, as analysed from the 1991 Population and Housing Census data. Positions of households were mapped by the 1996 Directorate of Surveys and Mapping 1:50 000 mapping project and by the Caprivi Environmental Profile project. Densities were then estimated by “spreading” the number of people at each household over 1 kilometer. Finally, the estimated density was increased by a growth factor by 6.3% to account for population growth between 1996 and 2000. The growth factor was based on population projections compiled by the National Planning Commission. - 20 pts in "North-Central Profile": presumably before 1996, could be GPS coordinates.				
Population estimate 1903, 1911	Based on expeditions from Volkmann and Streitwolf	Eckl, A.	2004	1903-1911	Kavango
population estimates 2001-2025	Population projection	US Bureau		2001-2025	Kavango-Constituencies
population estimates 1991-2021	population projections based on 5-years growth rates	Atlas of Namibia/CBS	2002	1991-2021	Kavango
Population census: Age and socio-economy	age, employment & income 2002; Rural / urban	Central Bureau of Statistics	2001	2001	Kavango
household sizes	Household counts acc. to household sizes, split by urban-rural	Atlas of Namibia/CBS	1994	1991	Kavango
Cleared land 1943	Shapefile; derived from Maps based on aereal photograph interpretation 1943; Origin: RAISON	Okavango River: The flow of a lifeline	2004	1943	Kavango
Cleared land 1972	Shapefile; derived from Maps 1:50 000 which is based on aereal photograph interpretation 1972; Origin: RAISON	Okavango River: The flow of a lifeline	2004	1972	Kavango
Cleared land 1996	Shapefile; derived from Maps 1:50000 which is based on aereal photograph interpretation 1997	Okavango River: The flow of a lifeline	2004	1996	Kavango

Cleared land 2007	Shapefile; derived from aereal photograph interpretation: cleared land, in wide parts of middle Kavango the split between „in use“, „fallow“, „given up“ was interpreted	self digitized	un-publ.	2007	Kavango
Cleared land 1998	Shapefile; derived from aereal photograph interpretation	self digitized	un-publ.	2011	approx. 10Km from river to the south and 60km around B8 highway
road data 2011	Road network „8“ of the Roads Authority (Ministry of Works and Transport) of major roads (="Trunk roads", „Main roads", „District Road") under national administration	Roads Authority of Namibia	un-publ.	2012	Namibia
road data 2010	Road network „7“ of the Roads Authority (Ministry of Works and Transport) of major roads (="Trunk roads", „Main roads", „District Road") under national administration	Roads Authority of Namibia	un-publ.	2010	Namibia
road data 2000	Major roads as in 2000	Atlas of Namibia	2000	2000	Namibia
road data 1996	Minor roads as digitized on aerial photograph 1996 for the Topographic Map 1:50k	MLR Topographic map 1:50k	2001	1996	Kavango
road data 1976	Kavango road network as digitized from 1976 Topographic Map 1:250k	self digitized from Top. Map. Sheets Karakuvisa, Rundu, Mukwe	2014	1976	Kavango
historic tracks	digitized historic tracks and roads	self digitized from International Map of the World 1:2Mio, sheet 30 Lusaka 1970, Deutscher Kolonial-Atlas 1905	1905; 1970	1905; 1971	Kavango
Agro-Ecological Zones	AEZ as done by the AEZ-Group in the MAWF	MAWF AEZ-Group	?	?	Namibia
National Soil Survey: Kavango River Terrace 1:100 000	Soil Survey 1:100 000 of the main settlement areas in Kavango Region	MAWF AEZ-Group	1999	1999	Kavango terraces, Mpungu area and Ncaute road
Soil type groups	from satellite pictures and soil samples derived soil group distribution map of the Natural Resource Mapping of Kavango Region	MET/ Interconsult	2001	2001	Kavango

growing period zoning map 1:250 000	growing period zones of the AEZ-project based on latest soil information (with reference to the respective soil survey)	MAWF AEZ-Group	1999	1999	Namibia
National Soil Survey: National soil survey map 1:1 Mio.	National soil survey map 1:1 Mio.	MAWF AEZ-Group	1999	1999	Namibia
Altitude level (20m steps)	Shapefile („kavango relief“)	Atlas of Namibia	2000	2000	Namibia
dune valleys	(mid)line of interdune valley floors	?	?		
Vegetation zones	from sample surveys, literature and satellite pictures derived major vegetation zones of the Natural Resource Mapping of Kavango Region	MET/ Interconsult	2001	2001	Kavango
Waterpoints Kavango	Boreholes, taps, waterpumps etc. collected by LuxDevelopment; without clear statement of the age	Ministry of Agriculture, Water and Forestry, Rural Water Supply	2001	2000	Kavango
Waterpoints Kavango	Boreholes, taps, waterpumps etc. collected by MAWF	Ministry of Agriculture, Water and Forestry, Rural Water Supply	2010	2010	Kavango
surface waters	permanent and non-permanent waterflows	MLR Topographic map 1:50k	2001	1996	Kavango
SRTM digital elevation model	downloaded from NASA website	NASA	2012		Parts of Kavango
Aerial photograph Kavango Region	Record date Oct 2007, pixel size 1m x1m	MLR	2007	2007	Kavango
Aerial photograph Kavango North	Record date Oct 2011, pixel size 0.5m x0.5m	MLR	2011	2011	approx. 10Km from river to the south and 60km around B8 high-way
Satellite picture Google Earth	changing record data between 2012 and 2014, pixel size estimated: 2m	Google Earth	2013	2013	Kavango
Digital terrain model	unknown source DEM; pixel size 50m;	?	?	?	middle part of Kavango

Remarks to the data sets

Data of remote areas in Africa are usually hard to get, but since independence the northern Regions, previously widely neglected in development, gained more focus and, when one look at the numbers of roads and hospitals, more investment for which data were needed. The overall data availability for the Kavango Region is even better than in other Regions of Namibia (own observation based on the Atlas of Namibia, 2000).

Digital Elevation Model

After downloading SRTM-elevation data from the USGS-website http://earthexplorer.usgs.gov/, the data format had to be converted from hgc-files into a Geodatabase raster mosaic named kav_SRTM_DEM (kav=Kavango; SRTM= space shuttle radar topography mission; DEM=digital elevation model)

The tiles of this mosaic are merged into a raster which is masked by the boundaries of Kavango plus a 300m buffer around it (Modell3b). The raster is named kav_DEM90m_WGS84 (kav=Kavango; DEM=digital elevation model; 90m= raster cell size is approx. 90m; WGS84=word geodetic system 1984).

The use of this DEM is limited since there seems to be a noise.

The other Digital Elevation Model was taken at the aerial photograph session in October 2007 (MLR). Unfortunately, only half of the Region's area is covered by it (unlike the Orthophotos themselves which cover the entire Northern Namibia). The data are given in a csv-file format so that they have to be converted first by "spatialite" into a dbf-file. This dbf-file agein is readable in ArcMap. Using the NwN-coordinates (New Namibia Transverse Mercator Projection), the table can be transferred into an event table and from there into a feature class stored in the same "Kavango_DEM.gdb" geodatabase and named kavDTM50bl09_NwN (kav=Kavango; DTM=digital terrain model; 50m= raster cell size is 50m; NwN=New Namibian Transverse Mercator projection)

Model1 "create DTM50m rasters" serves to create a raster fds by applying the tool "feature to raster" for each of the input point feature class for Kavango.

Model2 "create DTM50m mosaic" creates a mosaic dataset named kavDTM50m by applying the create-mosaic-tool.

Model3a "convert DTM50m mosaic to raster and mask to kav" reates from the mosaic dataset a usual raster which is then cut by a mask to the outer boundaries of the Kavango Region (+300m to cover floodplains which are not constantly part of Namibia due to flow direction changes). The output raster name is kav300mbf_DTM50m_NwN

(kav300mbf= extent of Kavango Region and a surrounding buffer of 300m).

Soil, vegetation and landform data

Soil data vary in position accuracy and thematical classification. The usual problems with these data are the generalization and the fact that vector data show discrete boundaries where in reality is a continuum. The Agro-Ecological Zone map 1:1 Mio. for example, was used to assess the cropping suitability in the nationwide AEZ project. Therefore it generalizes dune landforms (and with them interdunal valleys as major cropping areas) into a „intersected plain“ class.

The Natural Resource Mapping of Kavango Region Project (Simmonds, E., Burke, A., 2001) mapped unfortunately only the Vegetation Unit (virtually a refinement of the agro-ecological zones) and the Soil Groups, not the Land Systems. The project's soil group map has got the useful scale. But, due to its survey methodology (derived from remote sensing data) plausibility and the automized categorisation might be subject of verficiation on the ground.

For the northern part of Kavango, the 1:100 000 soil map „Kavango River Terraces“ does not tend to delineate strictly distinct as by remote sensing data, but takes (spatially continous) soil processes into account and is therefore more in line with the landform descriptions of Simmonds and Burke (Simmonds, E., Burke, A., 2000). Omuramba valleys are therefore more plausible. It is also more precise in the crop field zone near the river, where the majority of test pits lies.

Cleared land data

All data of cleared land are derived from Orthophotos, but only the ones of 2011 and 2007 were interpreted and digitized by the author of this document. The methodology/sketching details of the previous digitizing is unknown. This is important with respect to the stage of the crop field and the „generousity“ of delineation. In the latter regard, the two „historic“ data from 1943 and 1972 seems to draw somewhat fuzzy boundaries in the sense that they are generalized coarsly. That can be seen for example at the usual rectangular corners of crop fields in younger days. It can also be assumed that there are islands of not cultivated fields. Those cannot be found. In total, it gives the picture, that maybe because of the aerial photograph quality at that times, the digitization was neither accurate nor precisely done and that everything that looked somehow cleared was incorporated gently: household plots, public grounds, road area and foremost fallow land. These two datasets are anyway not too important for an analysis because the historic distance make it uneasy to extrapolate statements such as the length of fallow period, the local settlement direction etc. . The most remarkable finding is that in 1972, the most important settlement kernels in the hinterland existed already which we can find in later orthophotos.

The data of 1996 are of key importance for the comparison with later ones. They show remarkably precision in sketching the crop fields. Unfortunately, it is not clear to which extend „cleared“ means the different stages of cleared land:

a) crop fields currently (still) „in use“,

b) „fallow land for a soon re-use“ or

c) „completely given up“ (because of proven failure).

These three categories are difficult to distinguish since the subject can widely be seen as a continuum with few objective hints that helps to proper classify. Not only that it is dependent on the interpreter, also the orthophoto quality, the land itself and neighboring crop fields, the time in the season might influence how it is categorized. Because the orthophoto of that time was not available, it could not checked, what stage fell under it. The 1996 data don't distinguish these categories, but compared with 2007 , they look still quite generously digitized. The shapes of the individual features are not similar fragmented as in 2007 and 2011. Fragmentation is everywhere observable but in the interdune valleys, where most fields are of rectangular shape running from one dune fringe to the other.

This difference makes it very likely that the 1996 interpreters incorporated „fallow land“ and maybe even few parts of „given-up land“. If so, crop field growth over time must compare either again both stages together or apply a ratio of the stages. This ratio varies according to the different soil conditions in soil types and catenary position.

Another issue are the so called „road reserves“ which are obligatory since the early 1970ies for all types of major roads: Trunk Roads, Main Roads, District Roads. They have by default a 30m road reserve zones to each side from the middle of the road, in which any land must be left open unless there is an extraordinary permission by the Road Board to use this land. Trunk roads like the Trans-Caprivi-Highway from Rundu to Katima have in addition to the reserve a 100m construction zone, in which the construction of dwelling units and even fences must be explicitely allowed by the mentioned body. If those zones are digitised as „cleared land“ and interpreted as „crop fields“, then local sum values of crop field area might be overestimated, which can be well observed for the B8 (Rundu-Grootfontein-road). Clipping the „cleared land“ by road reserves results in an area of 3052ha, (alone 342ha on Trunk Road Reserves), which could be crop land enough for 600-1000 households. However, these zones are not everywhere strictly respected, so that a general erase would again not reflect the reality.

Not the entire Region could be digitized on the basis of the 2007 aerial pictures: the Mpungu area and the river terrace zone were left out. The remaining area is again divided in one part which is digitised as complementary to 1996, the other part, covering the central parts of Kavango including the Rundu-Grootfontein-road was digitized as from scratch (without taking the 1996 interpretation as a basis) and additionally with the distinction of the three stages „in use“, „fallow“, „given-up“ (see map „Kav_digitization_areas_A0_NwN“).

The Orthophoto of 2011 was available for the more densly populated areas of the Region only, along the river and the Rundu-Grootfontein-road. Digitization was done as complementing the 1996 features. Those fields were not checked again if they are still valid. It is assumed that under the current land pressure conditions near the river very few land will not be used or dealt as fallows. Most likely all land there is given a fallow period and will be re-used as soon as regenerated (or even sooner) and that the regeneration time on calcisols or fluvisols with a certain base saturation is significantly shorter than on Arenosols (a concrete value was not found in the literature).

Bush-fire burnt areas do appear easily distinguishable different.

Waterpoint data

The main three shapefile sources of waterpoint data differ a lot in spatial accuracy, metadata, data types, consistency, classification, completeness, content (here especially drilling dates) and volume of fill, spatial placement (outside Kavango) etc. and had to be harmonized in one feature class.

There is an indirect source which is the Top. Map from 1976, of which 27 waterpoints (13 in the LuxDev. Data, 14 in the MAWF data) were digitised while checking, if they are not yet reflected the existing point data (true in 11 cases). Drilling dates of them have been set to 1976 where necessary.

Data curations details are given in Annex „Waterpoint data curation“.

After all actions to populate the YearAll-Field that gives a chronological reference, still 158 out of 906 valid values remain without being dated. That's a pity especially for those 77 in the remote reserve lands, because some of them might be old and explain very much the distribution of population represented by household points or density areas (see f.e. Mpuku Omuramba area).

It can also not be completely excluded that some of the MAWF data contain test drillings. There are no explicit hints for that but some waterpoints' location don't make much sense: 15 of them in all communal areas (=not „given“) in 2007 have no crop field in a distance closer than 2km.

With the exception of few waterpoints in the LuxDev. data, there are no dates of non-functioning or for whatever reason not active waterpoints any more. For this study it is assumed that all waterpoints remain active at all times even if temporarily or permanently out of order or giving unsuitable or no water. This cannot be proven and will appear probably as outliers.

Population data

A secondary source of population data is the population distribution map 1970 (without scale) of Page (Page, 1979). In order to reduce the potential misplacment due to the scanning process of the map paper, the digitizing of the household points were conducted while comparing the locations with more plausible ones from the reliable and correctly georeferenced Topographic Map 1:250k in 1976. Page gives here the data from the 1970 census, but indicate only a big point for 100 people, and a small point for 25. Hence, the real numbers might carry quite a standard deviation but a) this does not account too much since relatively few settlement took place in the reserve lands (precisely: 32000 households (out of 47925) are closer than 5km to the river), b) the real value of the map is to get know the location of the growth kernels in these times.

Census point data of household positions are only available for 2011 and not even for the entire number of Enumeration areas (EA). They do not contain the real household size.

For the Census' 1991 and 2001 only aggregated data on EA-level are available. However, it is still possible to derive data since usually household points are quite clustered and do seldomly move far if dependend on a waterpoint access. In this argumentation, the population sizes Pages data (Page, 1979) can just be calculated by the annual growth rate from 1970 to 1972.

More problematic is that spatial data for the 1980 census lack completely.

While exploring the National Census' Enumeration area data, several data gaps and spatial inconsistencies were found:

a) Enumeration areas of 1991 differ significantly in their number (164) and spatial extent from those in 2001 (320).

b) The Enumeration areas of 2001 are given in two different shapefiles: „BDR_Namibia_enumerator_area“ (used in the Regions Administration) and „CBS2001_enum_areas_results“ (given by the Census Office), which vary slightly. Not a single EA is completely spatially identical with the feature of the correspondent shapefile. BDR... is more accurately digitized, but it is visible that the same area is meant. BDR has altogehter one more EA (321), but subdivisions of BDR-EA by the CBS2001 shapefile happen as well.

Regarding the 1996 data, the MLR Topographic Map 1:50000 has mapped „houses and huts“. Locations are derived from the 1996 Orthophoto, but household sizes are of course not given. In this case, the an average of the EA is applied (total population / household location count).

Methods

The general approach to derive the year when the land is depleted is a simple calculation: the average land demand per person (ALD) times the population growth number per year gives the total new land demand per year. The current available, unsettled land divided by this new land demand per year gives the number of years from now.

But, there are influences on those parameters.

The settlement does not take place spatially randomly. There are temporally varying spatial factors (water and road access, soil suitability) which attracts settlers to favorable places. If those places are too densly settled, and the remaining lands are not attractive enough settlers might move outside the region which reduces the population growth, hence the land demand, hence the time of depletion.

Therefore, urbanization and migration also need to be observed on potential trends.

The target of the methodology is to come up with weighting factors for the perceived strongest factors that influence settlement patterns: water, roads, suitable soils, land forms (somewhat homogenous in a „land region“). Those factor‘s attraction is expressed by proximity to a household point. For example the presence (5km buffer around a household) and distance to a waterpoint is considered to be a stronger factor than the presence of a better soil. As a first step, *household point distance* data as metric covariables need to be collected for waterpoints, roads, other households and crop fields. They need to be assessed if it feasible to do a multiple regression.

To run the different processings, a folder system was designed to host the data, several Geodatabases have been created and populated with data and toolboxes. All geoprocessings have been done using ArcGIS 10.1. More can be read in Annex „Preparations, tools and data management“.

Calculating increase of waterpoints and water supplied areas

Numbers of waterpoints per drilling year have been summarized cumulatively to evaluate the degree of constant growth of opening reserve lands for settlement with a linear Regression. This shall answer the question if the provision of water hinders potential settlers to move into the reserve lands or not. The average water supply area per waterpoint in time is also observed.

The Model „61Buf5kmThiessenCut“ (geodatabase waterpoints.mdb) results in areas of each waterpoint with a buffer radius of 5km, stored in the feature classes „AllvldWaterptCatchm_YEAR_NwN". Due to a cut done by Thiessen-polygons of the same points, the „catchment"-areas of the waterpoints do not overlap. Each is clipped on the Kavango Region's area.

Merged togehter with a 5km buffer band around the Kavango river, but reduced by the waterpoint catchments that fall inside given land, one can get the total water supplied area (model „63WaterSupplyAreas").

Population dynamics

The total population census data are compiled and the absolute intercensual growth and growth rate was calculated for the total, the rural and the urban areas. The years in between are linear interpolated. Getting an overview about the population trends is needed to assess what is the quantity of potential settlers in the future. How many are they? How many of them move to the reserve lands and clear new fields for permanent cropping? How many migrate to which other area? How many remain? Where are growth areas? Numbers have been computed with spatial queries where data are missing for five settlement areas: Urban centres, the densely settled rim near the river, the settlers on „given" land, the remaining area with the reserve land, areas outside Kavango Region.

The Enumeration areas have been attached with the attribute „adjacent to river" to indicate those one where the majority of the settlers live close (max. 7km) to the river in the natural conditions more favorable for settlement (and therefore primarily used).

Distances to waterpoints and roads

Identifying distances between waterpoints and households/cleared land in the local water supply radius

The histogram of household point distances to the next waterpoint shall give a picture to which extend settlers are attracted by waterpoints. The Near-tool was used to determine the euclidical distance of the nearest waterpoint. Households outside the supply radius can be identified with a usual spatial query, for the cleared land outside the radius, an Erase-Tool helps doing so. Again, this is observed for all years with household point data (1972, 1996, 2011). The results needed to be split for those waterpoints with a radial catchment area (inland waterpoints like boreholes, wells, reservoirs etc.) and the river which has got a river bank zone and floodplain areas between households and waterpoints.

Identifying distances between households to major roads

The same tools were applied for the euclidical distance to major roads. Interesting is not only the distance but the road hierarchy as a rough indicator for the traffic on that road.

Identifying average distances between households to cleared land

The cleared land feature classes were converted into a raster, using the DEM90m as the snap raster (land_use_gdb: model „17Raster_clearedLands_DTM90m“). It is then reconverted in a point feature class (Raster.gdb: model „01_convert_clearedland_to_points“). Each point represents the area of 92.2m^2 = 0.85012ha. Those points are equipped using the Near-tool with the next household’s ID and distance (land_use_gdb: model „41_affiliation_CL_to_HH“). Distance measures (min, max, mean, standard deviation) were calculated per household.

Creating chronological land use maps

The land use feature class (based 2011) given was curated and equipped with a date field for designation and a field for de-designation in case an area changes its purpose. Both were populated by information taken from the various literature resources (The same was done for the feature classes for roads and waterpoints as described in the „data“ chapter). The communal land resources (cleared lands+commonage) were given value „2099“ so that it will not be selected by a date query. Model „LanduseChronology“ of the Landuse Geodatabase derives land use stages according to date field for 1968, 1996, 2007, 2011. First, the feature class „Land_use_empty_NwN“ is created that only distinguishes the Kavango Regions land area and the river's area. Secondly, for each of the various years, this feature class have been updated by the area cleared, called „Landuse_YEAR_sine_given_NwN“. Another set of feature classes were derived from the land use feature class, using the date of designation/de-designation field to get „Landuse_YEAR_sine_Cmg_NwN“, so that they do only cover land given to private individuals (not communal land). Finally, the „Landuse_YEAR_NwN“ is an update of the „sine given“ by the „sine communal“, so that crop fields outside communal land disappeared.

The Model „60WaterpointsChronology“ of geodatabase „waterpoints.mdb“ selects first the valid entries in „All_waterpoints2010_NwN“. It selects then in which year which waterpoints were existent („AllvalidWaterpts_YEAR“). An exclusion of the waterpoints on given land is then done using the „Landuse_YEAR_sine_Cmg“ of the Landuse

Geodatabase.

In Geodatabase „Kavango_Population.mdb" the various population data on household level for 1972, 1996 and 2011 have been compiled. For 1972, population data of 1970 have been multiplied with the respective calculated average annual population growth (linear) between 1970 and 1991. Population numbers for 1996 were derived for each household point of the 1996 mapping by applying the household density on Enumeration area level from the 1991 census.

The nearest waterpoint (model 30NearWaterpts) and Road of the household point (model 40NearestRoad) is calculated (both times euclidical distance).

While the resulting data are ready to be statistically analysed, land use maps are created to get a visual impression where population and main factors correlates spatially (LandUse_YEAR_A0landsc_NwN.pdf).

Identifying local mahango cropping suitability

Generally there are the following sources to identify potential land for cropping (each with their „pro's" and „con's"):

a) explicit delineations in soil maps,

b) semi-explicit catena descriptions as given by Simmonds and Burke,

c) implicit occurence of crop fields in the various orthophotos (not an evidence, but likely to be on a suitable soil type)

Another indirect method is

d) to observe the soil's color, since under the Kavango climatic conditions that color is steered mainly by the subsurface drainage dynamics of upward movement of iron oxid, which is reddish, because it has no or limited time to hydrate. Those colors can therefore indicate the fast or slow hydration of the oxids and therefore of the upper soil horizons, showing more yellowish or brownish colors on the slopes (see following picture). In the valley floors, where (depending on the clay content) waterlogging can appear temporarily, soils show the greyish color, because bacteria remove the bound oxygen in anaerob conditions (Simmonds, E., Burke, A., 2001). To choose this method would require a lot of time for digitizing, which cannot be done in the framework of this study.

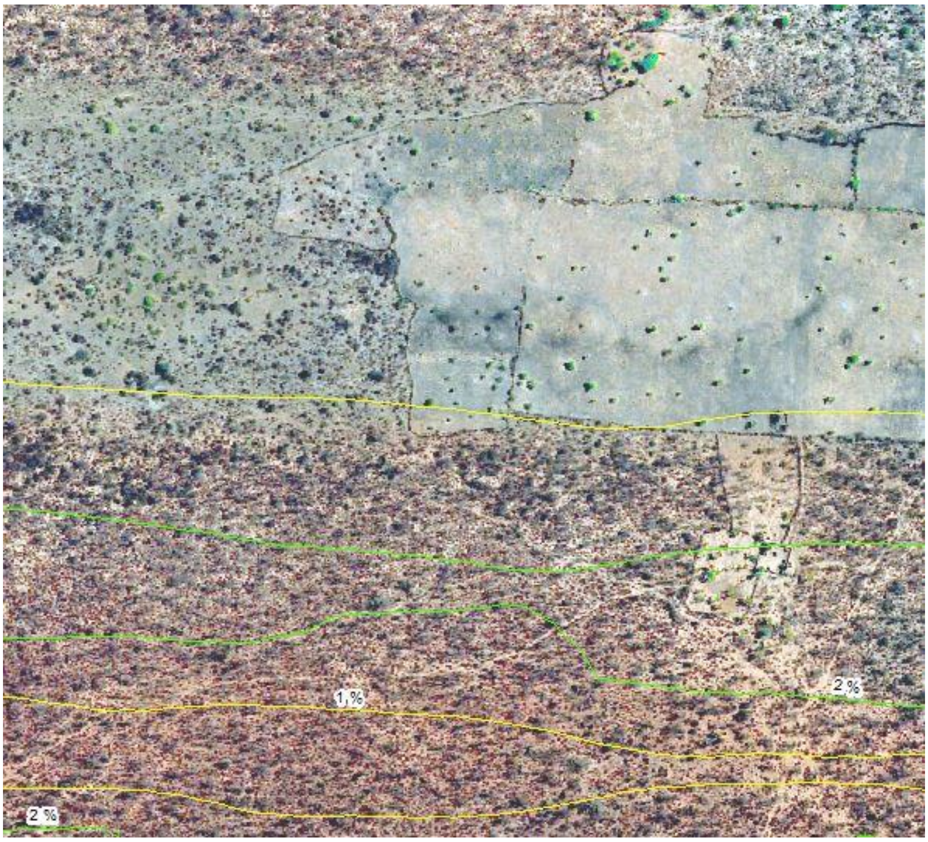


Figure 9 This screenshot shall underline the close relationship between landforms, soil conditions/color and crop potentials. Areas for potential and realised crop fields show greyish colors, in the interdune valley starts approx. below 1% slope (yellow isolines) at the southern (ex lee) dune fringe.(own figure).

ad a) Soil suitabilities in soil maps

The only map that explicitely talks about „millet suitability“ is the AEZ-map, based on the 1:250 000 Growing Period Zone map. The map describes it using an ordinal ranking of „not suitable“, „low“, „medium“ and „high“, but it can be assumed that this scale is more or less an interval based one: „not suitable“ gives in average a total crop failure, and „high“ gives in average the best local harvest possible (under the same locally usual practices). It can be derived from the Agro-Ecological-Zone map, that the climatic conditions, namely the length of the growing period, which is at least 61 days even in the driest southern part, are not limiting mahango cropping (on suitable soil types) in median years of water deficit. However, not very much reserve land exists there in between the hugh blocks of cattle farms and the National Parks and the current population density is nowhere lower.

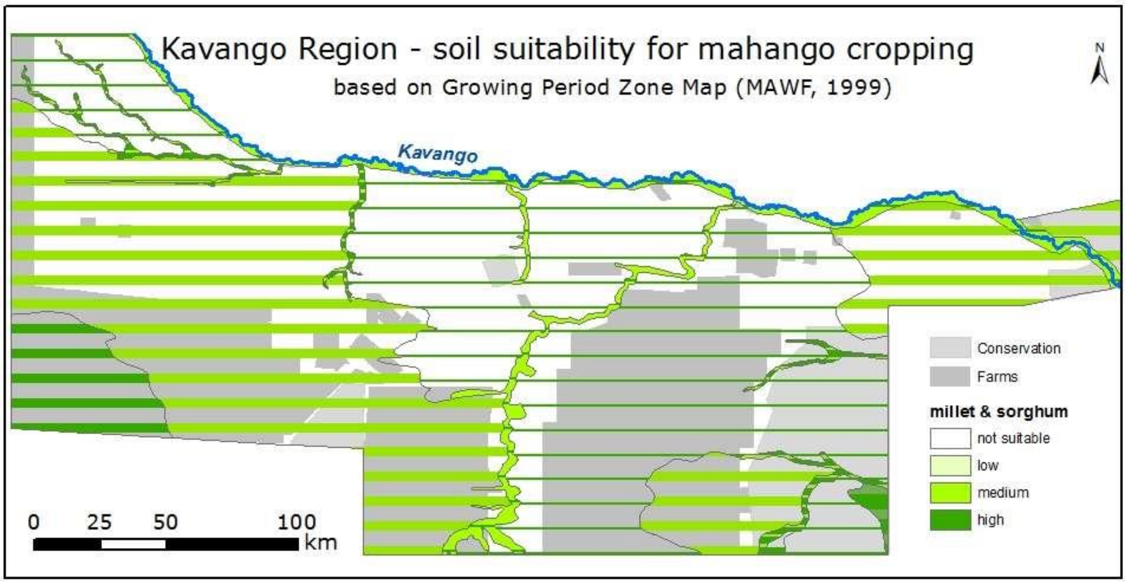


Figure 10 Kavango Region - Soil suitability for Mahango cropping (MAWF, 1999)

Explorative spatial data analysis

One target of the exploration is to assess to which degree the delineation of soil map units are in line with the „reality“ of an interpreted orthophoto. Ideally the found landforms match a) the description of landforms and associated soil groups respectively the catenas in the MET resources assessment (Simmonds, E., Burke, A., 2001) and b) the outline of the vegetation type areas. Both documents are based on a regional study. Because various sources define which soil types are how much suitable for mahango cropping, the most accurate and precise positioning with a mininum of generalization of these areas is important.

Deriving suitibility values from existing data

Each of the land units (topologic position in the catena) has one or more most likely associated soil unit(s) and vegetation type(s) linked. The soil unit again is linked to millet suitabilities. Hence the land units function as a variable for land demand if it is possible to derive average crop field demand per soil unit. The correlation of soil type and water access should be nearly zero in the Kavango scenario. The correlation with road network is only valid in Omuramba valleys, but many modern district roads avoid the valley bottom today because of the many meanders. The whole concept works best in distinguishable catenary positions, not in virtually flat areas.

Suitable soil types for mahango cropping under the given climatic conditions are:

Table 2Suitability of soil types for Mahango cropping (MAWF, 1999)

Soil Unit	Soil group	millet&sorghum suitability
petric calcisols	*Calcisols*	High
haplic calcisols	*Calcisols*	Medium
arenic fluvisols	*Fluvisols*	Medium
leptic-chromic cambisols	<no adequate>	Medium

Ferralic arenosols are usually very poor in nutrients and with a very unfavorable soil water regime. These soil types suitability were assessed, but it covers also subtypes with loamy fine sands, probably in local depresions (Simmonds, E., 1998). That could be one explanation for finding crop fields deep inside an arenosol area.

In conclusion, the given soil data are merged in the way that signals of Calcisols and Fluvisols as well as delineations of the 1:100 000 soil map will both be used to indicate an overall millet suitability. This will be conducted using an 'union' function and a field „suitMil“. Similar to the AEZ map[4], this field will be populated with a short Python script as follows:

- A „3“ (for „high“) if in one of the sources the type „Calcisols“ (haplic or petric) or the texture „sandy loams“ appears, which is mostly coincident.
- A „2“ is given for „(haplic or arenic) Fluvisols“ or „loamy sands“.
- A „1“ is given for arenosols. It is also given for the very small rock outcrop areas.
- A „1“ is also given for all others, including arenic-leptic Regosols and sandy arenic Fluvisols on Terraces.

Identifying ratios of stages „in use“ vs. „fallow“

It is assumed that in a shifting cultivation context, the *place* of a crop field plot of a farmer might shift within the farmers settlement radius, but, under the same soil conditions, the *ratio* between in-use and fallowed land should be constant.

The zones in which stages of cropfields were digitised (OID 8 and 13) make around 24205 sqkm of which 1104sqkm are „cleared“ (830sqkm „in use“; 194sqkm „fallow“; all data only in 2007).

---

[4]The AEZ map is assumes polygons with a dominant soil „chromic Cambisols“ or „haplic Calcisols“ have no constraints for agronomy, while polygons are rate „medium“ if they show an associated soil of “chromic Cambisol-“ or „haplic Calcisol“-type. All other polygons are excluded (Coetzee, M., 1999)

The Square kilometers of the crop fields categorized as „in use“ had been divided by those as „fallow“ (Field „USES“) throughout these two capturing zones, differentiated by the different mahango suitability zones (done by geoprocessing model „Ratio_Stages“ in ArcGIS). This ratio shall give a quantification how much more suitable the suitability zone 3 is compared with 2 and 1.

Annex „Identifying stages of crop fields“ gives more details about the identification of cleared lands and the different stages in the aerial photographs.

Identifying local land demand for settlement

Since there are no records in Kavango which crop land (with which size) belongs to which household, this affiliation need to be done by the distance household to cleared land. The cleared land must be within a distance of 5km and outside given land. Theoretically, one must draw a circle of 5km around each household to determine its search radius, to erase the given land and then to intersect geometrically all circles so that search parcels are generated. For each of these parcels, there is the information of the household(s) attached. Those households divide the total cleared land to be found inside the parcel among themselves according to their household size weights. The results would be that all land is distributed fairly on the households inside 5km.

In reality, this method failes due to processor overload and too many sliver polygons. And even if it would work technically it would overestimate the land of remotely households compared to the densely standing households, because the 5km radius is far beyond what is needed to saturate an average land demand.

The alternative approach is as follows:

The „other location“ column data in the household feature class needed to be curated so that household can be grouped into villages (synonym: „location“ or „loc“) without exclaves. These villages shall reflect clusters of households which presumable have their field in their neighborhood only. The total area of a village is simply defined by the Thiessen-polyogons of the households (outside private land) that belong to this village (minus the private land) (geoprocessing model 1003 in Kavango_Population.mdb). This is then the search parcel for the entire village community. An intersection with the crop land feature class and other parameters (soil suitability, land region, watersupply) results in the feature class kav_HH2011locs_onComLandTh_NwN (model 1080). This can be taken for further analysis, especially the cleared land per village (model 1081, output:

table „kav_HH2011Locs_Stats_PivotUse“) and its ratio against household numbers respectively per head of population (models 1005, 1081, 1082, 1084). The actual cleared land is also set into relation to the locational average land demand ALD per person. The locational ALD is derived by dividing the total cleared land per region through the regions population and then multiplying by village inhabitants.

Results

Comparing growth of population, increase of waterpoints and cleared land

Waterpoint number increase

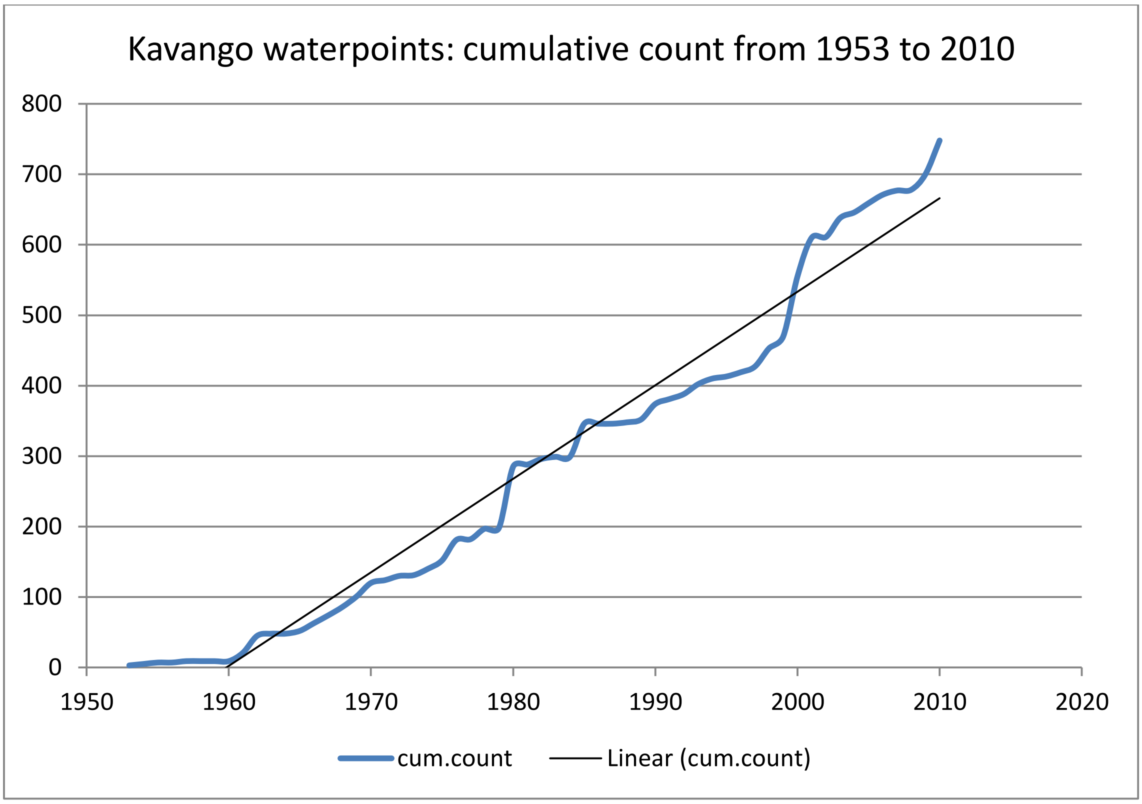
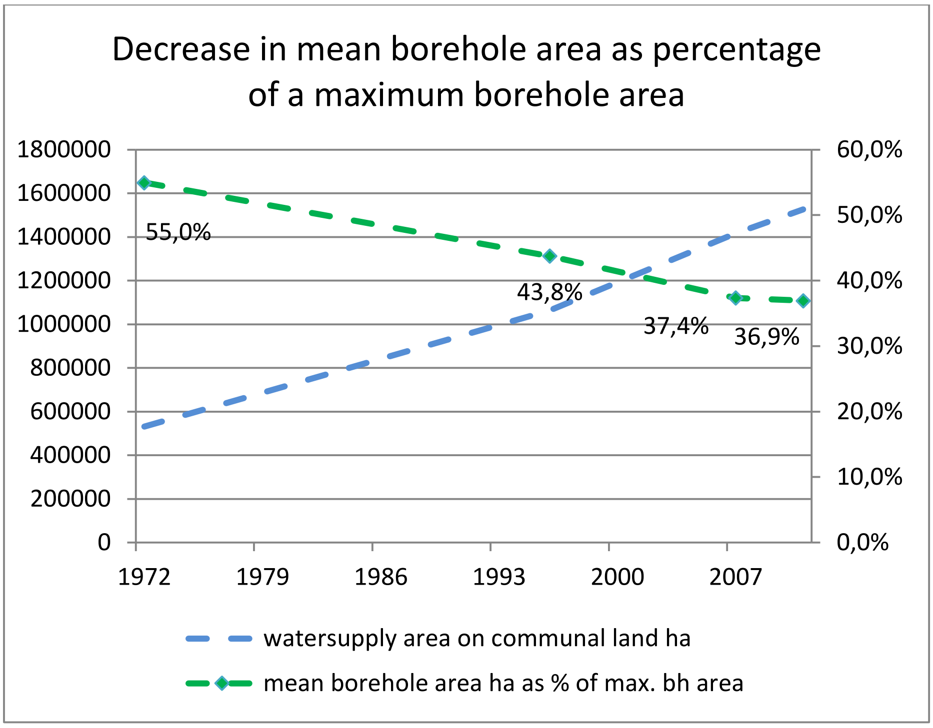


Figure 11 Kavango waterpoints: cumulative count from 1953 to 2010

The result shows a remarkably constant increase per year of roundabout 13 waterpoints starting from 1960. It can be described by the formula

$$Wi = 13.273x - 26013 + □$$

(Wi: increase in waterpoints, x: annual rate; Standard squared error is 39.3).



The maximum area that one borehole alone supplies with water is approx. 7854ha (radius=5km). This is when there is no given land in it and no overlap occur with other boreholes‘ supply area. The graph underlines how this supply area shrinks against its potential maximum because boreholes are placed increasingly overlapping with other water supply areas. This shrinkage is roundabout 0,46% per year or 36 ha. This number need to be applied when extrapolating potential increase of water supply areas using the previous formula.

Population dynamics

The totals show that a transformation period has taken place from about 1960 up to today in which the population has grown dramatically. Two peaks appear: in the 1970ies and 1990ies (The Census 2001 noted an intercensal annual growth rate of 5.66%) and on that high level a relatively dramatic decrease in the growth rate identified in the Census 2011 down to 1% annually, which is near to the number of 1.4% for the entire Namibia. This shifts the overall land depletion while freezing the current circumstances theoretically to centuries in the future and makes this study obsolete. An annual growth rate of 2% would still give around 100 years to depletion, 3% time up to the year 2083.

Urbanization

The graph shows the different development of total population numbers in rural (blue) and urban (red) areas. In 2011 time the urban center Rundu counted 62295 inhabitants, of which approx. every third came in the last decade. For comparison: the total popluation grew from 2001 to 2011 by 20658 people. That means that it reduced also a big portion of land demand for mahango cropping.

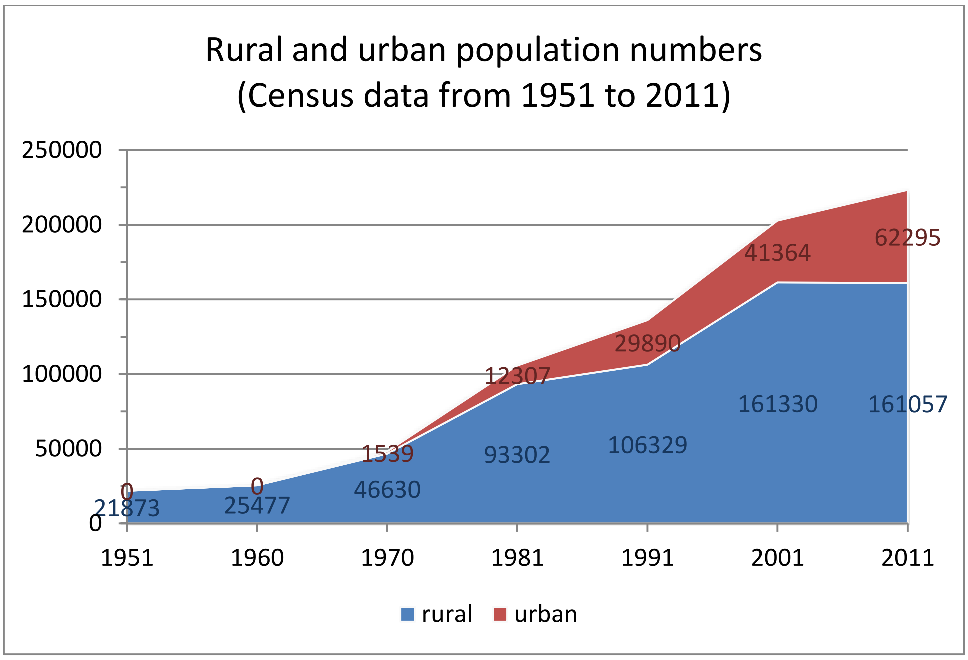


Figure 12 Rural and urban population numbers (Central Bureau of Statistics, 2011)

According to the 2011 Census, 1097 urban households (approx. 6143 people or 10% of Rundu population) still practice farming as the main source of income and even 2234 Rundu households in total having a crop field. All those „city farmes“ are responsible for the hugh belt of cleared land for agriculture around Rundu. That means for calcuations on village-level that those villages near Rundu influenced by this factor have not an own household's born land demand and should therefore be excluded when calculating average household‘s land demand per location.

Migration

Not all migration to Rundu was at all times Kavango born. The Rundu refugee center counted approx. 10000 registering refugees, virtually all Angolians, between 1999 and 2002 only (Mendelsohn, J. 2004). Mendelsohn further states that one third of the Rundu residents speak an Angolan language as their mother tongue and 15% of the rural population do so. The first number could be estimated a bit too high, because if this is applied to the 2001 Census results that he seems to refer to, it results in 12315 Angolians alone in Rundu and 24208 in the rural areas, together 36523, which is a percentage of 18% of the 2001 total population. This number seems to contradict the census data which counted about 9% speaking a Non-Kavango language in 2001, that is only 18242 people respectively 184451 people who speak Rukavango.

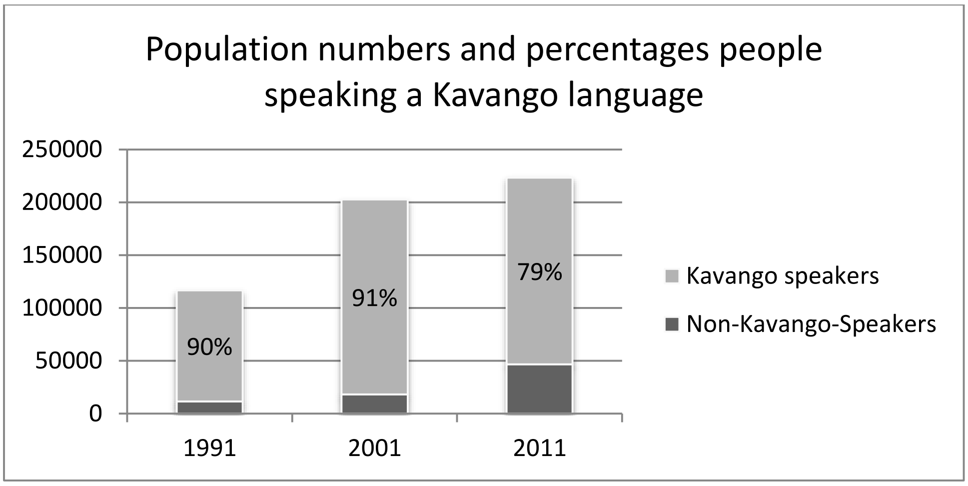


Figure 13 population numbers and percentages of people speaking a Kavango language (Central Bureau of Statistics, 1994, 2001, 2011)

Cleared land and population numbers

The total population numbers and the total hectares of cleared land have a stable ratio to each other throughout the years which scores between 1.08 (in 2007) and 1.23 (in 1972). The ratio remains even in 2011 when 8989 urban households do not practice farming.

A median score of 1.15 in 1943 fits probably best to calculate with.

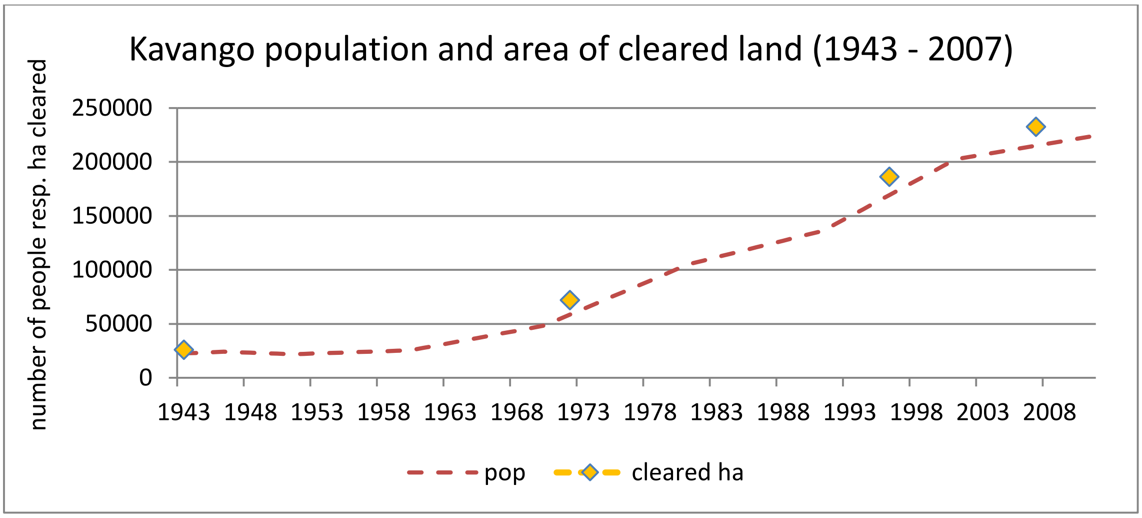


Figure 14 Population and area of cleared land

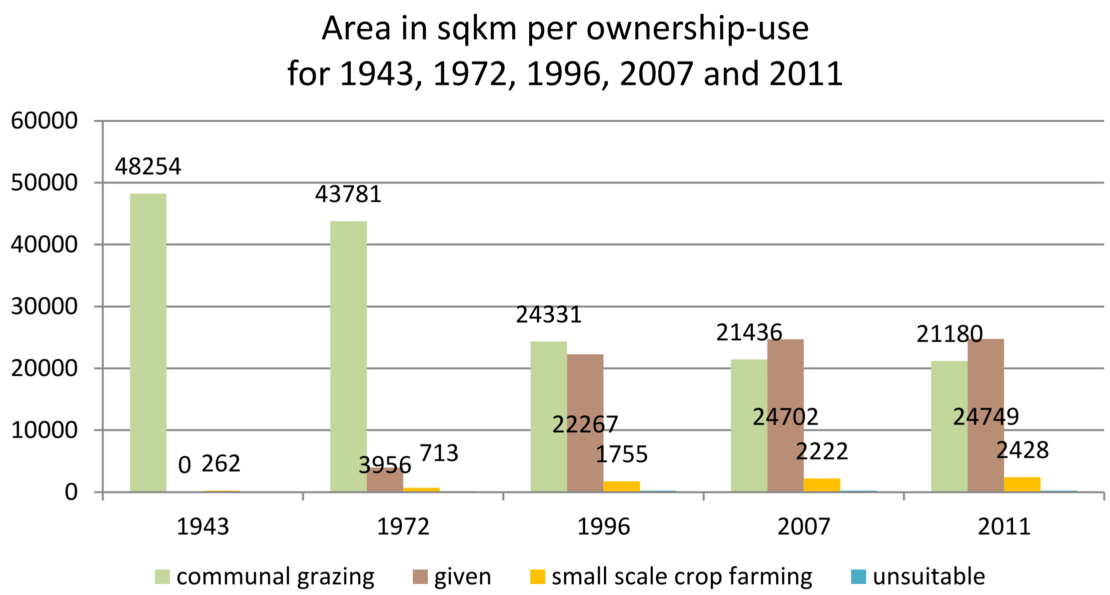


Figure 15 Land use area in sqkm per ownership for 1943, 1972, 1996, 2007 and 2011 („given"=non communal land resources)

This graph confirms the observations on the allocation practices. The trend of land given to private individuals (mainly farms) continues, but discontinously. Meanwhile reflect the cleared land numbers very well the growth of the population.

The columns of communal grazing (commonage) and the cleared land still differ a lot. However, this graph doesn't show how many commonage is on unsuitable soils or in the very south, where crop farming is of high risk.

Soil suitabilities

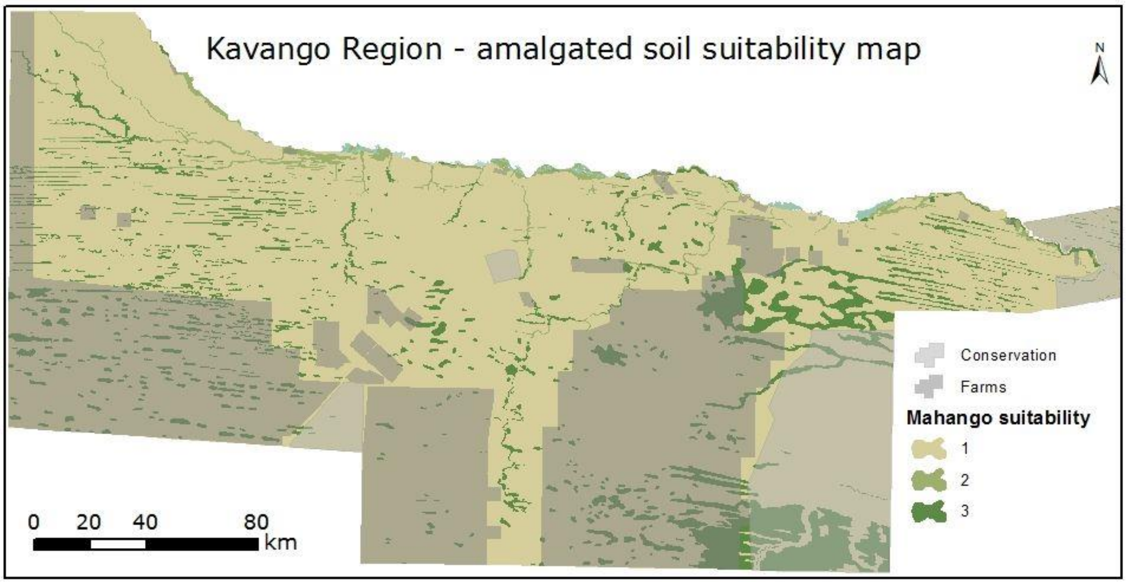


Figure 16 Kavango - amalgated soil suitability map (based on MAWF ed., 1999; Simmonds, E., Burke, A., 2001)

Explorative spatial data analysis

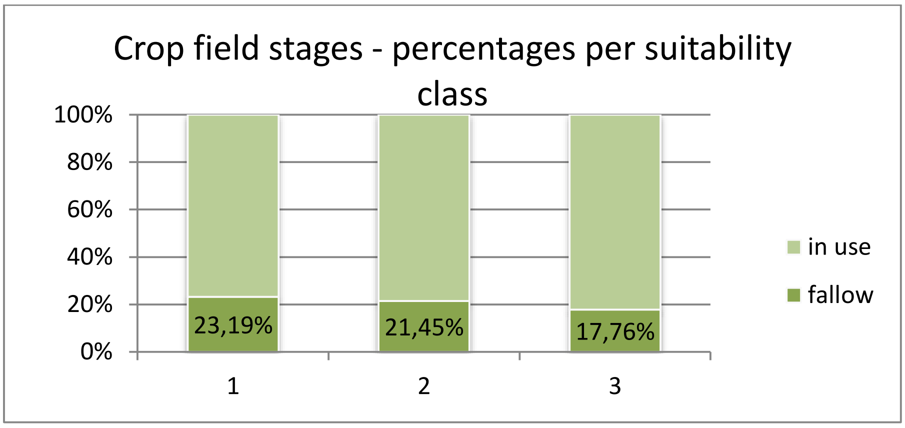
The main finding is that in most cases the soil maps are still too generalized or fragile in its delineation methodology. So they do not reflect properly the local land form and therefore the suitability. In fact the main omurambas and some interdune valleys are visible, but for many areas, a larger mapping scale would be necessary. These areas are all areas, where the landform is not distinct enough to derive clear soil type boundaries. In particular the northern parts of the „Northern Sandplain“:

a) to the North and Northwest of the Kaudhum National Park: differences in soil conditions and soil patches are very small due to the occurence of small pans. The area is actually fertile and due to some surface waters in the pans since long time a settlement area (1132 ha of cleared land already in 1972).

b) the Northern Sandplains especially between Mpuku and Matende Omuramba (west-south-west from Rundu; west of Grootfontein Trunk Road). Map units and DEM describe a slightly dissected plain, but dunes are not obvious. Nevertheless, most of the crop field show a lenghty shape oriented in East-West direction, just as in the dune zones.

The result is that the suitability map is of not much use.

Ratios of stages „in use" vs. „fallow"



The results showed that there is only a very slight difference in the ratio: crop fields on best (3) soils have a ratio of 4.6 while fields with suitability „1" score with 3.3. For the suitability 2 the total number of samples (3.500ha) was probably not high enough.

Distances to waterpoints, roads and cleared land points

Distances between households and cleared lands

Year	total count cleared land points	total distances to cleared land points	Cleared land
1972	84391	100279279.24	118.82
1996	224268	180883702.51	806.55
2011	282776	290149041.58	1026.07

table 3intermediate results from calculating distances to cleared land points

Distances between households to major roads and waterpoints

	Average distance to nearest			Median distance to nearest	
Year	major road	waterpoint	Cleared land[5]	major road	waterpoint
1972	1093.5	1455.7	118.82	437.8	1067.4
1996	223.7	1354.9	806.55	121.0	917.7
2011	395.9	1284.3	1026.07	151.4	1095.7

table 4Distances to major roads and waterpoints - average and median results

[5] Only distances of HH to cleared land points inside communal land

Discussion

Waterpoint number increase

The Graph does not take into account the location and the ownership of the waterpoint. Both are decisive if the waterpoint is available for settlement. If one wants to calculate the real number of yearly borehole investment in the reserve lands, all the farm waterpoints need to be taken out. However, the counterargument is that new farms with new boreholes are also a kind of new settlement. It just attracts other people: the relatives of the farm owner – and the rapid growth of the population numbers inside the leasehold farms underline this attractivity. And in development aspects, it spatially distributes the investments more equally. The more new boreholes are placed evenly, that means with no or a minimum of overlap of its 5km catchment radius, the number 13/year can be taken as the pace of opening an area for new settlement.

The start of the Regression at 1960 can be justified in that way that the earlier waterpoints‘ position (at Missions and at Tsitsib) show that their purpose was not for serving the local settlers demand, but mainly or even exclusively for whites as a stopover water supply and had therefore no direct influence on settlement.

The area of Kavango that is not yet having a full waterpoint coverage, in 2011 it covers 1526376 ha. The area on commonage without water supply is 841947 ha in 2011. Applying the regression formulas pace (roundabout 13 new boreholes per year) means that soonest in 2019 all area is water supplied. That is just a theoretical result, because the geometry of circles always results in some overlaps and gaps. Secondly, not the maximum area coverage of a waterpoint can be applied, but its (decreasing) mean, which is 2904 ha in 2010. This would shift the earliest date of full coverage to year 2034. Moreover it is not the policy to cover all communal land with boreholes, especially not completely untouched or unsuitable or very remote areas such as the many squarekilometers between Khaudum National Park and the Farms.

In summary, the water supply will take pace with the increase in land demand, especially with the current trend of cutting down communal land resources by giving it to private leaseholder.

Population dynamics

The two peaks in the total population count are certainly coming from the influx of Angolian refugees. Accurate data are missing, but this influx was a non-continuous process. Linear interpolation cannot reflect that, but other interpolations cannot too. For the interpolated data of 1972, the numbers might be slightly too high since the Angolian civil war started in 1975. It‘s similar in 1996. However this deficiency is small compared to the total population and data can still be used.

Urbanization

The most prominent observation of the population graph is that the rural population counted nearly the same in 2001 and 2011. In this period there was no expansion of townland with the exception of Nkurenkuru whose inhabitants were counted 618 only in 2011 (NSA, 2011).

The reasons might lie in

a) the availibility of land near to the river comes to an end and forces more and more people to migrate both to the reserve lands (neutral in the statistics) and to town (surely the majority) where people assume to find better job opportunities.

b) in the general population trends that show a declined fertility and mortality rate. At the same time the Census 2011 reports that Kavango has still the highest crude birth rate in Namibia. This contradiction can only be explained if lots of mothers die younger than usual and consequently give less birth to children in total during their life. This fact again leads to HIV-AIDS. This epidemic mostly do not kill immediately but some years after infection. This period can even be stretched with antiretroviral therapy whose coverage in Kavango increased from 3% in 2004 to 65% in 2008. Together with a decrease of HIV prevalence among women

Migration

According to the 2011 Census, the ratio of Kavango speakers to the total population decreased significantly. Roundabout only 176448 Kavango residents (=79%) speak a Kavango language in 2011.

Taken into account that very few Angolians came later than the end of the last UNITA fights in 2002 as „refugees“, and considering also some few Angolians settling back in their country, the number of 21% Non-Kavango speakers in 2011, equals 46903 heads, is as high as expected if one disrespects the Census numbers in 2001. Taken the 2001

Census data seriously would mean an increase of 28.661 heads in ten years. Possible reasons for the incorrect numbers and the rising migration into Kavango are:

a) the 2001 census numbers as well as the „90%“ from 1991 census give incorrect („shadow“) Angolian percentages because many refugees tried to hide their refugee status resp. origin when answering to the enumerators. Otherwise a stagnant percentage can't be explained while having another immigration wave was yet to come in the 1990ies. The entire high growth rates from the 1970ies on can not sufficiently explained without a strong immigration from Angola in all these times.

b) Angolian families still stay in Kavango due to economic situations but also bringing relatives from Angola into Kavango even after the war because of better opportunities to make a living (similar to argumentation of: Mendelsohn, J., 2004),

c) strong interregional and even international attractivity of Rundu as the dominating administrative and very dynamic economic hub in Northeastern Namibia. This argument could be supported by the 2011 census data about inner Namibian migration especially from Caprivi and the Owambo-Regions. Furthermore, the bridge across the Zambezi to Zambia and the Katwitwi border post to Angola might have pushed the international traffic in the last decade.

d) the long term migration (in 2011: 7% loss) might have become more dynamic (higher migration levels to Windhoek in the post-Apartheid era, tertiary education related migration, higher mobility) than in the census decades before and so the relative ratio of Kavango speakers in Kavango declined.

To summarize, the language data during the Angolian war are not reliably feasible to correctly estimate the migration, especially the inner regional migration. Without a proper quantification of the „Angolian factor“ and the lack of historical (<1990) data about the fertility/mortality rate and the interregional migration, it is hard to exactly quantify the Kavango born population.

The reserve land might not have been influenced a lot by the Angolian influx because those concentrated mainly in Rundu and (overproportionally) the densly populated areas where the refugees find help from their Namibian relatives.

Distances to waterpoints, roads and cleared land

The average nearest distance to a major road alone is not too much helpful. On the one hand, multicollinearity is an issue for roads, on the other hand do household differ in terms of welfare, marketing orientation and transport facilities and those factors might influence the weight of the factor „distance to roads“.

More interesting is in which relation the wish to be close to a road is to the abundance of a suitable soil. There are examples where households position are close to the B8, but no larger fields are visible in the direct neighborhood. The households fields are 3-5km far away.

Temporarily, the increase in the average road distance in 2011 compared with 1996 can be explained by the extraordinary growth of settlements in remote areas where few roads exists. That includes especially the households on farms. Before 1996, the new settlers seem to focus on „filling up“ the Kavango terrace ribbon, the omuramba valleys and the Rundu-Grootfontein road with rural, cropping based households. Those settlement areas did reach already densities of over 40people per sqkm. New settlers are therefore more and more forced to move away from those major roads.

The same is valid for the waterpoints. Here, the average is more robust, following the long term trend to narrower distances. Waterpoints can have in their very near area not as much events. Surrounding HH’s have a space demand hence there is maximum number of HH directly next to a household.

The trend in the distances HH to cleared land (crop field) is clearly increasing. However, decisive for the new settlers are not the regionwide distances which are biased by the densely populated river ribbon, but the ones in the hinterland. This calculation need to be done separately to see whether settlers do cropping right where they are or if they are willing to walk long distances and which role that play against the road and waterpoint distances.

Land demand

The methodology to affiliate pieces of cleared land to a household has constraints.

One issue is that the household size data, the main factor of the households land demand, seems to vary strongly and is not available on household level. The assumed household size is derived from the average household size on enumeration level. An enumration area aggregates approx. 80-100 households of an area which is not delineated by settlement or crop suitability pattern, but by enumeration administrative aspects. Therefore it often cuts settlements for example in the middle along a road or aggregates households in and outside commonage land. This results in wrong numbers of people per village and consequently in a distorted ratio cleared land/household.

Another problem deals with identifying a village boundary by using Thiessen polygons is very much dependend on the spatial scatter of settlement and crop land. It works best for village types where there is an ideal village centre point and both the household density as well as the crop lands decreases radially from this point. Then, the household's Thiessen boundaries, dissolved by village, reflects very well the plausibel village boundary. But for household patterns where single, „outlying" households are located somewhere in the middle of two villages, these single households shift the village boundary over crop fields which more plausibly belong to the neighboring village.

The spatial patterns in the household distribution can be grouped as follows:

a) there are the longish villages with households concentrated along roads and omurambas (land regions „omurambas", „Northern sandplains" on river terraces)

b) there are scattered households in the dune regions („Western stabilised dunes"). Mostly, the households belong together if they share the same or neighboring dune valley. The distance does not steer the village affiliation predominantly. Thiessen polygons do not reflect this. Furthermore these are the villages with high distances between households and crop fields. Additionally, the small number of households per village (sometimes 3 only), it lacks the leveling effect of averaging and so wrong assumptions on the household size weigh even more.

c) radially centred villages with no or slight dune shaped crop land patterns (mainly land regions „Northern sandplains" and „eastern paleo drainage")

d) settlements that are close to farms that, despite private, allow surrounding settlers to cultivate on their land.

A third constraints deals with the fact that the higher the population density, the more likely does the proportion of households rise which do not cultivate themselves but buy their staple food. If this is done locally (= in the same village) then this behaviour is neutral to the land demand per village. But where food is bought masswise non-locally and where suitable crop land on communal land is scarce already, the ratio cleared land/household sinks drastically. This is mostly the case near the trunk roads but also in smaller villages where a critical proportion of village inhabitants assumably got a nearby job (or crop field) in a neigboring farm or irrigation scheme (Hamwiyi, Mururani, Gcwasa, Shitemo, Ndonga Linena, Muroro) or the tourism industry (Kamutjonga, Bagani).

A similar, inverted constraint concerns the fact that pupils especially from remote small villages and outlying households are often sent to towns for secondary school. While they are counted as village inhabitants their (crop) land demand is realized somewhere else. This effect is minor and disproportional because children have a smaller land demand than adults.

A fifth constraint is that the mobility in the remote areas is still high and even necessary where suitable land is scarce and not radially but longish distributed. In these areas, one can find cleared land far away from any household (even with boreholes) and vice versa. People practice shifting cultivation on a short, but decisive distance. While they have already moved, their previous fields are still visible in the orthophoto.

Constraint six is about the fact that in densly populated areas there is little space to shift the crop field once it needs a fallow period. It is likely that farmers continue to cultivate the same land while people in the remote areas just clear a new area which increases the total cleared land in the village.

Summary and outlook

The study dealt with the question „When will the land reserves in Kavango Region be depleted?“. Disregarding the fact that the answer is always scenario based, the analysis revealed some trends and settlement behaviours.

The main driver for land demand, the population, made a transition period in the last decades and is now „back“ to 1% annual growth rate. This shifts the overall land depletion under freezing the current circumstances theoretically to centuries in the future and makes this study obsolete. An annual growth rate of 2% would still give around 100 years to depletion, 3% up to the year 2083.

The study could not identify a strong tendency in the use of soils of different suitabilities for cropping. That could have been an approach to exclude land for settlement. If this could be done, hugh amounts of land must be substracted and show the actual scarcity of suitable land.

It was further found that the land demand will likely be the population number times 1.15ha. This ratio, found as suprisingly stable through the decades, might decrease in the future the more especially the urban population moves away from consuming traditional food. The crop fields expansion comes more and more from the reserve lands, but higher crop field sizes are necessary there to produce under a higher risk of crop failure. A special preference for a specific land region/vegetation zone is not as decisive as a close distance to the road.

It was found that waterpoints are neither currently nor in the foreseeable future the major limitation for settlement if one accepts a distance to a waterpoint of max. 5km. Planning carefully the areas supplied with borehole water will open new settlement opportunities and can play an important role in the enhancing the livelihood of currently landless people. The produced maps show potential areas for it in every Tribal area, but the highest demand in terms of need and usefulness seems to be in the Mpungu Constituency (very western part of Kavango), specifically in the area close to the new trunk road to Tsumeb. One can find here good circumstances (clayish soils that reduce the risk of crop failure, proper road connection) but not yet enough borehole coverage. It is unlikely that the most southern remote areas will attract many people since the risk of crop farming is high and the space for cattle grazing decreasing at the same time. Here, other land use options and income opportunities in connection with the many neighboring cattle farms can be considered.

Literature

- Andersson, L., Wilk, J., Todd, M.C., Hughes, D.A., Earle, A., Kniveton, D., Layberry, R., Savenije, H.H.G., 2006. Impact of climate change and development scenarios on flow patterns in the Okavango River. Journal of Hydrology 331, 43–57. doi:10.1016/j.jhydrol.2006.04.039
- A preliminary survey of the natural environment and the agricultural resources of the Okavangoland, 1967. . Pretoria.
- Ashley, C., 1994. Population growth and renewable resource management: the challenge of sustaining people and the environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism.
- Birmingham, David B., 1966. Trade and Conflict in Angola. Oxford.
- Bock, Bernadette, Falk, Thomas, Kirk, Michael, 2008. Rural water supply in Namibia: effects on natural resource management and livelihoods, in: XII World Congress of Rural Sociology, Goyang, Korea, 6-11 July 2008. Philipps-University of Marburg.
- Central Bureau of Statistics, 1995. 1991 population and housing census: basic analysis with highlights. Republic of Namibia, Central Statistics Office, National Planning Commission, Windhoek.
- Central Bureau of Statistics, 2003. Report on the Annual Agricultural Surveys 1996-2003 - Basic Analysis of communal agriculture.
- Central Bureau of Statistics, 2010. An atlas of Namibia’s population: monitoring and understanding its characteristics. Central Bureau of Statistics, Windhoek, Windhoek.
- Eckl, Andreas, 2004. Konfrontation und Kooperation am Kavango (Nord-Namibia) von 1891 bis 1921. Köln, Köln.
- Hentze, K., 2011. Die Bedeutung von Landnutzungsstrategien im Rahmen von

Community Based Natural Resource Management – Eine sozialökologische Analyse in der Kavango-Region, Namibia.

- Hilferink, M., Rietveld, P., Institute, T., 1998. Land Use Scanner: An Integrated GIS Based Model for Long Term Projections of Land Use in Urban and Rural Areas, Discussion paper. Tinbergen Institute.
- Hines, Chris, 1998. The Biophysical and Human Environment (Namibian Sector), Okavango River Basin Preparatory Assessment Study. Windhoek.
- Hoffman, M.T., Jürgens, N., Schmiedel, U., Metzing, D., 2010. Biodiversity in Southern Africa: BIOTA; [BIOLOG] CD-ROM CD-ROM.
- Jonathan Barnes, Dorothy Wamunyima, 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module - Socio-Economics.
- Jones, Brian, 2001. Socio Ecological survey report for the Okavango basin.
- Kaiser, T., 2013. Conceptual design on systematic sub regional land use planning.
- National Soil Survey, 1999, Kavango River Terraces 1:100 000, 1999.
- Koomen, E., Borsboom van Beurden, J.A.M., 2011. Land-use modelling in planning practice. Springer, Dordrecht; New York.
- Koomen, E., Koekoek, A., Dijk, E., 2011. Simulating Land-use Change in a Regional Planning Context. Applied Spatial Analysis and Policy 4, 223–247. doi:10.1007/s12061-010-9053-5
- Koomen, E., Rietveld, P., Nijs, T., 2008. Modelling land-use change for spatial planning support. The Annals of Regional Science 42, 1–10. doi:10.1007/s00168-007-0155-1
- Low, A., Kamwi, K., 1998. Estimating relative magnitudes of components of farm production in semi-subistence farming: the case of Kavango. Agrekon 37, 483–494. doi:10.1080/03031853.1998.9523523
- Mendelsohn, 2009. Land Use in Kavango: Past, Present and Future, The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports. OKACOM, Maun.
- Mendelsohn, J., 2001. A Preliminary Profile of the Kavango Region in Namibia.
- Mendelsohn, J., 2004. Okavango River: the flow of a lifeline, 1st ed. ed. Struik, Cape Town.
- Mendelsohn, J., Jarvis, A., Roberts, C., Robertson, T., 2000. Atlas of Namibia. A Portrait of the Land and its People. - Cape Town (David Philip Publishers; New Africa Books (Pty) Ltd). Zoosystematics and Evolution 80, 129–129. doi:10.1002/mmnz.20040800111
- Mendelsohn, J.M., 2003. Sand and water: a profile of the Kavango region. Struik Publishers ; RAISON, Cape Town : Windhoek, Namibia.
- Namibia Nature Foundation (Ed.), 2010. Land use planning framework for the Kavango Region of Namibia within the Okavango River Basin. Windhoek.
- Namibia Statistics Agency, 2011. Namibia 2011 population and housing census preliminary results. National Planning Commission, Windhoek.
- Namibia Statistics Agency, 2012. Namibia 2011 Population and Housing - Census Indicators, Namibia 2011 Population and Housing Census. Namibia Statistics Agency, Windhoek.
- Namibia Statistics Agency, 2013a. Namibia 2011 Population and Housing - Census Main Report. Namibia Statistics Agency.
- Namibia Statistics Agency, 2013b. Namibia 2011 - Population and Housing Census -

Regional Tables. Namibia Statistics Agency, Windhoek.

- Namibia Statistics Agency, n.d. Namibia 2011 Census Atlas. Namibia Statistics Agency, Windhoek.
- Page, D., 1980. ’N Raamwerk vir Ontwikkeling van Kavango. University of Stellenbosch Institute for Planning Research, Stellenbosch.
- Permanent Okavango River Basin Water Commission, 2011. Cubango-Okavango river basin transboundary diagnostic analysis. Okacom, Maun, Botswana.
- Pröpper, M., Vollan, B., 2013. Beyond Awareness and Self-Governance: Approaching Kavango Timber Users’ Real-Life Choices. Land 2, 392–418. doi:10.3390/land2030392
- Republic of Namibia, 2003. Communal Land Reform Act.
- Ritsema van Eck, J., Koomen, E., 2008. Characterising urban concentration and land-use diversity in simulations of future land use. The Annals of Regional Science 42, 123–140. doi:10.1007/s00168-007-0141-7
- Schuh, Christian, Werner, Wolfgang, 2006. Analysis of Small-Scale Commercial Farming Units, in: GTZ (Ed.), Economics of Land Use. GTZ, Windhoek, pp. 20–44.
- Seiner, Franz, 1912. Wie steht es am Okavango? Deutsche Kolonialzeitung 269–271.
- Simmonds, E.B., 1998. Soils of the Okavango River Basin, Okavango River Basin Preparatory Assessment Study. OKACOM, Windhoek.
- Simmonds, E.B., 2000. Natural Resource Mapping of the Kavango Region - Specialist Report 2 - soils of the Kavango Region. Ministry of Environment and Tourism, Republic of Namibia.
- Simmonds, E.B., Burke, A., 2001. Natural Resource Mapping of the Kavango Region - Final Report. Ministry of Environment and Tourism, Republic of Namibia, Windhoek.
- South-West-Africa Administration Water affairs branch, 1967. Report on a Reconnaissance Soil Survey of Okavangoland with particular Reference to the Riparian Land.
- The Namibian: The Red Line And The Goose, 2013-09-10. [online] Available at:.

  http://www.namibian.com.na/

- Van der Merwe, Johannes Hermanus, 1983. National Atlas of South West Africa. University of Stellenbosch.
- Volkmann, Richard, n.d. Bericht über eine Reise nach Andara am Okawango, 1 October 1903. pp. 92–95.

Annex: Preparations, tools and data management

The folder structure follows a simple principle: the first level of folders is steered by the most recognizable data detail: the data format. In the folder „jpg“ all pictures of this type can be found. Few exceptions exists regarding the shapefile-dbf's, the geodatabases (some File Geodatabases .gdb exist in folder „mdb“).

The second level is ruled by the scale of the spatial extent of the data (for example „A02_National“), the third level gives the name of the spatial extent itself (for example „Kavango“). The different themes and subthemes build the following levels.

For populating the geodatabases, ArcGIS geoprocessing models („upload“) where used. The major Geodatabase which incorporate the models are four:

1. Kavango_raster.gdb
2. Kavango Integrated Regional Land Use.gdb
3. Kavango population.mdb
4. Waterpoints.mdb

Annex: Locating households based on aerial photographs

Household locations, if not in the given data, can be acquired through an interpretation of the aerial photographs of 2007, 2011 and additionally the googleEarth images of 2013 in combination to verify in case of local reductions in the orthophoto's quality.

All the five Kavango tribes seem to have traditions in shaping a household building area. As a result, most of them look very similar in the orthophoto, which make it easier to identify.

Identifying criteria are:

- The „typical“ household uses a quadrangle ground plan of 0.065ha in average and is surrounded by a fence of wooden poles and/or thatch grass longer than at least 2 meters. Their shadow is in most cases visible since its ground extent meets or exceeds the pixel size of 1 meter.
- The huts inside the household plot appear in the photo as black or yellowish (fresh roof thatch grass) rectangular dots of 6-15 pixels.

- If the household lies in a distance to the main crop field, it might be surrounded by a cleared area of varying sizes, in average estimationswise around 5-10 times the ground plot size.
- Furthermore, a rectangular or round kraal can sometimes be found close to the household, and a neighboring water place for the cattle.
- Of course the presence of GPS points of a census also documents a household. However, this survey-GPS-point is often to be found not exactly inside the household plot but before. In seldom cases it can even be found on a crop field and the correct matching to a suitable near household plot is difficult.
- GPS points of the 2011census indicate households of new settlers, if their household is not yet visible in the 2007 picture.

Seldomly, given-up households can be identied. This identification is based on a) observing missing household fences and b) context information, that gives a hint this plot is not any more in use (vegetation growth, undistinct or disappeared footpath and cattletracks, remoteness of the location, brown color of the kraal disappeared, and the like).

Annex: curation of waterpoint data

1. The Identificator of the MAWF2010 (the WWnumber) data were taken as valid throughout. The proper standard code had first to be created using the schema WW+6 number digits, empty ones filled after WW with „0“, for example „WW004013“ instead of „WW 4013“.

2. A query was run on equal ID's first to link the boreholes that have numbers.

3. Using the geoprocessing model „20NearestBH“ of the Waterpoints geodatabase, nearest features inside 200m got the number of the nearest borehole via a join of the near table. 200 m were considered to be the maximum placement shift caused either by mislocating using GPS, doing mapping or using the wrong projection (Schwarzeck Datum).

4. Verification of the location in the Orthophoto showed: Especially MAWF data are unfortunately very much misplaced for unknown and obviously varying reasons. They are hardly to accompany with the other data if there is not a common WW-ID. LuxDev. data are best located since they are GPS measurements in the field. Whenever a duplicate of WW-number were created, the LuxDev. Position were taken and all other got a „1“ in the new field „duplicate“ (107 times).

5. A spatial query resulted in populating the new field „outside Kavango“ with „1“ for „yes“ (13 times).

6. MAWF has got drilling date data (479 out of 834 are virtually unknown („01.01.1900“/“1905“), while the two other sources have only implicit ones. Using another query with laboratory data, approx. 80 dates could be transfered from the lab's records which show at least that the borehole existed at that time (means those ones could have been drilled potentially far earlier because not every new drilling is accompanied by a lab' analysis and an analysis can also be done years later).

7. In some cases the drilling year of the borehole have to be derived/estimated if enough criteria for it are present such as: statements in the 2000/2001 conducted LuxDev. Survey like „old infrastructure“, etc..

Annex: Identifying stages of crop fields

The stage „in use“ of the class „cleared land“ has got fuzzy borders to „fallow“. There are indicators that make it likely or even evident that the land is currently, that means in the coming season, in use. Because at the point of time, when the pictures are taken (end of Oct.-mid of November), the first rains might not have fallen, the visibility of the soil is never better (vegetation dried out after the dry season and partially opened by bushfires) and most important, people start preparing their fields (see crop calendar). In the photograph, these areas appear as a flat, ideally textureless surface. There can be even lengthy stripe patterns visible, especially on clayish soils.

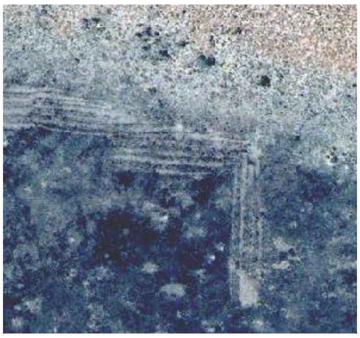


Figure 17 Screenshot: well visible ploughing rows in clayish soil

These are ploughing rows. The appearance of trees doesn't matter since larger trees, often visible by a thin dark shade, remain often inside a crop field. The more the texture turns into a spottled area the more this field is moving towards a fallow stage. When this stage is reached depends largely on the context:

1. the near uncleared context indicate the potential vegetation and so to a certain degree the growth potential. Included in this is also the abundance of bushfires. In the late dry season they occur naturally, but fire can also help clearing the field. Hence some farmer use it for that purpose. Thats why a black color could indicate that there was a vegetation cover easy inflamable (dense grass or shrub cover like on fallow land) (see figure 18).
2. shape and distinction of it: crop fields have often a rectangular shape. The shape becomes even better visible the more the removed bushes are deposited along the border. That makes even late fallows or given-up lands still visibel.
3. landmarks like paths, big trees (often used as cornerpoints of crop fields), fences, position of dwellings, village sites, given-up structures in the neighborhood

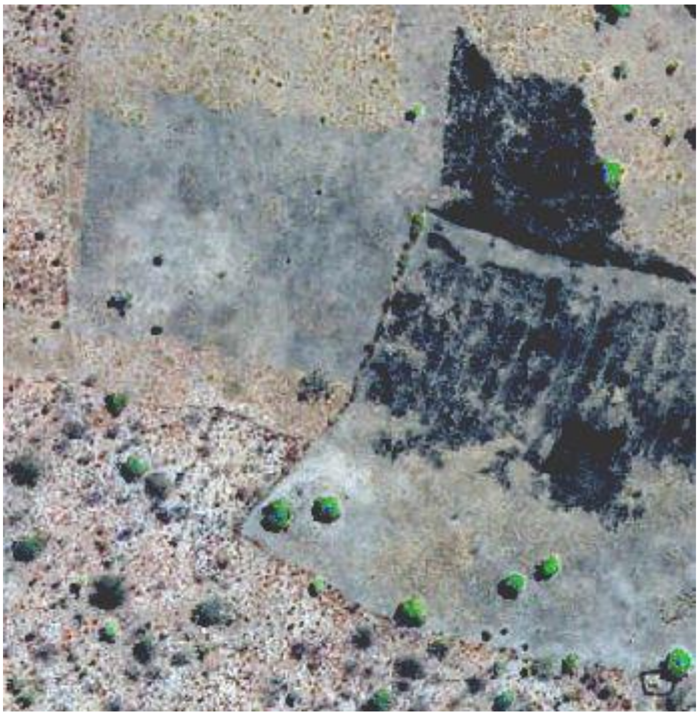


Figure 18 screenshot of remote crop field features: burnt areas, tree landmarks, temporal worker hut

4. remoteness of the area and likelihood to crop. There are very few cases of crop fields far away from any track, village or waterpoint. They are likely temporal ones and will hardly be maintained if the soil conditions are also unfavorable. In remote areas it can also happen that single huts or a small kraal is constructed for temporal residence of the field worker.