RESEARCH ARTICLE

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Examining the Drivers of Land Use /Land Cover Change: A Case of the Kavango River Basin and Its Immediate Environments in Namibia

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ABSTRACT

Understanding the drivers of land cover changes (LULCC) is very crucial for the development of management strategies as well as policy improvement and the sustenance of ecosystem services. This is crucial in preventing further degradation and proper planning of sustainable natural resources management. In this study, an attempt has been made to identify the drivers of LULCC in the Kavango East and West Regions of Namibia, from 1990 to 2018. Remotely Sensed Images were used to compute indices. Socio-economic surveys were conducted using structured interviews to share the past experiences of the local people, some key informants, and other stakeholders in the region. A combination of this information together with the Remote Sensing data was then used to derive the drivers of LULCC in the study area. Results of the study showed that changes were triggered by the interplay of more than five drivers identified and related to the environment, socio-economic, and other technical factors. In particular, the establishment and expansions of agricultural land, settlement, urbanization, and lumbering (for timber and crafting) were viewed by local people as the leading cause of deforestation. Other factors such as drought, flooding, and lumbering (for construction and firewood) cannot be undermined. Future studies will be targeted at assessing these drivers to evaluate their impacts on achieving sustainable development in the Kavango River Basin of Namibia and its immediate environments.

Keywords: Drivers, Land-Use, Land Cover, Kavango East, Kavango West, Namibia.

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I. Introduction

Land use/land cover change (LULCC) studies have become a very important tool for managing natural resources within our environment [1]. This comes as a result of severe pressure being exerted on the land due to increased human activities. Namibia as part of the sub-Saharan African Countries experiences immense LULCC. The drivers of LULCC can be categorized into two groups mainly proximate and underlying. Proximate involves direct changes that are caused by human beings such as individual farmers. These can be brought about by agricultural expansion, biophysical variables, wood extraction, and infrastructure extensions [2]. Underlying factors come as a result of interactions between socio-economic, policies, political and demographic factors [3], [4].

In Ethiopia, the main drivers of LULCC were identified to be both proximate and underlying causes [5]. Population increase has been put at the center as one of the driving forces behind these changes. These may be a result of the increase in population during the past four decades. [6]. This has further aggravated deforestation, which in turn leads to the replacement of natural vegetation with crops [7]. Previous studies documented that the drivers of LULCC in Sub-saharan countries are divided into five categories. They include long-term natural changes in climatic conditions, geomorphologic and ecological processes (such as soil erosion), human-induced alterations of vegetation cover and landscapes (such as deforestation and land degradation), inter-annual climatic variability (such as frequent droughts and floods), and human-induced climatic changes [8]. Understanding these drivers is very important for the development of management strategies and policies that help to prevent the further decline of natural resources [9].

II. The Study Area

The Kavango East and West Regions of Namibia are one of the driest parts of the country, with average annual rainfall recorded below 600mm [10] creating a semi-arid climate [11]. Precipitation differs by 148 mm/month between the driest and wettest months, while temperature varies during the year by 10°C. The average temperature is recorded at 22.1°C per annum, with winter seasons covering the months of May to August and extreme temperatures in summer [10]. This makes the region very vulnerable to drought and other attendant environmental issues. However,

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the drivers of LULCC remain controversial as various factors such as climate change continue to play a role in shaping the major processes that occur in our ecosystem. Therefore, the main objective of this article is to analyze and present the underlying drivers of LULCC in the Kavango East and Kavango West Regions of Namibia. Namibia is located in the Southwest of Africa and is bounded by Angola, Zambia, Botswana, Zimbabwe, and South Africa. Botswana, Namibia, and Angola share water rights within the Kavango River basin.

III. The Kavango River Basin

The Kavango River has its origins in Angola at the confluence of the Cuito and Cubango rivers. Records show that the Kavango basin within Angola remains underutilization [12]. Hence, this part of the Kavango River in Angola is referred to as "the sleeping giant" [13]. The length of the river in total is estimated to be 1860km with a total area of 170 000 km² [11]. The Kavango region on the Namibia side is subdivided into two sub-regions: Kavango East and Kavango West located in the North-Eastern part of Namibia. The two areas have a total of 48 742 km² [14]. The area is topographically flat with a maximum of 200 m elevation across the whole area. Most of the people who are settled along the Kavango River depend on natural resources for their daily lives and activities. This has led to the destruction of about 95% of the natural vegetation along the river and replaced with field crops, settlements, or green schemes [15]. This study however will help us to understand the land use/land cover conversions that already took place in the study area.

IV. Methods

A combination of Remote sensing techniques coupled with field observations and socio-economic surveys was used in the study.

A. Socio-Economic Survey

LULCC occurs as a consequence of the interaction between human and physical activities of the ecosystem concerned. Therefore, it has led to various types of LULCC drivers.

These include physical factors, socioeconomic factors, neighborhood factors as well as land-use policies [4]. Consequently, this study considered several factors during data collection on the drivers of LULCC. It was the interest of the study to interview matured (as stipulated by the Namibian constitution) as well as experienced people who lived there for a longer time as adopted from [16]. Data was collected from various households in the villages through face-to-face interviews and discussions. The interviews were guided by a questionnaire. Most of the villages that were interviewed were located along the river with a few communities some distance from the river. Five villages were chosen from each constituency. Furthermore, five households from each village in Kavango East and West regions were selected at random and the questionnaire was used to interview the owners of the house. In cases where the owner of the house was not available, the spouse was interviewed or the present adult among the household members. Other household members were not excluded from interviews if they are willing to participate and provide additional information. Key informants were interviewed from various organizations to make a representative of both private, and government institutions. Other stakeholders included in the study including a few traditional leaders and commercial farmers were also interviewed. However, it should be noted that the study recorded low responses from this group as many of them maintained that they were busy and would not grant an interview. Other institutions in the study area such as the Ministry of Environment and Tourism as well as the Ministry of Agriculture Water and Forestry also took part in the interview process. The villages that were visited were Mururani, Gove, Utokota, Katimba, Mbeyo, Simone, Kapako, Sinzogoro, Shiguru, Shikenge, Ndonga Linena, Makandu, Siya, Halili, Mupapama, Muroro, Ngone, Kayengona, Katwitwi, Siudiva, Siyena, and Ncamagoro. During the interviews, respondents identified the major drivers of LULCC and the underlying causes of such changes. To quantify the results obtained from interviews and focal group discussions, the remote sensing indices were computed from Landsat images as well as visual image interpretation. However, it was not easy to identify some of the changes that occurred during the past years, as the interviewees could not remember exactly everything that changed during the past years. Therefore, for the 2018 results, it was possible to match what was happening on the ground with the result from image interpretations. This was made possible by carrying out the fieldwork closer to the image acquisition date.

B. Remote Sensing Indices

1) Normalized Difference Water Index (NDWI)

Indices are part of modeling computed from mathematical formulas using various brands of the acquired satellite imagery [17]. For this study, the NDWI was computed to mask out water-stressed areas. Based on previous studies [18], [19] the NDWI has been successfully used as compared to other indices. Besides it being originally developed for Landsat MSS, the index has been used successfully to map out and measure open water in water bodies with other satellite sensors. It is computed by the combination of addition, subtraction, and division of the green (G) and near-infrared (NIR) bands of the electromagnetic spectrum.

NDWI = (Band 2-Band 4)/ (Band 2+Band 4),

Band 2= green

Band 4= the NIR wavelength of the electromagnetic spectrum [19].

Originally proposed by Gao (1996) in [20], the post-index computation results have values ranging from -1 to +1, whereby +1 values represent water-stressed areas and -1 areas with normal water levels. For this study, Boolean images with values ranging from 0 to 1 were created, which indicates water-stressed areas.

2) Normalized Difference Drought Index (Nddi)

To quantify the past and the current drought in the study area, it was deemed very important to compute the drought index. The decision came after finding out that there has been low rainfall averaged at 600mm/annum in the study

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area for the period of investigation. Furthermore, the results of the socio-economic study revealed that there is a water shortage within the study area. The Normalised Difference Drought Index (NDDI) has been recently developed to monitor drought in prone areas and was originally proposed by [21].

NDDI = NDVI – NDWI / NDVI + NDWI

NDVI = (NIR - RED) / (NIR + RED).

The results of the NDVI classified image have values ranging from -1 to 1, with 0-value representing no vegetation, negative values (-1 to -0.1) representing water–stressed vegetation, and positive values (0.1 to 1) indicating healthy vegetation. It is for these reasons that the NDVI is part of the NDDI, which is a surrogate for water shortage.

V. Results And Discussions

A. Proximate Drivers of LULCC

Research on LULCC for Kavango East and West regions has been poorly documented. Scarce literature is found in this particular research area. [11] assessed urban growth in rural land use transformations of a cross-border situation, involving Southern Angola and Northern Namibia on the Okavango River basin. Their study identified several factors such as deforestation and human-wildlife conflict to be posing major threats to the ecosystem. [22], carried out a study on land-use change and nutrient water quality of the Kavango River. The results show that land-use changes in the two Kavango regions have low impacts on the water quality of the Okavango River. However, LULCC studies have been documented in Namibia for other regions such as the Zambezi, which provide relevant information on how the current study should be conducted. This is documented in the study carried out by [23], where the relationship between LULCC in communal and commercial areas of the Zambezi region has been established. The sub-sections that follow describe proximate LULCC drivers in detail.

1) Agriculture

The demand for food has led to the expansion of croplands at the cost of natural vegetation and grasslands [24]. Therefore, it puts more pressure on the land as both livestock and human population increase [7]. Besides being a source of food, the establishment of agricultural areas has its drawbacks when it comes to LULCC. It is well-known that when one establishes a crop field, natural vegetation will be destroyed to pave way for cultivation. During the period of observation, the study area experienced a huge increment in crop fields, especially green scheme projects. [25] noted a similar observation in Western Ethiopia, where they found agriculture to be the main driver of LULCC. Fig. 1 to follow is a Landsat subset image for the year 1990. It is apparent from the image that agricultural expansion has not yet taken place in the area concerned. In Fig. 2, it is clear that agricultural expansion has taken its course and a display of a green scheme project can be seen in the image, which was not there before. It is notable from the figure that agricultural areas have expanded during the period of observation. It was also noted that deep Kalahari sands with low water retention and low nutrient quantity dominate the two regions. Consequently, many of the farmers here change crop patterns or turn to shifting cultivation as current lands are not fertile to support crops. This practice over time leads to severe environmental degradation as the natural vegetation is being destroyed and replaced with fields for cultivation. Similarly, the land which was formerly used for cultivation becomes abandoned [26] hence resulting in a change in land use/land cover. It should be noted that the results from interviews revealed that Kavango West Region is more dominated by farming land as compared to Kavango East. The latter has more protected areas and community forest areas. In a study by [27], agricultural expansion was found to be one of the drivers of LULCC, leading to the loss of natural vegetation in their study area. This was attributed to the fact that agriculture was the main center of attraction for casual jobs in the area. Increased investments by commercial farmers are also a scenario, which applies to Kavango East and West regions. Furthermore, a study by [28] revealed that intensive commercial horticulture has negative impacts on land use systems, especially in agricultural-dominated areas. To mention a few, uneven clustering of large-scale commercial farms, clearing of marginal lands, over-extraction of irrigation water, and clearing of natural vegetation. These were some of the many activities that were found to have negative impacts on sustainable management and utilization of environmental resources in Kenya watersheds [28].

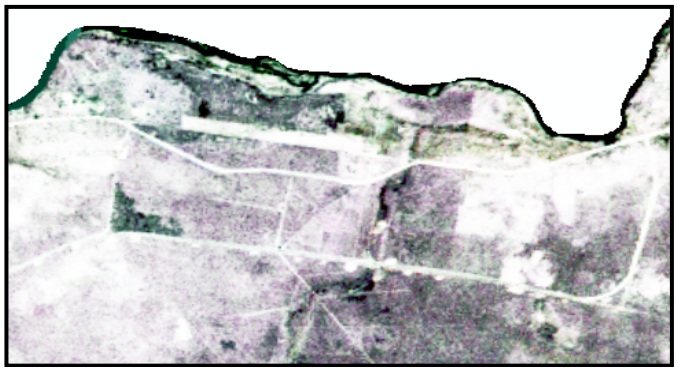

Fig. 1. A subset image of the study area without agricultural expansions in 1990.

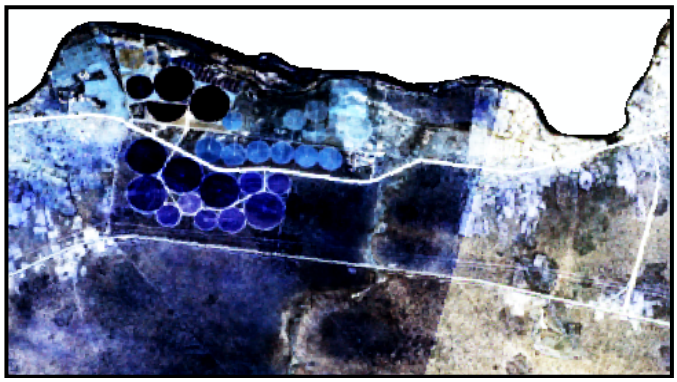

Fig. 2. An image subset of a study area showing agricultural expansions during 2018.

2) Fires

Forest fires are one of the biggest problems in Namibia's land resources and the study area is not an exception. Approximately 34% of the Kavango region burns on an annual basis [29]. The main reasons that people burn forests are, to encourage more growth for the grass, thereby providing enough food for livestock as well as clearing land

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for cultivation purposes. Unfortunately, these fires get out of hand due to the wind, become uncontrollable, and burn larger areas than expected. Some of the areas within the study area are burned every 3 years, causing huge damage to vegetation, loss of nutrients in the soil, as well as soil fertility. [30] reported that between 1989 to 2011 about 27-51% of the Kavango region experience fires every year which the study observes leads to a decrease in woodland areas.

3) Human settlement and urbanisation

Urbanization can be referred to as the physical growth of the urban area, which is brought up by the migration of people from rural areas to towns and cities [31]. Throughout the world, urbanization is one of the major factors that contribute to land use dynamics [1]. This happens when human beings move from rural areas to towns and cities in search of a better life such as employment opportunities. The process of reversing the situation such as moving from towns and cities back to rural areas is almost impossible. Hence, the population growth in urban areas emanates as a result. This is so because people that flocked to towns go back to rural areas only for visiting, holidays, or special events such as weddings or burials. This means that they only stay there for a limited time and go back to towns for their jobs. The Okavango River basin has a complex socio-ecological system with a variety of physiographic characteristics on the livelihood of the people [32]. Most of the people are settled along the river on the Namibian side of the Kavango region where they form part of the rural communities. Approximately 68% of the people in the Kavango region live within 10 kilometers of the Kavango River. These people rely on small-scale farming such as livestock keeping and generate income from natural resources such as wood (for timber, fuel), wild fruits, and thatching grass. Although the region is regarded as a green basket of the country, its people are one of the poorest. [32], established that the savanna ecosystems in Northern Namibia and Southern Angola were converted into arable land for cultivation between 1990 and 2010. On the Namibian side, the expansion of Rundu town was recorded and the establishment of new larger irrigation schemes was realized. [33] noted cleared land from human activities in the region. The most dominant land conversion is woodland savanna into arable land for the cultivation of crops [32]. This resulted in a total area of 4602km² being converted. The region also experienced a 90% increase in population between 1991 to 2011 [34]. Furthermore, increased competition for grazing land was noted whereby wealthier people or farmers tend to fence off large areas as compared to other farmers [30].

4) Settlement and urbanization

During fieldwork, it was noticed that human settlement in the two Kavango regions is widespread. This is evident in the expansion of Rundu town and the establishment of new towns such as Nkurenkuru. Furthermore, some of the people settle deep in the forest far from society in search for fertile lands to support farming. They consider this a better option compared to remaining in their old farms where they would have to find ways to apply manure yearly to their farms which is characterized with sandy soils that are infertile. In addition, not everyone has the ability to purchase the required fertilizers. Also, livestock grazing becomes difficult in crowded settlements. To curb such situations, people are driven to settle in other areas together with their livestock (those who have), for better farming and improved grazing opportunities. However, not everyone would want to live in the middle of the forest far from schools, clinics, shops, and other relevant infrastructures. The implication of these is that during good years of rainfall, people are settling in the villages, as most of the required resources were available. However, during the dry season and poor rainfall years, people settled where the forest is dense, and they establish cattle posts for improved farming as well as forest resources benefits. Soils are better in dense forests which also provide rich grazing areas for livestock. They often return to their original settlements when the situation becomes better. Soils are better in dense forests which also provide rich grazing areas for livestock. The conversion of natural forests to grazing areas, human settlements, and urbanization contribute to environmental problems like loss of biodiversity, deforestation, and land degradation [35].

B. Underlying Causes and Drivers of Land Use/Land Cover Change (LULCC)

1) Flooding

Rivers store water and regulate water flow, but when the rain is too much flood occurs and water regulation becomes very less [36]. Amongst all other natural disasters, the occurrence of flooding is frequent especially when there are open water bodies in the nearby areas. Therefore, it is very important to consider them since they play a role in land use/land cover planning of affected areas. The occurrence of flooding usually destroys properties as well as planning and management for future purposes such as mitigation measures, which are required. Furthermore, areas that are closer to the rivers get flooded during heavy rainfall. To mention a few, the Awash River Basin of Ethiopia gets flooded frequently and flooding was found to be one of the main drivers of LULCC in the area [37].

Fig. 3. The carcass of an ox lies on the ground at one of the settlements in 2016, Source: “The Namibian” Newspaper.

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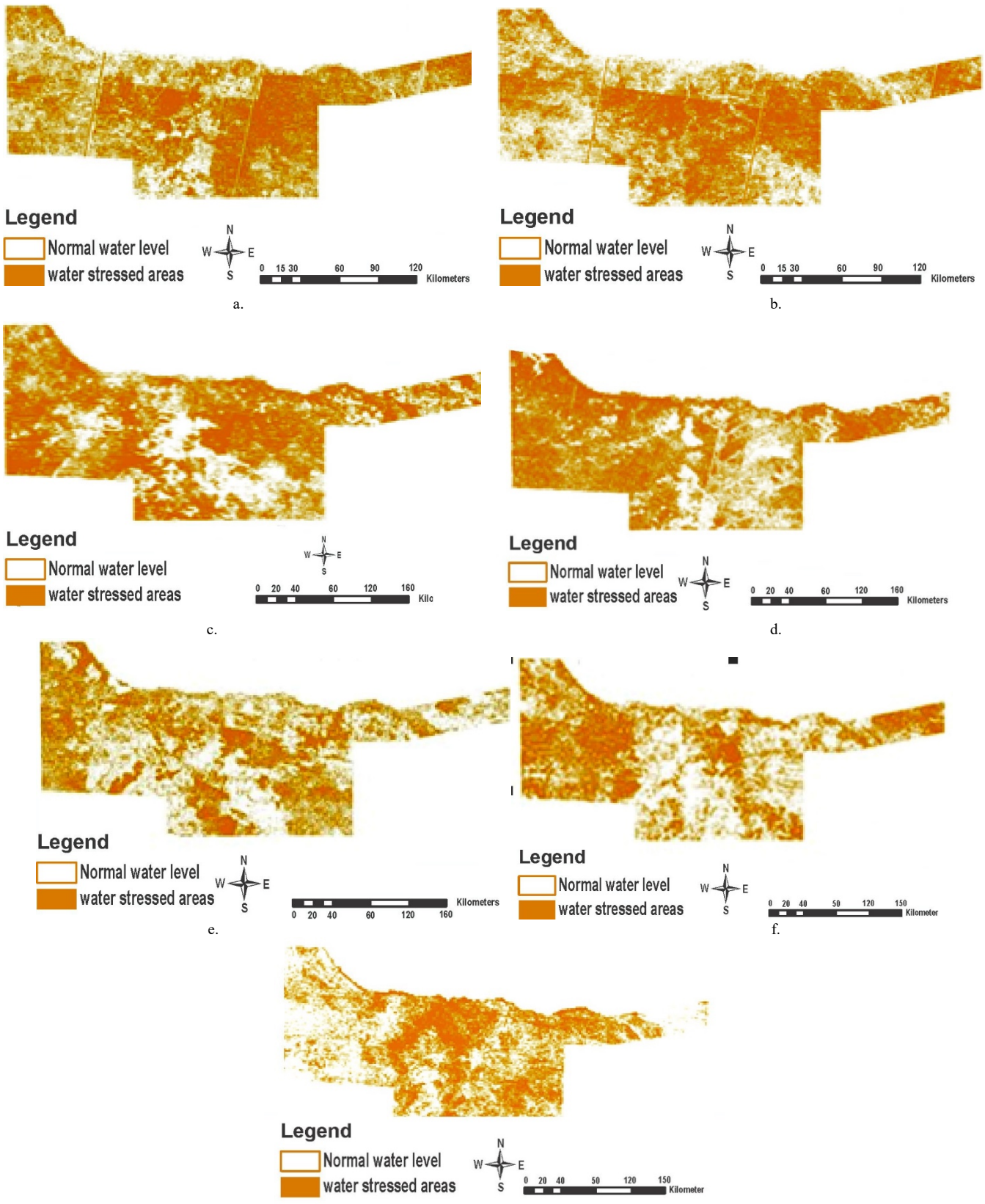

Fig. 4. NDWI images depicting water-stressed areas and areas with normal water levels for the years 1990-2018: a) Water-stressed areas and Normal water areas between 1990-1994; b) Water-stressed areas and Normal water areas between 1995-1998; c) Water-stressed areas and Normal water areas between 1999-2002; d) Water-stressed areas and Normal water areas between 2003-2006; e) Water-stressed areas and Normal water areas between 2007-2010; f) Water-stressed areas and Normal water areas between 2011-2014; g) Water-stressed areas and Normal water areas between 2015-2018.

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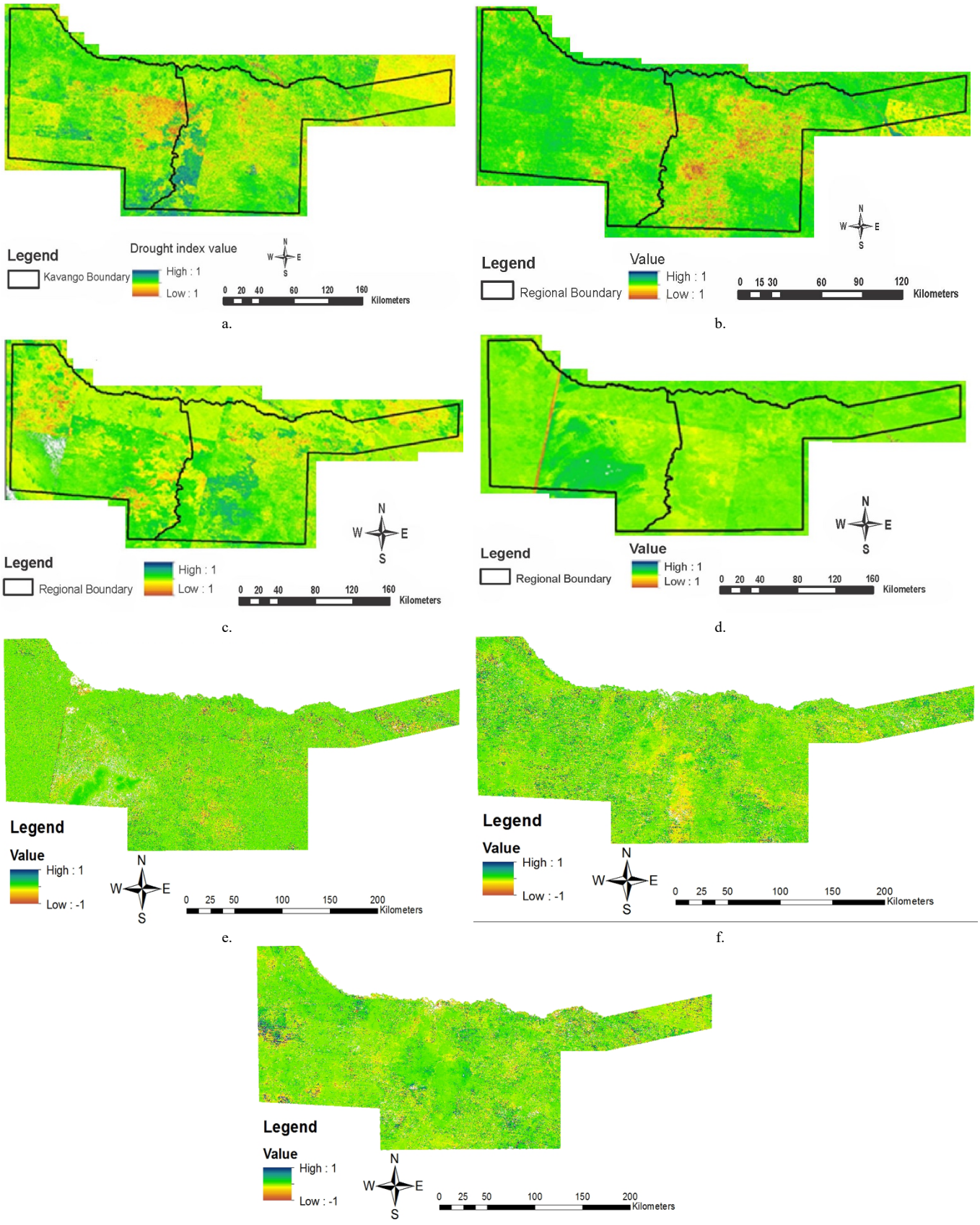

Fig. 5. Drought index's resultant images for the years 1990-2018: a) Drought index's resultant image between 1990-1994; b) Drought index's resultant image between 1990-19941995-1998; c) Drought index's resultant image between 1990-19941999-2002; d) Drought index's resultant image between 1990-19942003-2006; e) Drought index's resultant image between 1990-19942007-2010; f)Drought index's resultant image between 1990-19942011-2014; g) Drought index's resultant image between 1990-19942015-2018.

The Kavango river basin also gets flooded although not frequently. The flood event in the Kavango regions does not arise from the Namibian side of the river. High rainfalls in Angola, can promote flooding on the Namibian side of the basin. Previous studies have indicated that flood in Kavango is not a new disaster as flood incidence dates back to the 1950s in the Kondo community near Rundu [38]. Records show that the flood events resulted in the collapse of the whole Kondo community as they were relocated and scattered within other communities. They eventually became part of such communities leading to the loss of the Kondo tribe. During the years 2008 and 2009, the two regions experienced heavy floods after 40 years of being exposed to the same conditions [39]. With the history of severe floods in the areas, the affected people were relocated to dry areas. Besides floods triggered by excessive rainfall events, minor floodings are also triggered by irrigation projects. During the study, a community that was flooded by irrigation from the nearby green scheme (see Fig. 5a) was visited. The residents could still manage to stay in their house even though it was flooded. Although they are indications that the place could get severely flooded beyond the flood levels observed during the fieldwork. However, when the occupants were interviewed on whether they consider relocating they responded that they would want to benefit from the green scheme project. Furthermore, they indicated that they have been there before the establishment of the project and believed that relocation would be a better option compared to closing down a green scheme project. In their opinion, the green scheme project is a commercial entity that has improved food production and income in the region. The study observed that it is also not easy to relocate people from where they have been staying for years. In addition, it appears as though the relocation cost is a major factor affecting their decision to remain in the flooded homes. Hence, the owners of the house would like to relocate but it is a costly exercise for them, as they have to start looking for a place where they can reconstruct a new home. The cost of building a new home is also unbearable to them. This is why they believe they needed to come into agreement with the manager of the green scheme maybe they can be helped in any way. Besides the economic factors that could hinder the process of permanently relocating to another area, cultural and social norms could also play an important role in this situation. A study by [38] revealed similar opinions where the flooded communities in the Kavango region do not consider to be relocated to dry areas. Reasons are also tied to socio-economic and cultural values which come to play. Many of the respondents are living on the land that they inherited from their ancestors. Hence, they have a lot of attachment to it and would rather stay back.

1) Drought

Drought is one of the most serious threats to livestock and human beings. During years of poor rainfall, there is a low yield and reduced harvest as well as inadequate grass to be grazed. For these reasons, people may move their livestock to greener pastures and abandon their fields for regions with adequate rainfall. This is in line with the report by [8], that indeed drought is one of the major factors observed as one of the drivers of LULCC. To quantify that drought is a problem in the Kavango region the NDWI was computed to mask out areas that are water-stressed as supposed to areas with a reasonable amount of water (Fig. 4). Furthermore, the NDWI was used to construct the drought index (NDDI). The resultant NDDI (Fig. 5) shows that there are patches of permanent drought in the Kavango East and West regions and the inland areas in particular. However, this prompted people to settle along the river so that they can have access to the river for their daily household needs. See Fig. 4. e to follow an indication of NDWI's results depicting water-stressed areas for the years 1990-2018. Similarly, (Fig. 4. f) is the NDDI's resultant image for the years 1990-2018, which serves to prove that indeed there is an element of permanent drought in the study area.

Drought is regarded as a norm as well as a frequently observed phenomenon in Namibia and is expected at any time. The two Kavango regions are also not an exception when it comes to drought. On average, every third year Namibia is hit by drought events [40]. However, Namibia experienced the worst drought during the year 2018/2019 similar to the severe drought it had in 1930. According to [41], Namibia has an average of two drought occurrences every decade.

Between the years 1930 and 2017, the country including the study area has witnessed major drought events [40], [41]. In 2019 larger parts of the country did not receive any rainfall and only a few parts received rain - NMET, 2019. Recently, drought events killed about 64,000 livestock in the country in a space of six months - The Namibian, 2019. This number is skyrocketing and continues to affect the farmers in the regions.

VI. Conclusion

In this article, the main drivers of LULCC in the Kavango west and east regions had been identified and discussed. This information is very important for policymakers as well as management to plan accordingly. Furthermore, it also serves as a guideline for the traditional authorities when they allocate land to the people. New national policies should discourage people from settling within the environment of green scheme projects, the flood plains and other areas prone to flood events. However, the most attractive resource in the study area is the water resource, which has continued to provide a source of living for fishermen. Other resources derived from the basin include reeds for basket weaving and house construction, local dredging to provide for construction and brick making, and water for irrigation purposes and other daily needs. Hence, most of the people in the two regions settled along the river for economic benefits. This has led to overpopulation along the riverbanks which in turn exerts a lot of pressure on the fragile ecosystem owing to anthropogenic activities like crop farming and the expansion of human settlements. This is a clear indication that LULC change has been taking place in the study area since there is a conversion of natural vegetation to crop fields. It should be noted that population growth remains one of the major driving forces. Anthropogenic activities like clearing land for agriculture, livestock overgrazing, lumbering for timber, firewood, and poles for construction are the drivers of LULC change in Kavango's east and west regions. In addition, these factors contribute to severe

deforestation by creating bare surfaces. Similarly, the replacement of natural vegetation with buildings or areas for settlements and urbanization cannot be overlooked as they contribute to LULC change by increasing the area covered with impervious surfaces causing increased temperatures as well as low groundwater recharge. Other drivers of significant importance leading to LULC change include natural disasters like floods and drought which cannot be undermined.

However, since the local people are also affected by LULC change, it is very crucial to find out from them how these changes affect them. It should be noted that there has been a gap between Remote Sensing derived information and common belief amongst the people. Therefore, identifying the drivers of LULCC using various indices of Remote Sensing combined with local information, filled the gap between RS and indigenous knowledge from local people. As has been observed in the past, Remote Sensing image interpretation can only be supplemented with ground-truthing, topographic maps, the user's knowledge of the study area as well as aerial photographs. Finally, the study revealed that local's indigenous knowledge could smoothen the process of image interpretation as well as identify LULCC drivers.

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