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Characterizing Forest Cover Changes Based on Satellite Images cum Forest Dependents' Data

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ABSTRACT

While the reliable and consistent information on forests dynamic as well as communities living in their vicinities are fundamental to sustain their socioeconomic and environmental benefits, these information are lacking in Wad Al-Bashir Forest (WF) area that located in Sennar State of Sudan. Thus, this study assessed the land use/land cover (LU/LC) changes cum forests' dependents needs (FDNs) as well as forestland-related-activities (FRAs) using geospatial techniques alongside key informant interview (KII) cum structured questionnaire, respectively. For assessing the LU/LC, Landsat images of the years 1985, 2001 and 2017 have been downloaded and analyzed using ArcMap 2015 and ERDAS 2015 software, where supervised classification was applied with GPS points verification. While the assessment of FDNs and FRAs has done by which 61 respondents and 5 key informants were questioned and interviewed through random and purposive sampling respectively, and subsequently, descriptive analysis was carried out using SPSS. Results of LU/LC have shown considerable changes during the two study periods, where 2001 made a considerable forest cover (72.2%) compared to 1985 and 2017 (63.8% and 58% respectively), whereas 2017 encompasses vast farmland area (38%) than 1985 and 2001 which have been driven by some FDNs and FRAs. The major FDNs were needs for energy sources, farmland, building materials, and animals fodder respectively, while the main FRAs were crop farming inside forestland, illegal trees cutting as well as uncontrolled grazing. Decisively, conducting a small scale LU/LC detection (like WF) will give a genuine status of forest cover as well as the real FDNs and FRAs of the peoples living in the vicinity of the forest areas, and hence, this study recommends this method for further studies especially for establishing a baseline for forest monitoring and policymaking purposes.

1. Introduction

Quantifying the extent of forest and change in the amount of forest areas is key to ensure that appropriate management practices and policies are in place to maintain the array of ecosystem services provided by forests (Coulston et al., 2014). Forests in the arid lands cover more than 11 billion hectares and their trees tend to be integral and essential parts of the ecosystem and traditional food systems where forests dependents influences are being considered (FAO, 2016; Milton, 2015; Pretzsch, 2005). These resources are fluctuating in their trees' cover and eco-functions, especially in desert's bordering countries such as Sudan. Therefore, reliable and timely information on their land use/land cover (LU/LC) status, as well as activities associated with their dynamic, are fundamental to address their socioeconomic and environmental benefits in general and their sustainability in particular (Coulston et al., 2014; Mohamed et al., 2016).

Land use and forests are intricately linked to how and where people live and sustain themselves (Amatya et al., 2015). Generally, forests are known as one of the most important resources on the earth planet plays a pivotal role in the progress of human civilizations (Wang et al., 2012). A forest is widely defined as a biotic community predominated by trees and woody vegetation which is sporadically changing (FAO/FRA, 2015). These woody vegetations are significantly taller, greater, thicker, and deeper than other vegetation types and generally cover a large area (FAO/FRA, 2015; Grebner et al., 2013; Macdicken et al., 2015; Westoby, 1989). Globally, forests cover approximately 26.2% of the world, with 45.7% of Latin America and the Caribbean, 35% of East Asia and the Pacific, and 35% of the European Union. North America accounts only for 6.8% of the world's forests while Africa has even less 5.7% (Keenan et al., 2015). In this regard, forest cover in Sudan is reported to be 1.9 hectares, accounting for only 10.3% of the country's land area (FAO, 2015; Gadallah, 2018).

Forestry studies have always been an alive topic and with the advent of satellite remote sensing have made unprecedented development that alleviated the cost and time of gathering the LU/LC data (Wang et al., 2012). Although LU/LC are often used interchangeably in change detection studies, their actual meanings are quite distinct (Roy et al., 2002). Land cover refers to the surface cover on the ground whether vegetation, urban infrastructure, water or other, while land use denotes the purpose of land reserves such as recreation, wildlife habitat, agriculture (Arfat, 2010; Morales-barquero et al., 2015). Identifying, delineating and mapping of LU/LC is a key for global monitoring studies, resource management, and planning activities, because it establishes the

baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for the baseline thematic maps (Alhassan, 2010).

As indicated by Wolfersberger and Delacote (2015), LU/LC mapping and subsequently monitoring the changes from year to year are partaking to ecosystem sustainability, because these changes having a significant influences on the ecosystem with impact on biotic diversity, soil degradation and ability of biological systems to support human needs and venerability to climatic and socioeconomic changes (Olander et al., 2008). Understanding these surface processes and predicting the impact on the environment and food production system is necessary for militating against the continuous negative impact of these changes (Zuzana et al., 2015).
Normally, forests are continuously changing, where change is known as an alteration in the surface components of the vegetation cover or as a spectral/spatial movement of a vegetation entity over time (Köthke et al., 2013). However, the rate of these changes can be either dramatic and/or abrupt, as exemplified by large-scale tree logging; or with natural origins resulting from fires, insects, and disease epidemics (MacDicken, 2015). In this respect, forest cover in Sudan has witnessed considerable changes in the last decades as reported in many reports (FAO, 2015; Gadallah, 2018). FAO (2015), stated that the annual forest cover change between 1990 and 2015 accounted for -0.8%. While the global data set on forest cover changes was lately published and made freely available for each country (Keenan et al., 2015; Song et al., 2018), this data has been criticized for lack of accuracies in distinctive vegetation types at the local scale. Eventhough, it remains a respected source of forest cover information for areas where local data is severely lacking. Wad Al-Bashir forest, for instance, is an area for which very little spatially explicit forest cover information is available especially in recent decades. Yet, this dryland forest is undergoing a dramatic rate of forest degradation and deforestation through illegal selective logging, uncontrolled grazing, slash-and-burn agriculture. Also, underground water and soil properties have greatly affected by these activities as reported in plethora of literature (Lewis & Liljedahl, 2010; Sulieman et al., 2018; UNCCD, 2009). These activities may have resulted in relatively diffuse and small-scale changes in the area's LU/LC. Unfortunately, we do not know how much Wad Al-Bashir forests' area is changing and what are forest dependents' needs that related to these changes. Thus, this study attempted to assess and map the forest's cover as well as LU/LC changes using remote sensing and GIS in relation to the needs and activities of the communities in the vicinity of the study area.

2. Materials and Methods

2.1. Study Area

Wad Al-Bashir Forest lays in the southwestern part of Gedaref State which is located in the eastern part of Sudan (Figure 1).

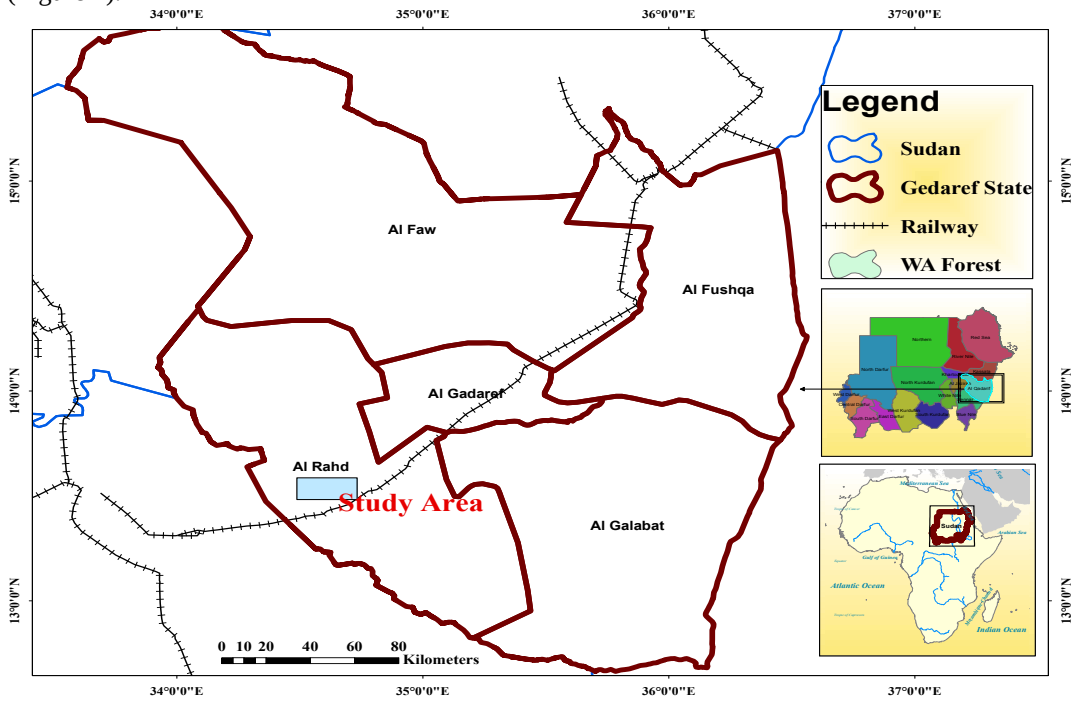

Figure 1. Study Area (Wad Al-Bashir Forest in Gedaref State of Sudan)

As reported widely the agriculture was and still the backbone of the economic activity, followed by livestock raising and forest products trading (Glover, 2005). The area is located in the semi-arid zone, with summer rains

and warm winter. Its climate is characterized by a unimodal rainfall pattern ranging from 400 to 800 mm (Glover, 2005). Temperature is very high in summer and mild in winter, the average daily maximum temperature ranges from 25° to 40° C (Sudan Metrological Corporation, 2018).

Specifically, Wad Al-Bashir forest is positioned between Al-Hawata and Al-Mafaza areas at the longitude of 3436□36□′E - 3430□37□′E and latitude 139□30□′N -1319□33□′N, with an area of 3,468 ha. As reported by Harison and Jackson (1958), the vegetation map of Sudan shows this area in the zone of low rainfall woodland savanna on clay. According to this report, Wad Al-Bashir forest is located near the transition between two main vegetation types of low-rainfall woodland savanna on clay: Acacia mellifera thorn land and Acacia seyal-Balanites aegyptiaca woodland (Harison and Jackson, 1958). Therefore, this area has been selected due to its geographical position in Sudan's dry regions category as one of class two (moderately desertified) States, which had a fairly good vegetative cover but, currently, the land has undergone serious degradation as irrational mechanized farming, extensive woodcutting and over-grazing are over mining land resources (NDDC/UNDP, 2006). For this study, two methods were applied: geospatial techniques as well as the social survey for gathering remote sensing and socio-economic data respectively.

2.2. Detecting land Use/Land Cover Changes

For identifying the LU/LC changes, remotely sensed data were used, where satellite images have chosen form the Landsat sensors. These images were clear of cloud cover and freely downloaded from the United State Geological Survey website (GloVis) at the path of 172 and row 51. Consequently, four Landsat images were used with spatial resolution 30 m (Table 1), where Landsat 5, Landsat 7 (ETM) and Landsat 8 (OLI_TIRS) images were downloaded for years 1985, 2001 and 2017 respectively. Landsat images were selected purposely because of their geographical cover ability and temporal availability.

Table 1. Landsat Images that Used in LULC Determination of the Study Area

Satellite/Sensor	***Pass/Raw***	***Acquisition Date***	***Spectral Bands***
Landsat 5 TM	172/51	14/3/1985	1, 2, 3, 4
Landsat 7 ETM	172/51	06/01/2001	2, 3,4, 5
Landsat 8 OLI/TIR	172/51	02/01/2017	2, 3, 5,7

Source: (GloVis, 1985 ; 2001 ; 2017)

The analysis step and for processing the satellite images, ERDAS Imagine 2015 and ArcMap 10.5 software were used with the aid of Microsoft Excel 2016, which was used in computing the areas of land use and land cover changes showing their percentages and changes. Accordingly, Image calibration, geometrical and atmospheric correction were completed; as well as layer-stacking and composite bands tool to convert the bands (2, 3, and 4 for TM, and 2, 3, 4 for ETM and 3, 4 and 5 for OLI_TIRS) for each year into a single-layer file (preprocessing and enhancement). Then, sub-scenes were clipped. Afterward, Normalized Difference Vegetation Index (NDVI) for the Landsat TM, ETM and OLITIRS images was examined, in an attempt to identify the forest cover. Next, Supervised classification where the Maximum Likelihood Classifier was applied for the LU/LC classification of acquired Landsat images of 1985, 2001 and 2017. Lastly, the accuracy assessment was systematically performed for each image; the results revealed that the overall accuracy and kappa coefficients represented for each classified image were greater than 75% for all images.

2.3. Assessing Forest Dependents' Needs and Their Forest-Associated Activities

The determination of forest dependents' needs along with their forest's related activities was conducted using a socioeconomic survey by which key informant interviews (KII), as well as a structured questionnaire, were carried out. Consequently, 61 respondents and 5 key informants were questioned and interviewed through purposive sampling to the community leaders, Nomads leaders, leaders of farmers union, and forest personnel as key informants. Whereas random sampling was conducted for questioning households using a structured questionnaire; it examined the history of Wad Al-Bashir forest; in terms of its past and current trees cover, direct and indirect benefits as well as these communities source of income, energy sources among other activities inside the forest area. The analysis of the social data which was obtained from KII and the questionnaire were first coded before using the SPSS software (version 25) for the statistical analysis, where the descriptive statistics were used to describe frequencies of selected variables in percentages. The summary of the methodology and research procedure has depicted in Figure 2.

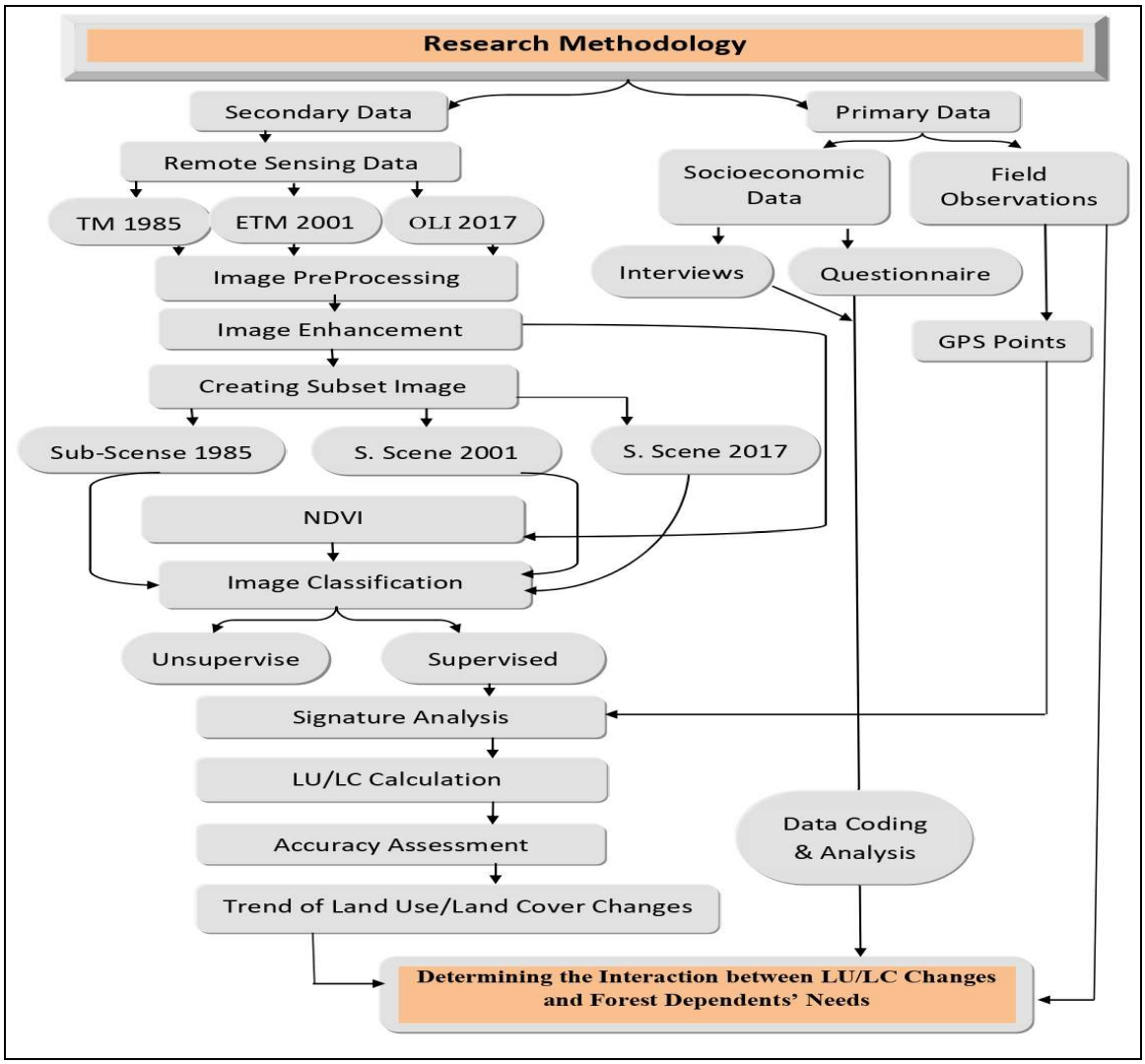

Figure 2. Schematic representation of the research methodology

3. Results and Discussion

3.1. Land Use/Land Cover Changes

Worldwide, LULC changes are reported to be among the most persistent and important sources of recent alterations of the Earth's land surface (Imai et al., 2018; Matteucci et al., 2016). Thus, their identification establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps. In this study, and as depicted in figure 3, and due to the human and environmental factors, LU/LC have witnessed considerable changes during the two study periods (1985-2001 & 2001-2017). It's clearly showed that 2001 had considerable forest cover (72.2%) compared to 1985 and 2017 (63.8% and 58% respectively), whereas 2017 encompasses vast farmland area (38%) than 1985 and 2001. Specifically, the annual forest cover loss between 2001 and 2017 was estimated at 0.87% (see Table 2). In this line, in a study conducted by Arafat (2010) stated that the LU/LC changes could take place due to numerous factors like; deforestation, flooding, soil erosion, unplanned urban and agricultural expansion. The same study pointed out the changes of LU/LC in particular, to a long period under different environmental, political, demographic, and socioeconomic conditions, which they often vary and have a direct impact on people living in the neat to the forest.

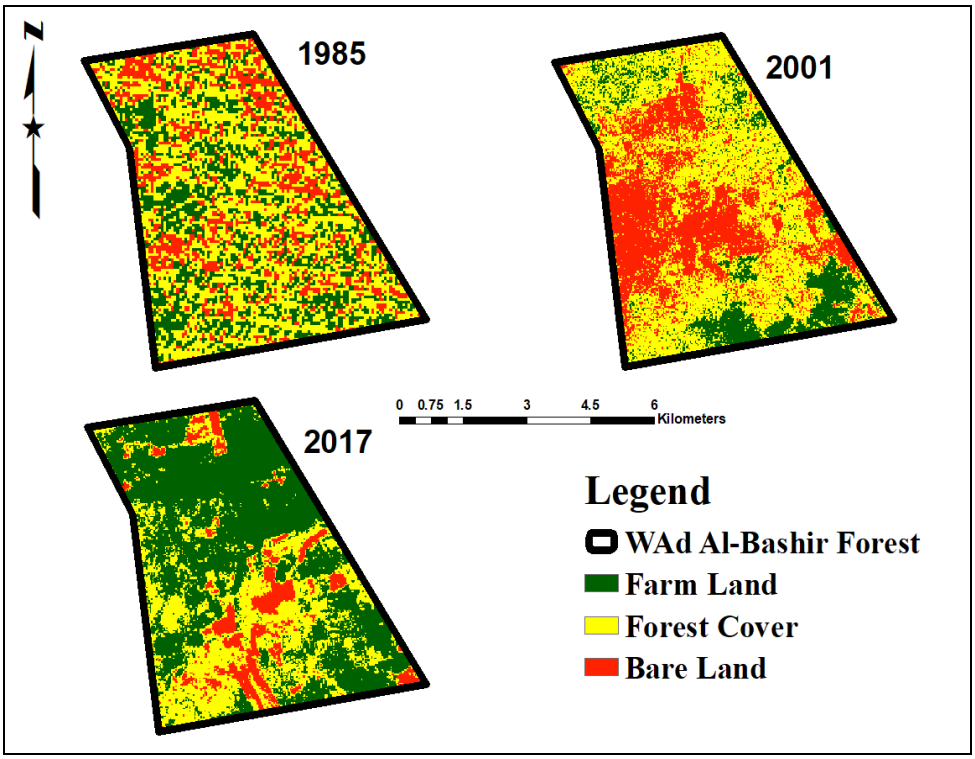

Figure 3. LU/LC Classes in Wad Al-Bashir Forest in 1985, 2001, and 2017

According to the findings, these changes and alterations have been driven by anthropogenic activities that create disturbances and alter the normal cycle of vegetation greenness in the study area. For instance, according to the information gathered for the questionnaire and KII as well as RS result, the LU/LC has witnessed great changes during the study periods. The 2001 experienced vast forest area, which was due to the sound management activities that directed by refugees affected areas project; which funded by Higher Commission of Refugees of United Nation (UNHCR) and United Nations Sudano-Sahelian Office (UNSO). Subsequently, Wad Al-Bashir forest management has shifted FNC in 2004, where the degradation had commenced. On the other hand, the year 2017 encompasses vast farmland areas than the previous years, which reported as due to the conversion of vast area to the farmlands under what's called Taungya system (Table 2) .

Table 2. LU/LC Classes and their Area in percentage for 1985, 2001 and 2017

Classes	*2017 Area(ha)*	*%*	*2001 Area(ha)*	*%*	*1985 Area(ha)*	**%**
Forest-Cover	2004.7	58.0	2489.8	72.2	2205	63.8
Farmland	1324.4	38.3	891.8	25.9	209.4	6.1
Bare land	125.3	3.6	65.8	1.9	1039.6	30.1
Total	3454.4	100	3447.5	100.0	3453.9	100

3.2. Forest Dependents' Source of Income and their Forest-Associated Activities

The geography, culture and social patterns of the peoples are limiting factors towards any natural resource (Gadallah, 2018). Thus, studies conducted in the same State stated that the agriculture is a pillar of Gadaref State's economy, alongside with animal husbandry in the traditional seasonal transhumance pattern and village livestock raising (Glover, 2005; Hemida, 2016), where most of the farmers grew the principal food crops such as sorghum and sesame. Similarly, this study's findings showed how the neighboring communities are linked to the forestland and have been using the forestland in their distinguished activities (Figure 4, A) where about 50% were using the forestland for farming and grazing purposes.

Moreover, the major jobs of the respondents were as 41% farmers and 40% supplemented their income from animals rearing. Only a small percent (11.8%) have engaged to trade work, while very view of them attached to the civil service employment (see Figure 4,B). The main reasons for communities-forestland engagement are fertile soil for crop farming as well as land for grazing purposes which could deteriorate forest state if nothing has been done to control and curtail these interventions, because these communities' lives are stick to these forests (Hlaing et al., 2017).

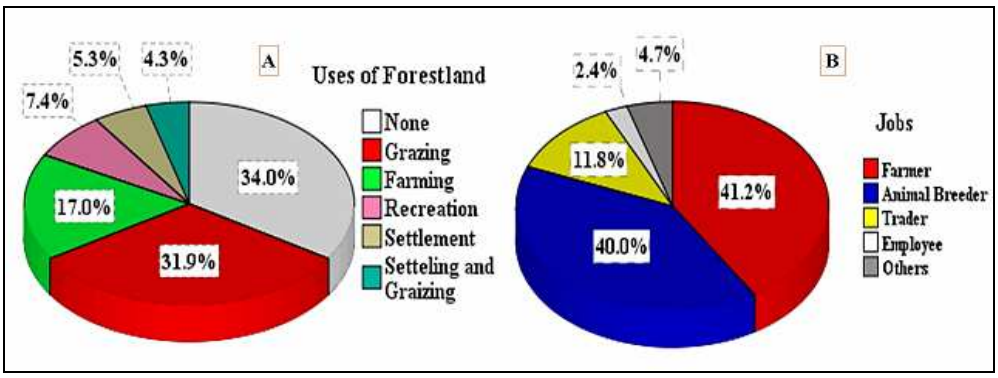

Figure 4. Uses of forestland by Respondents (A) and their jobs (B)

3.3. Forest Dependents' Needs in Relation to Forest Degradation

Based on the socio-economic survey's result, most of the respondents affirmed the existence of forest degradation due to the rampant forest dependents' needs and activities. For instance, energy, building materials, fodder, and other non-wood forest products are all gathered and collected from the forestland. Accordingly, in recent times, Wad Al-Bashir forest has been suffering from severe deforestation due to a complex array of social, economic and political factors. The directs causes brought from questionnaires and KII outcomes indicated large areas which have been cleared and converted to mechanized farms inside and in the forest frontier where peoples are seeking for farmland. Other reasons stood behind forest degradation, were illegal cutting to meeting fuel wood and building materials demands. Firewood and charcoal were the main sources of energy for the respondents which were reported as important sources for cooking fuel (see Figure 5, A). Most of the fuel wood was collected from the forest. Hence, despite the hard conditions in the area and the alarming threat of degradation/desertification, local people still exert pressure on natural forests and planted trees (NDDC/UNDP, 2006).

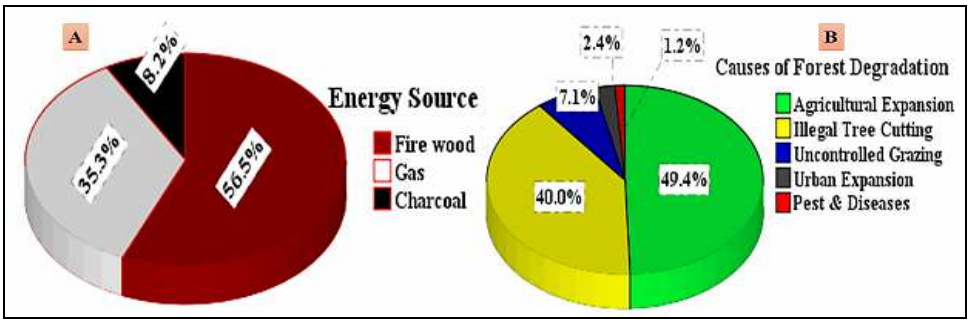

Figure 5. Energy sources (A) and major causes of forest Degradation (B)

4. Conclusion and Recommendations

This study assessed the land use land cover changes in association with the forest' dependents' needs and forestland-related-activities. Thus, the study concluded that there were sizeable LU/LC changes during 1985-2017 with different trends and percentages. These changes and alterations have been driven by dependent activities such as crop farming inside forestland and the illegal trees cutting. The major forests' dependent needs were energy, building material and grazing purposes which all have a role in forest degradation and forest cover changes. Conducting a small scale LU/LC detection will give a truthful status of forest cover as well as the real forests dependents' needs and forestland-related-activities by peoples living in the vicinity of the forested areas,

and hence, this study recommends this method for further studies especially for founding a baseline for the monitoring and policymaking purposes.

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