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Effects of *Prosopis juliflora* Invasions on land use/cover change in South Afar region, Northeast Ethiopia

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ABSTRACT

Prosopis juliflora (henceforth referred as *Prosopis*) plant is an invasive species affecting the health of rangelands in Afar region of Ethiopia. The study aims to assess (1) the effects of *Prosopis* invasion on land use land cover (henceforth referred to LULC), and (2) extent of vegetation cover changes. We used a combination of remote sensing data and field observations to analyze the effects *Prosopis* invasion on land use/ land cover dynamics and changes (LULCC) for the patterns and dynamics of land-use/cover changes for 31 years from 1986 to 2017 in the arid and semi-arid of Sothern Afar rangelands, Ethiopia. The overall accuracy for 1986, 2000, and 2017 were 81.4%, 82.3%, and 84.9% with Kappa statistics of 0.77, 0.79, and 0.82 respectively. In Amibara district, farmlands, water bodies, land under *Prosopis*, and grassland areas were increased during 1986-2017 by 1879 ha (10.8%), 1197 ha (55.6%), 3132 ha (99.0 %), and 31,039 ha (22.0 %), respectively. However, bare lands and woodlands areas were decreased by 1239 ha (56.7 %) and 36,065 ha (49.9 %), respectively. In Awash Fentale district, changes in land use/land cover types showed positive trends for farmlands, water bodies, *Prosopis*, and grazing lands by 4258 ha (81.4 %), 1035 ha (97.4 %), 2335 ha (97.0 %), and 18,187 ha (25.8 %) respectively in the same period. However, bare lands and woodland areas decreased by 59.78 ha (59.8 %) and 51 ha (50.9 %), respectively. If the present change continues, pastoralists grazing lands will be lost.

Keywords : Afar pastoralists, vegetation cover, *Prosopis*, rate, invasive, encroachment

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I. INTRODUCTION

Invasive species are species of all taxonomic groups whose spread outside their natural past or present distribution threatens the environment such that the well-being of humans will ultimately be affected [17], [32]. Globally, alien plant invasions have major impacts on biodiversity, ecosystem services, agriculture, forestry, human welfare and the economy [36]. Roadsides, river courses, farmlands, irrigation canals, wetlands, grasslands, conservation areas, and homesteads areas are the most severely invaded habitats in Afar region [15], [38]. *Prosopis* is dominating large areas of prime grazing land of Afar region. Consequently, nutrient-rich palatable grasses, the main feed source for grazers are progressively outcompeted [7].

Prosopis has been introduced consciously to Ethiopia in Afar region for windbreak, shade and shelter in the late 1970s and 1980s by foreigners working in the Middle Awash without detailed information about the plant [8], [1], [16], [7]. In lowlands of Ethiopia,, rangelands are subjected to different human and natural impacts. Consequently, undesirable weeds and woody plants are encroaching rangelands that have become the the threat to pastoral production systems [12]. Among woody encroachments, *Prosopis* is the most jeopardy to lowlands in east and northeast Ethiopia particularly in Afar region [1], [32].

Change detection is the process of recognizing differences in the state of an object and noticing changes of different episodes [32]. It is the distinct data frames accustomed to realize the relationships between human and natural interaction phenomenon [21]. Land cover refers to the physical state of the land surface, whereas land use involves how human exploit and modify the land and its resources [3].

LULCC is an important tool to quantify global biophysical changes in different spatiotemporal scale [19]. It is a widespread and accelerating change in environmental processes. As the result, it is a major problem of concern with regards to change in the global environment [10] and it is induced by human activities [5], [18], [19].

LULCC studies in the region have been discussed by many researchers such as Gatew [15], Mehari [24], Kebede [20], Tsegaye et al. [35], Luleseged et al. [22], Wakie et al. [37], Fantaye et al. [13], but updated change detection information in relation to the effects of *Prosopis* invasion is lacking. Moreover, the LULCC is a continuous process and a dynamic through time [19]. Therefore, extensive research on LULCC pattern is important for social and environmental consequences at different spatiotemporal scales. Techniques based on multi-spatiotemporal, satellite-sensor acquired data have used to detect, identify, map and monitor ecosystem changes [11]. Digital change system depends on variances in radiance value between two or among more dates [28]. Therefore, information produced from remotely sensed data is used to plan and judgment making for impacts of environmental monitoring and natural resources management [6], [23]. In this study, understanding LULCC is useful for early detection and management of land use changes to reduce the spread of *Prosopis*. Therefore, the study aims to assess (1) the spatial effects of *Prosopis* invasion on LULC detections, and (2) the temporal effects of *Prosopis* invasion on LULC in Amibara and Awash Fentale districts Southern Afar Region in Ethiopia.

II. MATERIALS AND METHODS

2.1 Description of the study area

Amibara district is located in between 741-746 m.a.s.l. altitudes and 9°19′43.83″ N and 40°10′51.6″ E longitude, whereas Awash Fentale, are located at 700-1000 m.a.s.l. altitude and $9^{0}10'$ 00″ N latitude and $40^{0}03'33''$ E (Figure 1).

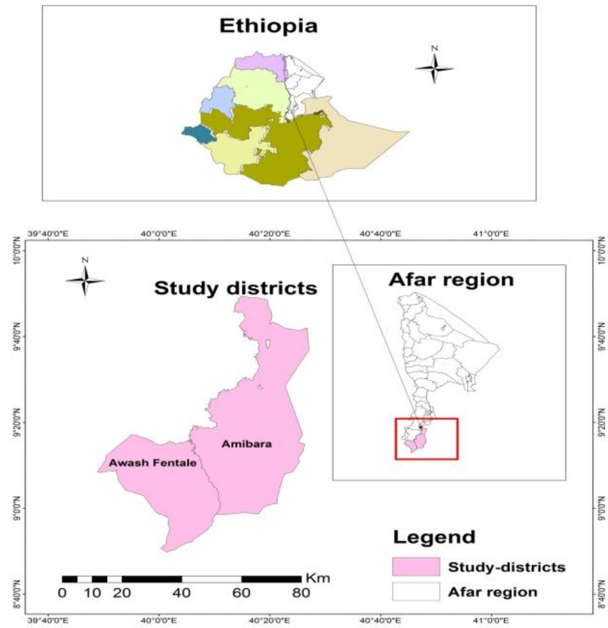
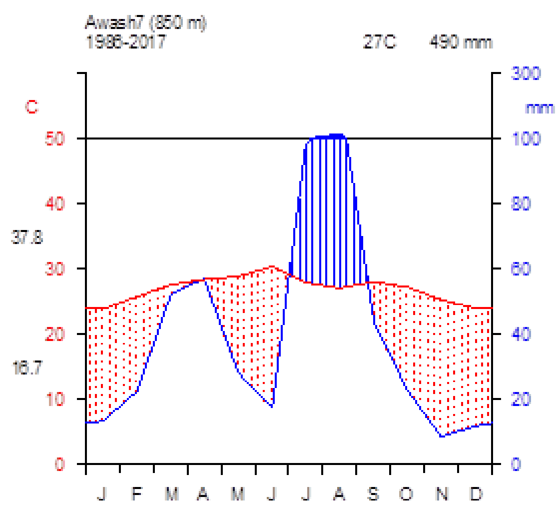


Figure 1 Map of the study districts

The mean annual temperature for Awash Fentale district was 27^{0}C. The mean minimum annual temperature for the district was 16.7^{0}C. Meanwhile, mean maximum annual temperature for the district is 37.8^{0}C (Figure 2A). On the other hand, the mean annual temperature of Amibara district is 26.8^{0}C. The recorded mean minimum annual temperature for the district was 13.8^{0}C. On another hands, mean maximum annual temperature for the districts is 38.2^{0}C (Figure 2B). The study areas are located within lowland agro-ecological zones of Ethiopia. The annual precipitation of Awash Fentale and Amibara districts were 490 mm and 416 mm respectively (**Figure 2**A&B).



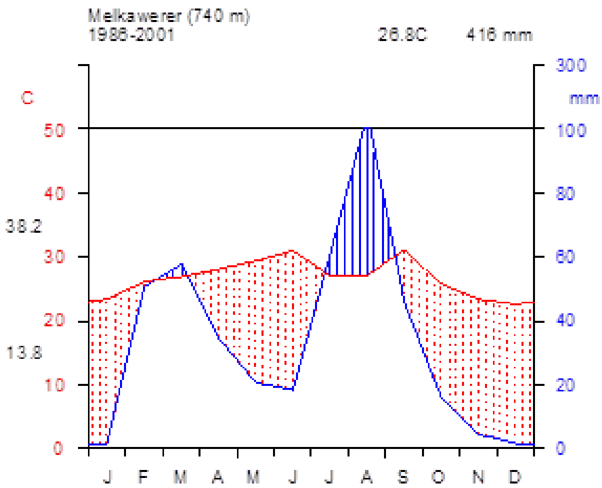


Figure 2 Thirty one years of climatic diagram for Awash Fentale (A) and fifteen years for Amibara district (B)

Geology of Afar floristic region is many Quaternary extrusive, intrusive and eolian formations. There are alluvial and colluvial deposits on the foot escarpments and Afar plains. Quite recent lava is found in the floristic region. The texture of the soils is usually sandy, originated from Jurassic and Cretaceous limestone and other sedimentary rocks. According to FAO soil classification and ISRIC-world soil information, the the soil of Afar floristic region is Lithic and Eutric leptosols, and Eutric fluvisols [14].

Acacia-Commiphora woodland and bushland is among vegetation types in Ethiopia which are characterizing the floristic region [14]. 83, 851 and 40,901 population numbers were living in Amibara and Awash Fentale respectively [9]. 90% of Afar people are pastoralists, while another 10% are considered agro-pastoralist [36].

2.2. Data and methodology

The required satellite images for the study area were downloaded from the USGS Earth Explorer (https://earthexplorer.usgs.gov/) [29]. Following Rwanga and Ndambuki [30], processing the imagery and image interpretation for the development of land use/land cover maps was performed (Table 1).

2.3. Images Classification

The pre-processed images were classified by supervised classification methods. In the supervised classification technique using the maximum the likelihood, algorithm classifies the image based on the training sets (signatures) provided by the user based on field collected ground truth data. Accordingly, 50 validation points (signatures) for each land use/land cover type were used for the supervised classification. Accordingly, seven land cover classes namely *Prosopis* invaded the land, farmland, settlement, bare land, grazing land, woodland and water bodies were identified in the study area (Table 2, Figure 3).

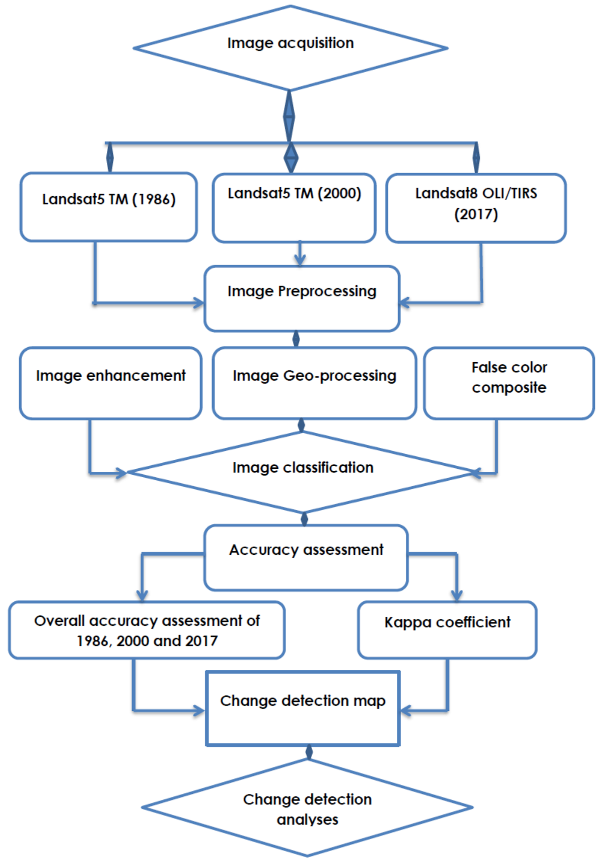


Figure 3 Frame work of data analysis

2.4. Land covers change detection analysis

To compute the accuracy assessment for the resent period of 2017, and previous periods of the 1986 and 2000, ground truth data with satellite imageries from Google Earth Pro v.7.1.5, and discussion with key informants of the local community of the study areas were used, respectively. Satellite imageries were combined manually and used to recognize different features in the study area. To differentiate *Prosopis* invaded lands from other land cover types. The magnitude of change for each LULC class was calculated by subtracting the area coverage of initial year from that 2nd year as shown in Eq. (1) following [19].

Magnitude =Magnitude of the New Year - Magnitude of the previous year …………….. (1)

Percentage change (trend) for each LULC type was then calculated by dividing magnitude change by the base year (the initial year) and multiplied by 100 Eq. (2).

$$\text{Percentage change} = \frac{\text{(The magnitude of change*100)}}{\text{(Base year)}} \quad \ldots.(2)$$

III. RESULTS

3.1 Accuracy assessment

The accuracy assessments for the supervised land use classification were done for the years 1986, 2000, and 2017 image by using ArcGIS. From the classifier, 350 points were generated randomly for 2017 supervised image. Each and every point had a specific color tone and the pixel value which was recognized by the software itself when the data sets were trained during supervised land use classification. These values were considered as reference values. All the randomly generated points were then identified by the user and assigned in different classes. The correctly identified points were considered as classified values. An error matrix and Kappa statistics were also generated from this reference and classified data.

The overall accuracies were calculated from the error matrix by dividing the sum of the entries that make major diagonal by the total number of examined pixels. Kappa coefficients of agreement were also calculated by using the following equations (Afify, 2011).

3.1.1. Classification accuracy of the landscapes

The overall accuracies for the year 1986, 2000, and 2017 were 81.4%, 82.3%, and 84.9% with Kappa statistics of 0.77, 0.79, and 0.82, respectively. Producer's of individual classes of the classified map ranged for the year 1986 were from 60% for woodland and grassland areas to 100% for water bodies and *Prosopis* invaded lands). Whereas the user's accuracies of individual classes of the classified map ranged for the year the same year were ranged from 50.9% for woodland and grassland areas to 100% for water bodies, settlement areas and farmland areas (Table 3). On the other hand, the producers' of individual classes of the classified map ranged for the year 2000 were from 62% for settlement areas to 94% for water bodies. Whereas the user's accuracies of individual classes of the classified map ranged for 2000 were ranged from 66% for grassland areas to 96% for farmland areas (Table 4). The producer's and user's accuracies of individual classes of the classified map ranged for the recent year of the 2017 were from 60% for settlement areas to 100% for farmlands, and 66.2% for grazing lands to 100% for settlement areas, respectively (Table 5).

3.2. The spatial extent of LULC types in Amibara district

A total of seven LULC types were extracted in the study landscape with different reference years of the 1986, 2000 and 2017 (Figure 4). In 1986, out of 20,1047 ha of LULC, grasslands were the dominant making up 54.8% followed by woodlands (36 %), farmlands (7.7 %) and bare lands (1.09 %). However, water bodies and *Prosopis* invaded lands (*Prosopis*) shared a small proportion of 0.48 %, 0.02 % respectively of the entire area. In 2000, LULC of the district was also dominated by grasslands (62.5 %) followed by woodlands (27.4 %), farmlands (7.6 %) and *Prosopis* (1.3 %). Water bodies, bare lands, and settlement were accounted 0.53 %, 0.68 %, and 0.007 % respectively of the total area (Table 6). Grasslands continued to dominate the LULC (70.2 %) in 2017. Woodlands and farmlands were the second and the third dominant LULC types covering 18.03 % and 8.64 % respectively in the study area (Table 6and Figure 4). Other small proportion of the landscape was shared by *Prosopis* (1.57 %), water bodies (1.07 %), bare lands (0.47 %), and settlement areas (0.03 %) in 2017.

3.2. Magnitude of LULC changes in the Amibara district

In the first period from 1986 to 2000, water bodies, *Prosopis*, and grasslands showed positive trends of magnitude by 10.6 %, 8237.5 %, and 54.7 % respectively. Meanwhile, farmlands, bare lands and woodlands showed the the negative magnitude of changes by -0.85%, -37.6% and -24% (Table 6 and Figure 4). In the the second period from 2000 to 2017, farmlands, water bodies, *Prosopis*, grasslands, and settlement areas were showed positive changes by 13.1 %, 104 %, 18.6 %, and 280 %, respectively. However, bare lands and woodlands continued to show negative trends by -30.6 % and -34.1 %. The overall magnitude and rate of change of LULC types in 31 years (1986-2017) showed positive trends for farmlands, water bodies, *Prosopis*, and grassland areas by 12.1 %, 125.5 %, 9787.5 %, and 28.2 % respectively in the district. However, the trends of bare lands and woodlands were also showed negative by -56.7 % and -50 % (Table 7 and Figure 4).

3.3. Change matrix of LULC types in Amibara district

The change matrix analysis shows that from 1986 to 2000, about 57,953 ha (52.65%) of the land within the study landscape experienced LULC changes in one or another way in 14 years period. During this period, the level of changes differed among LULC types. For instance, out of 72,312 ha woodlands in 1986, only 35,547 ha (49.2%) remained unchanged during this period, implying that 36,765 ha (50.8%) of the woodlands were converted to other LULC types. Of the 50.8% converted woodland areas, 91.5%, and 7.1% were converted to grazing lands and *Prosopis*, respectively. The remaining <1% area of woodland conversion was shared by farmlands, water bodies and bare lands in the district. During the same period in 1986, out of 110,076 ha (54.8%) grazing lands, 90,739 ha (82.43%) remained unchanged areas. The remaining 17.6% of grazing land areas were converted to other LULC types. Of these converted grazing land areas, 97.4% were encroached by woodlands; 2.2% and 0.2% were converted to bare lands and *Prosopis*, respectively. The rest small proportion about 0.18% of grazing land area conversion was shared by farmlands, settlement areas and water bodies in the study area (Table 8 and Figure 5A).

During the second 2000 to 2017 period, change matrix analysis showed that about 43,352 ha (21.6 %) of the land study area were converted to other LULC types in 17 years' time. For instance, out of 125,610 ha grazing lands in 2000, about 91.1 % remained unchanged. Of the 8.9 % converted grazing land areas, 24 % and 1 % of land areas were converted to woodlands and farmlands respectively. The small proportion (0.6%) of the grazing land areas were converted to *Prosopis* lands. Out of 54,980 ha woodlands in the same period, only 19.6 % of the land areas remained unchanged. The remaining woodland areas were converted to other LULC types. Out of the total converted woodland areas, 85.6 %, 5.4 %, 5.3 %, and 3.6 % were converted to grazing lands, *Prosopis*, farmlands, and water bodies respectively in the district. Meanwhile, the smallest proportion of woodlands was converted to settlements and bare lands (Table 9 and Figure 5B).

3.4. The spatial extent of LULC types in the Awash Fentale district

The same reference years 1986, 2000 and 2017 were also used to classify the district into existed LULC types. Accordingly, seven LULC types making up a total area of 104,596 ha were classified in the district (Figure 5). In 1986, grazing lands and woodlands were dominated in the district making up 50.1 % and 48.8 % respectively. Meanwhile, farmlands, bare lands, *Prosopis*, and water bodies were shared the remaining 1.1% in the district. The spatial extent shows that the same trend for grazing lands (65.5 %) and woodlands (31.9 %) in 2000. But, the increasing trend for the earlier and decreasing for later LULC type in the same period. In 2000, *Prosopis* increased by 1.4% of the entire area of the land. The remaining small land areas, about 1.1% were shared by farmlands, water bodies, bare lands and settlement areas. During this, the result showed that the same size of farmland areas was noticed for cultivation in the study area. In 2017, the same trends of change for grazing and woodlands were observed. In this period, 67.4% and 24% for grazing land and woodland areas respectively were detected. Moreover, grazing lands were insisted to rise and woodlands declined in the study area during the same period (Table 10 and Figure 6).

3.5. Magnitude of LULCC in the Awash Fentale district

Relative change in LULC of the district (Figure 6) was assessed based on data presented in Table 10. LULC from 1986-2000 showed the positive magnitude of changes for *Prosopis*, bare lands and grazing lands by 1,772.2 %, 201.1 %, and 30.9 % respectively. On contrary, water bodies and woodlands showed negative trends by -67.9 % and -34.7 %. In the second period from 2000-2017, farmlands, water bodies, grazing land, and settlement areas showed positive increment by 436.3 %, 11,711.1 %, 3.0 %, and 1,900 % respectively. Although, land covered by *Prosopis* showed a positive trend (76.7 %) but declined by 39.4 % relative to 1986-2000. In this period, bare lands radically declined than previous and showed negative trend by -86.6 %. But, an increasing trend of woodland areas was noticed than earlier period though negative change by -24.9 %. In general, the overall LULCC for 31 years (1986-2017) showed positive trends for farmlands, water bodies, *Prosopis*, and grazing lands by 436.3 %, 3696.4 %, 3208.9 %, and 34.7 % respectively. However, bare lands and woodlands showed negative trends by -59.8 % and -51.0 % in that order (Table 11 and Figure 5).

3.6. Change detection matrix of LULC types in Awash Fentale district

In the first 14 years (1986-2000), the change matrix shows that 31, 858 ha (30.4%) areas of land were converted to other LULC types. The level of changes varied among the LULC types. For instance, results showed that 72.6 %, 4.4%, and 0.4 % of woodlands were converted to grazing lands, *Prosopis*, and bare lands, respectively in the district. Furthermore, 21.6 % and 0.4% of grazing lands were converted to woodlands and bare lands, respectively in the same period. During this period, only 16 ha (17.4 %) of bare lands remained unchanged. But, 0.2 % and 0.1 % bare lands were converted to grazing land and woodland areas. As the result, land degradation was recovered from lacking vegetation. On the other hand, about 0.1% for *Prosopis* and water bodies each was converted to woodlands in the district (Table 12 and Figure 7C).

During the 2000 to 2017 the change matrix indicated that the overall area of land conversion was declined by 7,562 ha (23.7 %) than the first period (1986-2000). In the later period, 24, 296 ha (23.2 %) areas of land were converted to other LULC types. During the second reference period, only 8,975 ha (13.1 %) of grazing lands were converted to other LULC types. In the same time 23.7 %, 10.7 %, 1.7 %, and 0.3 % grazing land areas were converted to woodlands, farmlands, water bodies, and *Prosopis*, respectively in the district. The remaining small proportion (0.3 %) of grazing lands conversion was shared by bare lands and settlement areas. Whereas, out of 14,503 ha (59.7 %) converted woodland areas most the areas about 73.4 % was converted to grazing LULC type in the district. Furthermore, 11.6 %, 10.5 %, and 4.4 % of woodland areas were also converted to farmlands, *Prosopis*, and water bodies, respectively in 2000 in the study landscape (Table 12 and Figure 7D).

On the other hand, in the second period (2000-2017), out of 463 ha (1.9 %) converted *Prosopis* 85.1 % and 14.5 % areas of land were converted to woodlands and grazing lands, respectively. In the same period, out of 75 ha (0.3 %) converted farmlands the major areas were replaced by woodlands (68 %), whereas 29.3 % and 2.7 % of farmland areas were replaced by grazing land and *Prosopis* areas, respectively in the study area. Change matrix also shows that major areas of bare lands (98.2 %) converted to other LULC types. For instance, out of 272 ha (1.1 %), 94.1 %, 2.9 %, 2.6 %, and 0.4 % bare lands were converted to grazing lands, woodlands, farmlands, and water bodies respectively in the same period (Table 13 and Figure 7D). As the result, quantitative change of analyses for 31 years (1986-2017) revealed that areas of farmlands, water bodies, *Prosopis*, bare lands, woodlands, grazing lands, and settlement areas were changed in magnitude by 6 ha,137 ha, 2,232 ha, 5,667 ha, -1,294 ha, -62,085 ha, 49, 226 ha, and 117 ha, respectively in Southern Afar.

IV. DISCUSSION

For both districts, the overall accuracies assessment of the years 1986, 2000 and 2017 were the the strong agreement between the classification and reference data in the study landscapes [23]. Moreover, Kappa statistics near 0.80 and more than 0.80 also shows better accuracy and the classification resulted from random points. In both years of 1986 and 2000 the producer's accuracies of woodlands and grasslands were lower than other land uses. Whereas the user accuracies of grasslands and settlement areas were also showed lower than the rest land uses for 2000 period. On the other hand, confusion matrix analyses revealed that producer accuracy for settlement and bare land areas were relatively lower than other LULC type. Whereas, user accuracy for woodlands and grazing lands were also relatively lower than the rest in the study areas. The reduction in user and producer accuracies of 2017 for aforementioned LULC types were due to their similar reflectance values of solar radiations that misclassified to either of the LULC types. Moreover, the broad ranges of accuracies indicate a severe confusion of bare lands and settlements with other LULC types and their omission errors were greater. Accuracy assessments made by Rwanga and Ndambuki [29] in Limpopo province of South Africa and Tadele et al. [34] in the case of Quashay watershed in northwestern Ethiopia argued similar trends for the aforementioned LULC types.

The LULC types in Amibara and Awash Fentale districts of southern Afar experienced various change detections for three decades (1986 - 2017). They have been persistent changes both spatially and temporally, resulting in 51.5% of the total areas experiencing changes among LULC types in the study areas. This result shows that the changes were higher than the one reported by Tsegaye et al. [35] in northern Afar during 1972-2007. For both districts, major conversions were detected during 1986-2000 which showed 57,953 ha (57.2%) and 31,858 ha (56.7%) of the total areas converted in Amibara and Awash Fentale districts, respectively. However, fewer conversions were detected in the second period (2000-2017) in which 43,352 ha (42.8%) and 24,296 ha (43.3%) of the total areas converted in Amibara and Awash Fentale districts, respectively. The major conversions of LULC types during 1986-2000 were attributed to the expansion of farmlands and invasion of *Prosopis*. Similar findings were suggested by Haregeweyn et al. [17] for the cause of conversions during 1973-2004 in Amibara district. Large areas of woodland might also be cleared for fuelwood purposes [35] during the same period. Furthermore, in 31 years' time,, large areas of land conversions were taken place in Amibara district (33.1%) than Awash Fentale (18.4%). The reasons might be due to the the expansion of large-scale farmlands and invasion of *Prosopis* in the former district.

In three decades from 1986 to 2017, the area of farmlands, water bodies, *Prosopis*, grazing lands, woodlands, and settlement areas consistently increased meanwhile the areas of bare lands and woodlands were decreased in Amibara district. On the other hand, the areas of farmlands, water bodies, *Prosopis*, grazing lands, woodlands, and settlement area were also steadily increased whereas areas of woodlands were consistently declined in Awash Fentale district in the same year. However, areas of bare lands revealed the the irregular trend in Awash Fentale district. The reductions in areas of woodland and bare land areas in both districts were mainly attributed to the conversion of the areas to farmlands, invasion of *Prosopis* and devastation of woodlands for construction, and charcoal and firewood purposes. Findings from elsewhere also showed that such changes are common in other areas with similar settings. For instance, the LULC dynamics of Merti district in Oromia region by Megersa [25] reported that shrublands and forest lands (woodlands) dropped by 56.8% and 26.4%, respectively in 29 years (1986-2015) time. Zerga [38] also reported similar trends for the changes of woodlands and farmlands during 1972-2007 in the the Afar region of Ethiopia. Furthermore, the author also reported increased trends of grazing lands and bare lands in contrast to the present study. This might be due to the expansion of *Prosopis* and other woody species into grazing and bare lands in the present study. Another study in Great Rann of Kachchh Biosphere Reserve of Gujarat, India during 1977-2005 also revealed the the expansion of water bodies and *Prosopis* [26].

In the first period from 1986 to 2000, change matrix analyses showed that areas of woodlands converted to grazing lands were ranked first and followed by *Prosopis* invasions in both districts of study landscapes. Furthermore, in the same period, grazing land areas were converted to woodlands, bare lands, and *Prosopis* in that order in both districts. However, in the second period from 2000 to 2017, major areas of grazing lands were converted to woodlands, farmlands, and *Prosopis* in both districts. On the other hand, in the same period, large areas of woodland were converted to grazing lands, *Prosopis*, farmlands, and water bodies in descending order in both districts. The change matrix analyses also showed that *Prosopis* invasion is progressing largely towards woodland and grazing LULC types in both periods. Moreover, grazing land areas were largely affected by woody species (native plus *Prosopis*) encroachments, expansion of farmlands, and become barren lands in the three decades (1986-2017) in both districts. The increases in areas of *Prosopis* in the districts were mainly owing to the woodland destruction and overstocking of grazing lands. Similar findings for instance reports made by Amboka and Ngigi [4] revealed comparable trends of LULCCs for 25 years (1985-2010) in Baringo Central of Kenya with the present study. Other reports made by Gatew [15] also argued similar patterns of LULCC in Amibara district in Ethiopia.

V. CONCLUSIONS

In both the Amibara and Awash Fentale districts, farmland, water bodies, *Prosopis*, grazing land and settlement areas were increased in the three decades from 1986 to 2017. But, woodland and bare land areas were declined in the districts. These imply that woodlands were devastated for charcoal and firewood purposes. On the other hand, barren lands were recovered at the expense of grazing land and woodland areas during this period in the study areas which implied that better in precipitation in the districts. In the Amibara district, in the first 14 years (1986-2000), farmland and bare land areas were decreased. On the other hand, farmland, water bodies, woodland, and settlement areas were decreased in the Awash Fentale district in the same period. However, in Amibara district, water bodies, *Prosopis*, grazing land and settlement areas were increased from 1986 to 2000. Whereas, *Prosopis*, bare land and grazing LULC types were also increased in the

Awash Fentale district. The decrease of farmland areas in both districts; woodland, water bodies and farmlands in the Awash Fentale district implied the effects of the the invasion of *Prosopis* species which replaced other land uses in the districts.

In the second 17 years (2000-2017), in Amibara district, farmland, water bodies, bare land, settlement areas were increased, whereas farmland, water bodies, woodland, and settlement areas were increased in the Awash Fentale district. On the other hand, *Prosopis*, woodland and grazing land areas become declined in the Amibara district, whereas *Prosopis*, bare land and grazing land areas were declined in the same period in the Awash Fentale district of Afar region. The decline of *Prosopis* and grazing land areas in both districts indicated that management intervention of the *Prosopis* and encroachments woody species into grazing land areas in the districts. Moreover, the decline of barren lands in the Awash Fentale district indicated that the the recovery of lands which were replaced by farmlands, woodlands, and grazing land areas.

In both the districts, large areas of woodlands were converted to grazing land and *Prosopis* during 1986-2000 , whereas, large areas of grazing lands were converted to woodland and bare land in the same period. In the second period (200-2017), large areas of grazing lands were converted to woodlands, farmlands, water bodies, and *Prosopis*, whereas woodlands were converted to grazing lands, *Prosopis*, farmlands and water bodies in both the districts. Expansion of farmlands and invasion of *Prosopis* in the districts are symptoms for the reduction of the prime grazing lands for livestock and threatening of plant diversity through time in the Flora region. These give directions for monitoring and management grazing lands and water bodies in the districts. However, it can be seen that better management is needed so that the resources can be effectively utilized on a sustainable basis. These can be achieved through continues spatiotemporal detection of LULC changes using high-resolution satellite-sensor and GIS software. Therefore, the following recommendations are made to reverse the situations in the districts. The drivers for LULCC should be studied in detail to reverse non-equilibrium dynamics occur in ecosystems across spatiotemporal dimensions. Sustainable and multidisciplinary approach studies regarding history, properties of the invasiveness of *Prosopis* and its ecological and socioeconomic impacts have to be conducted. Create awareness for stakeholders about the monitoring and management of woody species encroachments into grazing lands in the region. Moreover, appropriate silvicultural techniques (e.g. thinning) of *Prosopis* should be practiced to lessen the invasiveness of the species. Furthermore, regional natural resource office should provide alternative energy sources such as solar radiation and biogas plants to alleviate devastation of woodlands in the region. Thus, long-term effects of alien invasive species on soil and biodiversity losses should be investigated in the future.

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FIGURE

Figure 4 LULCC classification of Amibara district in 1986, 2000 and 2017 2017

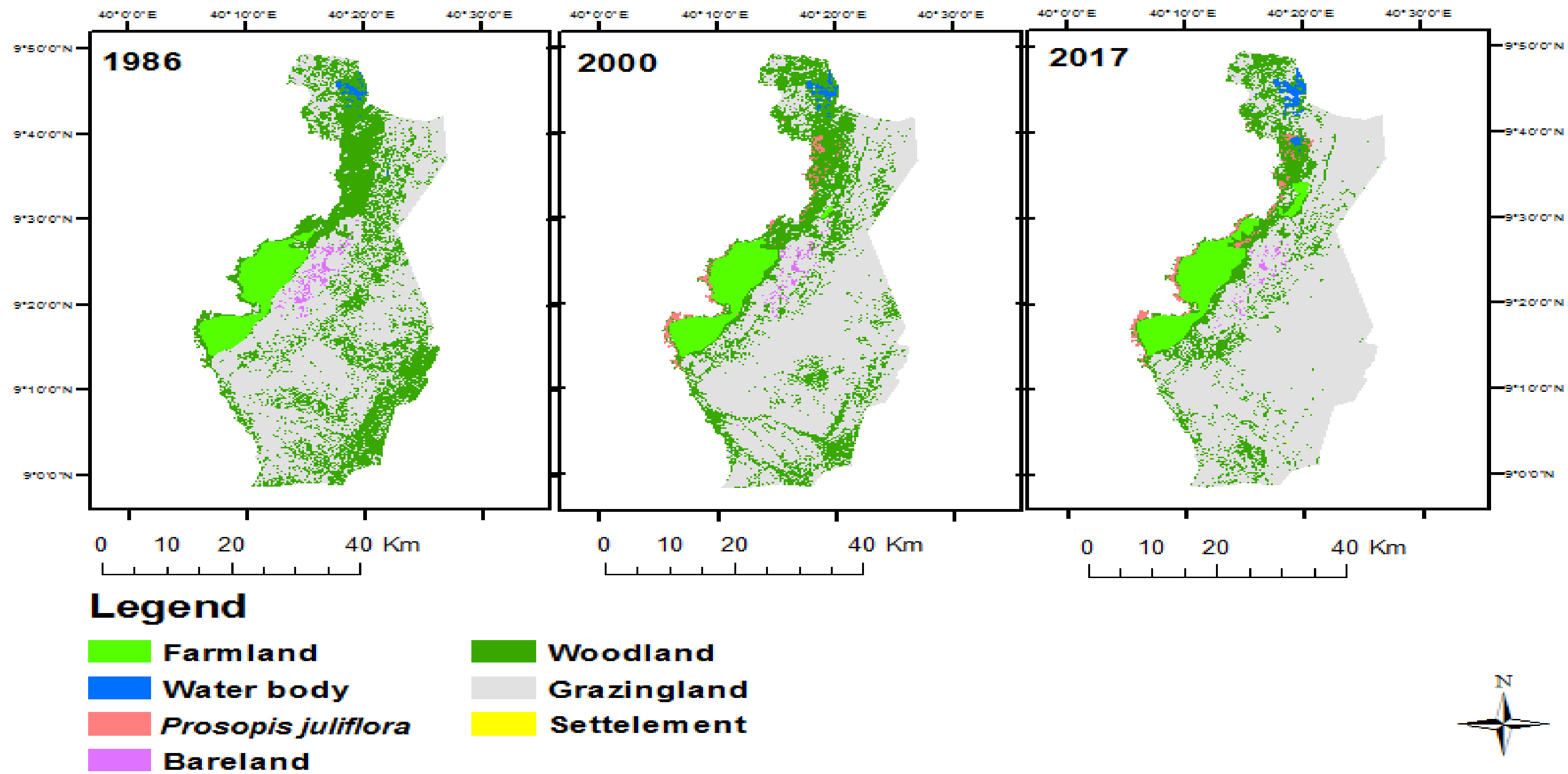


Figure 5 A and B. Change map of Amibara district in A=1986-2000, B=2000-2017.

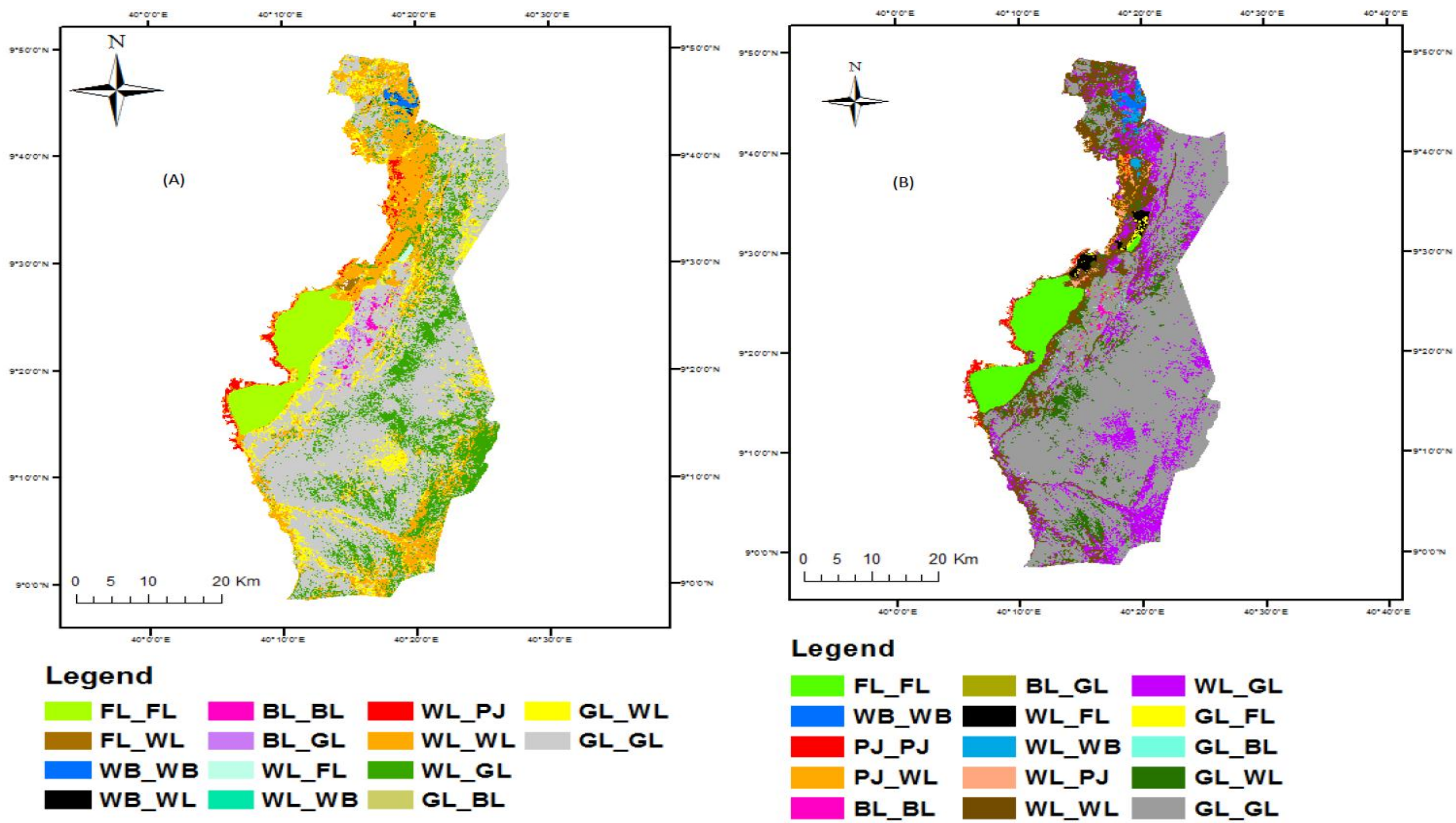
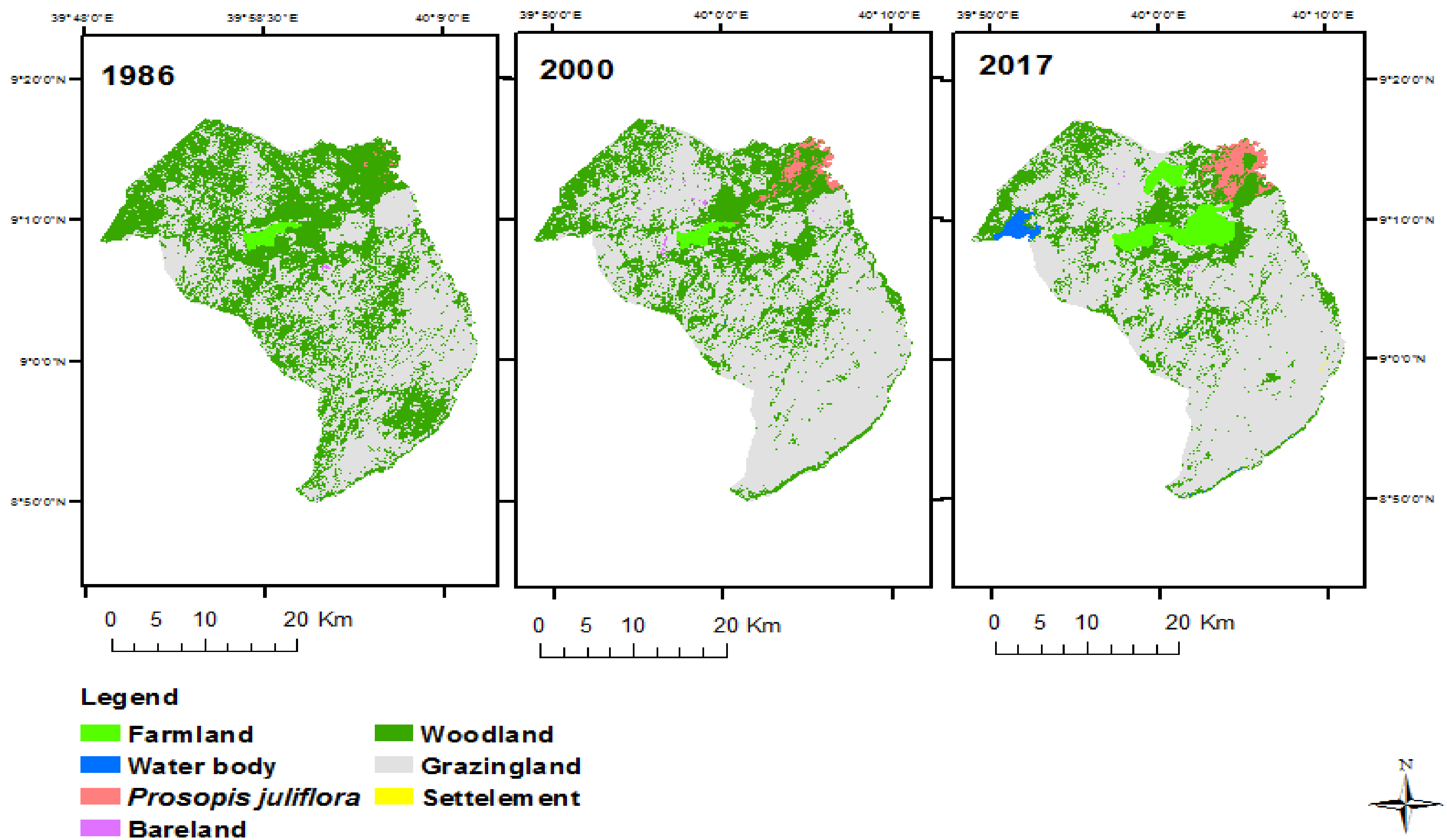
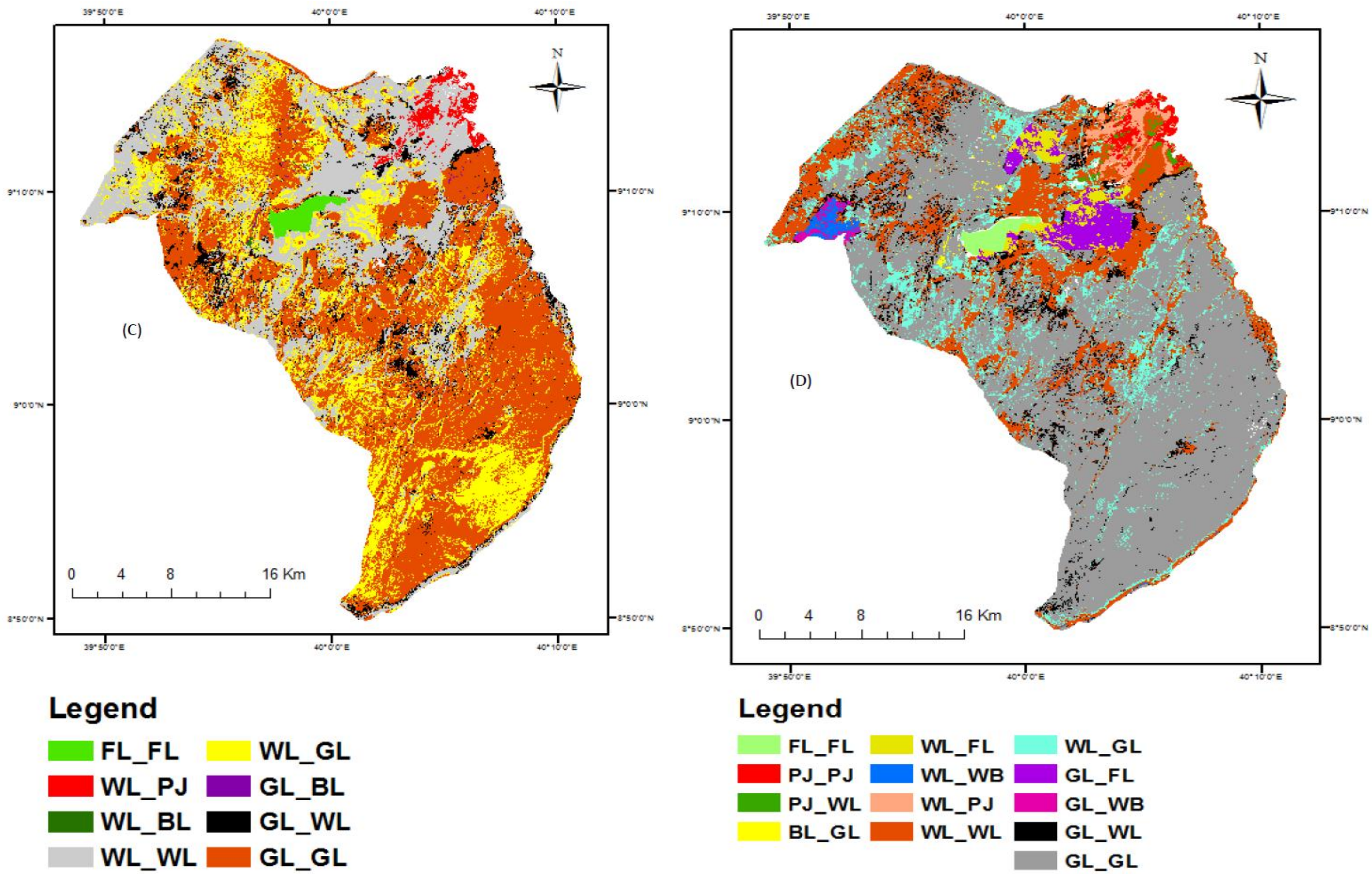


Figure 6 LULCC classification of Awash Fentale district in 1986, 2000 and 2017



ISSN : 2456-1045 (ONLINE)

Figure 7 C and D. Change map of Awash Fentale district in C=1986-2000, D=2000-2017 (Source: https://earthexplorer.usgs.gov/)



TABLES

Table 1 Satellite images used for LULCC of for the study districts of Afar Region in Ethiopia

Satellite	Sensor	Path/Row	Acquisition date	Spatial resolution
Landsat-5	Thematic Mapper (TM)	167/53	30/01/1986	28.5m
		167/54	30/01/1986	
		168/54	21/01/1986	
		167/53	06/02/2000	30m
		167/54	06 /02/2000	
		168/54	13/02/2000	
Landsat 8	OLi/TIRS	167/53	19/01/2017	
		167/54	19/01/2017	
		168/54	26/01/2017	

Table 2 Description of different LULC of the study area

Lists of LULC	Description
Prosopis invaded land	Areas dominated by *Prosopis* species with more than 100 stems and minimum area of 20m × 20m.
Farm land	Land under cultivation for crops (cotton, sugar cane, fruits etc.)
Settlement	Area covered with rural houses and buildings
Bare land	Land devoid of vegetation, pastoral houses and buildings
Grazing land	A field dominated of grass or herbage and with less than 10% canopy of woody species
Woodland	An area covered with acacia and other woody species or non-invaded area with *Prosopis*
Water bodies	A field covered with streams and wetlands areas

Source: own description

Table 3 Error matrix of classification accuracies for 1986

		Real data								
	Land use category	WB	PJ	BL	WL	GL	ST	FL	Total	PA (%)
Predicted data	WB	**50**	0	0	0	0	0	0	50	100.00
	PJ	0	**46**	1	3	0	0	0	46	92.00
	BL	0	0	**43**	3	4	0	0	43	86.00
	WL	0	6	1	**30**	13	0	0	50	60.00
	GL	0	6	2	17	**30**	0	0	30	60.00
	ST	0	2	3	2	9	**32**	0	50	64.00
	FL	0	2	0	4	0	0	**44**	50	86.00
	Total	100	62	50	59	56	32	44		
	UA (%)	100.0	74.20	86.0	50.85	50.85	100.0	100.0		

Overall accuracy = 81.4%; Kappa statistic = 0.77%, UA is users accuracy, PA is producers accuracy.

Table 4 Error matrix of classification accuracies for 2000

Real data

	Land use category	WB	PJ	BL	WL	GL	ST	FL	Total	PA (%)
Predicted data	WB	**47**	0	0	2	1	0	0	50	94.0
	PJ	1	**40**	0	8	1	0	0	50	80.0
	BL	0	0	**41**	1	8	0	0	50	82.0
	WL	0	5	1	**41**	3	0	0	50	82.0
	GL	0	0	0	7	**43**	0	0	50	86.0
	ST	0	2	0	5	12	**31**	0	50	62.0
	FL	0	1	0	4	0	0	**45**	50	90.0
	Total	45	59	41	49	68	37	51		
	UA (%)	95.6	79.7	87.8	83.7	66.2	94.6	96.1		

Overall accuracy = 82.29%; Kappa statistic = 0.79, UA is users accuracy, PA is producers accuracy.

Table 5 Error matrix of classification accuracies for 2017

	Real data									
	Land use category	WB	PJ	BL	WL	GL	ST	FL	Total	PA (%)
Predicted data	WB	**49**	0	0	1	0	0	0	50	98
	PJ	1	**47**	0	2	0	0	0	50	94
	BL	0	0	**35**	4	11	0	0	50	70
	WL	1	5	1	**41**	1	0	1	50	82
	GL	0	0	1	4	**45**	0	0	50	90
	ST	4	0	2	3	11	**30**	0	50	60
	FL	0	0	0	0	0	0	**50**	50	100
	Total	55	52	39	55	68	30	51		
	UA (%)	89.1	90.4	89.7	74.6	66.2	100	98		

Overall accuracy = 84.86%; Kappa statistic = 0.82, UA is users accuracy, PA is producers accuracy.

Table 6 Spatial extent and change of land use types in Amibara district in 1986, 2000 and2017

Land use category	Land use in 1986		Land use in 2000		Land use in 2017	
	Area (ha)	Land use (%)	Area (ha)	Land use (%)	Area (ha)	Land use (%)
FL	15487	7.7	15355	7.64	17366	8.64
WB	954	0.48	1055	0.53	2151	1.07
PJ	32	0.02	2668	1.327	3164	1.57
BL	2186	1.09	1364	0.68	947	0.47
WL	72312	35.968	54980	27.35	36247	18.03
GL	110076	54.75	125610	62.48	141115	70.19
ST	0	0	15	0.01	57	0.03
Total	201047	100	201047	100	201047	100

Note: *FL is farm land, WB is water bodies, PJ is Prosopis invaded land, BL is bare land, WL is woodland, GL is grazing land, and ST is settlement*

Table 7 Land use change assessment of Amibara district based on time frame data (1986–2017).

Land use	Land use change: 1986-2000	Land use change 2000-2017	Land use change 1986-2017

category	MA (ha)	% change	ARC (ha/year)	MA (ha)	% change	ARC (ha/year)	MA (ha)	% change	ARC (ha/year)
FL	-132	-0.85	-9.43	2011	13.1	118.3	1879	12.13	60.6
WB	101	10.6	7.2	1096	103.9	64.5	1197	125.5	38.6
PJ	2636	8237.5	188.3	496	18.6	29.2	3132	9787.5	101.03
BL	-822	-37.6	-58.7	-417	-30.6	-24.5	-1239	-56.7	-40
WL	-17332	-24	-1238	-18733	-34.1	-1101.9	-36065	-49.9	-1163.4
GL	15534	54.8	1109.6	15505	12.3	912.1	31039	28.2	1001.3
ST	15	NA	1.1	42	280	2.5	57	NA	1.8
Total	201047	100		201047	100			100	

Note: *MA is magnitude of change in area, ARC is annual rate of change, (+) Sign denotes Increase and (+) sign denotes decrease of magnitude of change of land use category, NA denotes not available for that category.*

Table 8 Change matrix of LULC from 1986 to 2000 of Amibara district

		1986							
	Land use category	**FL**	**WB**	**PJ**	**BL**	**WL**	**GL**	**ST**	**Total**
2000	FL	**15066**	0	0	0	268	21	0	15355
	WB	0	**789**	0	0	264	2	0	1055
	PJ	2	0	**23**	0	2601	42	0	2668
	BL	0	0	0	**930**	3	431	0	1364
	WL	377	162	9	58	**35547**	18827	0	54980
	GL	42	3	0	1198	33628	**90739**	0	125610
	ST	0	0	0	0	1	14	**0**	15
	Total	15487	954	32	2186	72312	110076	0	201047

Table 9 Change matrix of LULC from 2000 to 2017 of Amibara of district

		2000							
	Land use category	**FL**	**WB**	**PJ**	**BL**	**WL**	**GL**	**ST**	**Total**
2017	FL	**15329**	0	1	0	1600	436	0	17366
	WB	0	**1046**	0	0	1105	0	0	2151
	PJ	0	0	**1512**	0	1638	14	0	3164
	BL	0	0	0	**698**	5	244	0	947
	WL	26	9	1102	26	**24657**	10422	5	36247
	GL	0	0	53	640	25961	**114452**	9	141115
	ST	0	0	0	0	14	42	**1**	57
	Total	15355	1055	2668	1364	54980	125610	15	201047

Table 10 Spatial extent and change of land use types in Awash Fentale district in 1986, 2000 and 2017

Land use category	**Land use in 1986**		**Land use in 2000**		**Land use in 2017**	
	Area (ha)	**Land use (%)**	**Area (ha)**	**Land use (%)**	**Area (ha)**	**Land use (%)**
FL	976	0.93	976	0.933	5234	5.0
WB	28	0.03	9	0.01	1063	1.02
PJ	79	0.08	1479	1.41	2614	2.5
BL	92	0.09	277	0.27	37	0.04
WL	51070	48.83	33337	31.87	25050	23.95
GL	52351	50.05	68515	65.5	70538	67.44
ST	0	0	3	0.003	60	0.06
Total	104596	100	104596	100	104596	100

Table 11 Land use change assessment of Awash Fentale district based on time frame data (1986–2017).

Land use category	Land use change: 1986-2000			Land use change 2000-2017			Land use change 1986-2017		
	MA (ha)	% change	ARC (ha/year)	MA (ha)	% change	ARC (ha/year)	MA (ha)	% change	ARC (ha/year)
FL	0	0	0	4258	436.3	25.7	4258	436.3	137.4
WB	-19	-67.9	-4.9	1054	11711	688.9	1035	3696	33.4
PJ	1400	1772.2	126.6	1135	76.7	4.5	2535	3208.9	81.8
BL	185	201.1	14.4	-240	-86.6	-5.1	-55	-59.9	-1.8
WL	-17733	-34.7	-2.5	-8287	-24.9	-1.5	-26020	-51	-839.4
GL	16164	30.9	2.2	2023	3	0.2	18187	34.7	586.7
ST	3	NA	0	57	1900	111.8	60	NA	1.9
Total	104596	100		104596	100		104596	100	

Note: *MA is magnitude of change in area, ARC is annual rate of change, (+) Sign denotes Increase and (+) sign denotes decrease of magnitude of change of land use category, NA denotes not available for that category.*

Table 12 Change matrix of LULC from 1986 to 2000 of Awash Fentale district

		1986							
	Land use category	**FL**	**WB**	**PJ**	**BL**	**WL**	**GL**	**ST**	**Total**
2000	FL	**969**	0	0	0	6	1	0	976
	WB	0	**2**	0	0	7	0	0	9
	PJ	0	0	**48**	0	1395	36	0	1479
	BL	0	0	0	**16**	134	127	0	277
	WL	6	24	31	9	**26392**	6875	0	33337
	GL	1	2	0	67	23134	**45311**	0	68515
	ST	0	0	0	0	2	1	**0**	3
	Total	976	28	79	92	51070	52351	0	104596

Table 13 Change matrix of LULC from 2000 to 2017 of Awash Fentale district

		2000							
	Land use category	FL	WB	PJ	BL	WL	GL	ST	Total
2017	FL	**901**	0	2	7	1683	2641	0	5234
	WB	0	**4**	0	1	640	418	0	1063
	PJ	2	0	**1016**	0	1518	78	0	2614
	BL	0	0	0	**5**	0	31	1	37
	WL	51	5	394	8	**18834**	5758	0	25050
	GL	22	0	67	256	10651	**59540**	2	70538
	ST	0	0	0	0	11	49	**0**	60
	Total	976	9	1479	277	33337	68515	3	104596

*****