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Review

A review on Land Use and Land Cover Change in Ethiopian basins

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Abstract: Land Use Land Cover (LULC) changes analysis is one of the most useful methodologies to understand how the land was used in the past years, what types of detections are to be expected in the future, as well as the driving forces and processes behind these changes. In Ethiopia, the rapidly changing of LULC is mainly due to population pressure, resettlement programs, climate change, and other human and nature-induced driving forces. Anthropogenic activities are the most significant factors adversely changing the natural status of the landscape and resources, which exerts unfavourable and adverse impacts on the environment and livelihood. The main goal of the present work is to review previous studies, discussing the spatio-temporal LULC changes in Ethiopian basins, to find out common points and gaps that exist in the current literature, to be eventually addressed in the future. Seventeen articles, published from 2011 to 2020, were selected and reviewed, focusing on LULC classification using ArcGIS and ERDAS imagine software by unsupervised and maximum likelihood supervised classification methods. Key informant interview (KII), focal group discussions (FGDs) and collection of ground truth data using ground positioning systems (GPS) for data validation were the major approaches discussed in most of the studies. All the analysed research showed that, during the last decades, Ethiopian lands changed to agricultural land use, waterbody, commercial farmland and built-up/settlement. Some parts of forest land, grazing land, swamp/wetland, shrubland, rangeland and bare/ rock out cropland cover class were changed to other LULC class types, mainly as a consequence of increasing anthropogenic pressure. In summary, these articles confirmed that LULC changes are a direct result of both natural and human influences. However, most of the study provided details of LULC for the past decades within a specific spatial location, while they did not address the challenge of forecasting future LULC changes at the basin scale.

Keywords: Ethiopia; Geographic Information Systems; Land Use Land Cover; Remote Sensing

1. Introduction

Land use is defined as how the land is utilized by people and their habitats, usually with an accent on a functional role of land for economic activities, whereas land cover is a physical characteristic of the Earth's surface [1,2]. Land use land cover (LULC) dynamics are a well-known, accelerating, and substantial process that is mostly driven by human activities. Land use land cover changes (LULCC) analysis is one of the most used techniques to understand how the land was used in the past years, what types of detections are to be expected in the future, as well as the driving forces and processes behind these changes [3]. Besides natural variations, the increasing human population is driving modifications of the Earth's land surface that are unprecedented. Therefore, there is the need to better evaluate changes in the land cover (namely, the biophysical attributes of the Earth's surface) and land use for human purposes to understand the past variations and depict future trends for the coming decades.

LULCC are so persistent that, when aggregated globally, they expressively affect strategic aspects of Earth System functioning. They directly impact biotic diversity worldwide, contribute to local and regional climate change as well as global climate warming, are one of the primary sources of soil degradation. By altering ecosystem services at the local and regional scale, LULCC affect the ability of biological systems to support and adapt to human needs [4]. Indeed, the major modifications of LULC worldwide could be related to the intense agricultural development and the growing population [5].

Similar to the rest of the world, East Africa (Horn of Africa) is not an exception to these land use land cover changes [6]. In particular, very rapid changes are clearly recognizable in Ethiopia, due to the population pressure, resettlement programs, climate change, and other human and nature-induced driving forces. Similarly to other countries, anthropogenic activities are the most significant factors adversely changing the natural status of the Ethiopian landscape [7], involving detrimental and adverse impacts on the natural environment and livelihood [9]. The land is a critical resource for the livelihood of East Africans and there has been a steady decline in the size of land holdings per household. Following the demand for land, LULCC in this region have resulted in a decline of natural forests to human settlements, urban centres, farmlands, and grazing lands. Between 1990 and 2015, the East Africa forest cover decreased annually by about 1% while the human population increased at an average annual rate of around 2% [6]. As pointed out by Dibaba et al. [10], factors such as biophysical, socio-economic, institutional, technological and demographic, contributed to LULCC, which leads to a decline in the agricultural yield and a loss of biodiversity in the entire upper Blue Nile Basin, but significantly in the Finchaa sub-basin in the Oromia Regional State, Ethiopia. The authors also pointed out that extended aridity and persistent drought, land and soil degradation, as well as the decline of water resources in general, are the major consequences of LULCC at the regional scale.

Forest disturbance and the subsequent conversion to other LULC classes (such as grazing land, agricultural land, bare land, pasture or settlement areas) could modify the hydrologic cycle at the local scale, involving significant effects on water yields, water quality and streamflow dynamics [11]. The rapid rate of deforestation is mainly occurring because of several reasons like unsustainable large and small scale agriculture, forest fire, migration and population growth, illegal logging for construction purpose, charcoal and fuelwood production for cooking and poor resource management [12]. Where deforestation is connected to the increased occurrence of shifting cultivators, triggering mechanisms invariably involve changes in land development and new policies by the national governments that push migrants into sparsely occupied areas [4]. Focusing on the Horn of Africa, the main forest types that have undergone this decrease are tropical rain and dry forests, tropical shrubs, tropical maintain the forest, and mangrove forests, while there have been intensive efforts to establish plantation forests [6]. Land policy in developing countries like Ethiopia is considered a crucial part of the overall development policy that the national governments need for assuring rapid economic growth and poverty mitigation, regardless of the natural resources management [13].

Ethiopia is historically passed significant dynamics in LULC for many decades. But nowadays LULCCs and degradation are increasing at an alarming rate, playing a significant role in the increasing rate of soil erosion. The need for more cultivated lands has negatively affected the presence of forest and grasslands, eventually fostering soil erosion [14]. Environmental conversions and changes can be mainly attributed to various adverse human actions, like the expansion of farm plots at the expense of agricultural lands, massive fuelwood and charcoal production, overgrazing and encroachment of farmsteads into vegetated lands. According to Tefera [7], ecologically, Ethiopia is characterized by a rich, but shrinking, diversity in biological resources such as forest, woody and grassy lands, shrubs, varied wildlife, and fertile soil. It is also renowned for its massive mountain ranges, high flat plateaus, deep gorges, river valleys, lowland plains, extensive wetlands, and deserts. Landscape degradation by soil erosion has increased considerably in the Ethiopian highlands since the deforestation of the natural mountain forests and the cultivation of large areas, resulting in serious danger to the Ethiopian population [15]. This also affects the water balance of an area by changing the balance between rainfall, evaporation, infiltration and runoff. Based on the observed trends, it is clear that a systematic analysis of LULCC is crucial to exactly comprehend the extent of the changes and take necessary measures to scale down the soil erosion [16], rate of changes and protect the land cover resources sustainably.

The main objective of this article is to review the actual literature on LULC in Ethiopian basins, to point out what are the existing situations and the research gap that should be addressed in the future.

2. Case study: Ethiopia

Ethiopia is located in the North-Eastern part of the African continent, in the so-called Horn of Africa, which lies between 3º and 18º North latitude, 33º and 48º East longitude, within the tropics (Figure 1). The total area of the country is 1,119,683 km^2, while the area occupied by waterbodies is 7,444 km^2 [17]. Ethiopia is a country where about more than 80 million people, containing 50.46% male, is grappling with all sorts of natural and manmade problems, like famine; environmental degradation; erratic rainfalls; the prevalence of malaria and HIV/AIDS; poor, but improving, governance; and widespread poverty. About 84% of the people live in rural areas, assuring their livelihoods thanks to subsistence agriculture, which is a sector nowadays suffering from the lack of essential inputs and a very variable rainfall pattern. Poverty is more than common in Ethiopia, though slightly declining over time [7].

In terms of geography, the prominent features of Ethiopia are the extensive high lands, surging plateaus, and deep river canyons and the Great East African Rift System, dividing the country into the central/western part, mostly mountainous, and the southern highlands, which are surrounded by lowlands [18]. As indicated by Tefera [7], about 45% of the country is highland, with an average altitude greater than 1500 m and peaks of around 4000 m, in which about 88% of the country's population is located. Overpopulation, extensive croplands, and frequent incision by ravines and gullies characterize the highlands. On the basis of altitude, its influence on temperature and rainfall, Ethiopia is traditionally classified into four broad agro-climatic zones. These are termed as wurch (cold-moist); dega (cool-humid); woina dega (semi-humid); and qolla (arid and semi-arid). The wurch region encompasses all areas located around 3200 m above the mean sea level, with an average annual rainfall of over 22 mm. The dega zone consists of areas with altitudes and an average annual rainfall ranging from 2400 to 3200 m, and 1200 to 2200 mm, respectively. The woinadega zone covers areas within the altitudinal range of 1500 to 2400 m, having an average annual rainfall of 800 to 1200 mm. The qolla zone refers to areas lying below the altitude of 1500 m, where the average annual rainfall is around 800 mm [7]. In addition to these four regions, the Ethiopian physical environment can further be classified into eleven more detailed groups, still depending on average altitude and annual rainfall: bereha (namely, desert); dry-qolla; moist-qolla; wet-qolla; moist-woina dega; wet-woina dega; moist-dega; wet-dega; moist-wurch; wet-wurch; high-wurch.

The Ethiopian economy is among the most vulnerable in sub-Saharan Africa, and it is heavily dependent on the agricultural sector, which has suffered from the recurrent droughts, that reflected in extreme fluctuations of outputs. For example, agricultural production has been growing by about 2.3% during the period 1980-2000, while the population was growing at an average rate of 2.9% per year, leading to a decline in per capita agricultural production by about 0.6% per year [8]. According to this report, the percentage of people in Ethiopia who are absolutely poor in the year 2001 was around 44%, but the level of poverty shows significant variation among rural, urban areas and across regional states. In Ethiopia, the income distribution seems to be more unequally distributed in rural and urban areas, compared to other Sub-Saharan African countries. To tackle this situation, in recent time the Ethiopian Ministry of Agriculture and Rural Development (MoARD) announced one of the most detailed agro-ecological arrangements of the country, by taking also moisture regimes into account, in addition to altitude and temperature.

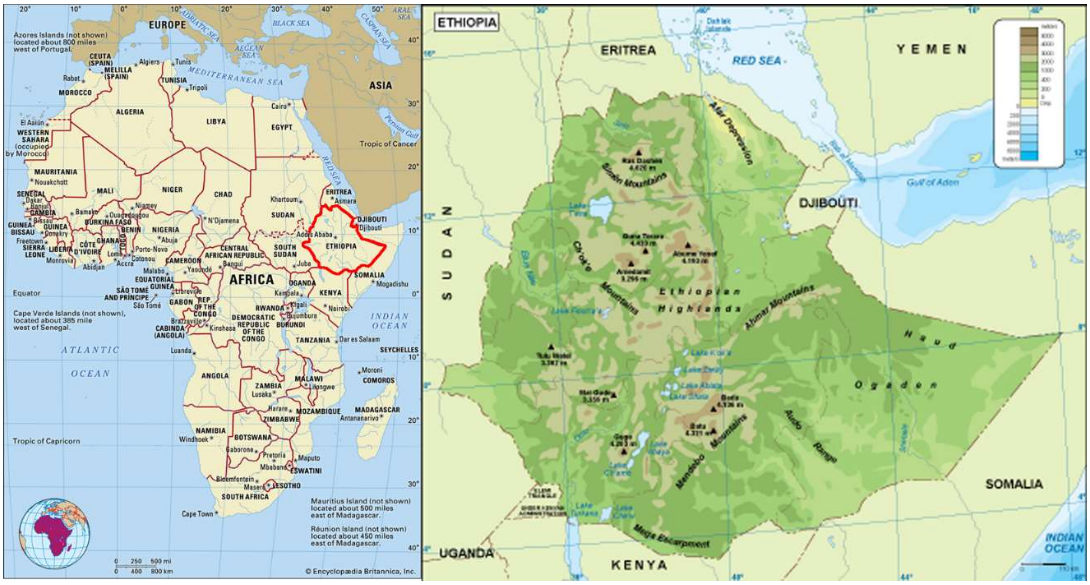

Figure 1. Maps of Africa (on the left) and Ethiopia (on the right).

3. Methodology

The present work is based on a review conducted on peer-reviewed articles published in the last ten year, from 2011 to 2020, which were focused on the issue of land use land cover change in Ethiopian basins. The search was based on the exact phrase of "Land use land cover changes in Ethiopia" in the Web of Google scholars, which searches within each article's title, abstract, keywords, years of publication and "keywords plus", a series of additional relevant keywords selected by well-known databases like Web of Science, Scopus and Google Scholars. Based on these criteria, seventeen articles were selected and systematically reviewed to find out the strength and the research gaps in the study of LULCC in Ethiopian watersheds (Table 1).

Table 1. Summary of the revised literature.

article num.	*authors*	*title*	*year*
1	Ayana, A.A.; Kositsakulchai, E.	Land Use Change Analysis Using Remote Sensing and Markov Modeling in Fincha Watershed, Ethiopia	2012
2	Dibaba, W.T.; Demissie, T.A.; Miege, K.	Drivers and Implications of Land Use/Land Cover Dynamics in Finchaa Catchment, Northwestern Ethiopia	2020
3	Ayana, A.B.; Edossa, D.C.; Kositsakulchai, E.	Modeling the Effects of Land Use Change and Management Practices on Runoff and Sediment Yields in Fincha Watershed, Blue Nile	2014
4	Betrua, T.; Tolera, M.; Sahleb. K.; Kassac, H.	Trends and drivers of land use/land cover change in Western Ethiopia	2019
5	Mariye, M.; Mariyo, M.; Changming, Y.; Teffera, Z.L.; Weldegebrial, B.	Effects of land use and land cover change on soil erosion potential in Berhe district: a case study of Legedadi watershed, Ethiopia	2020

6	Biazina, B.; Sterk, G.	Drought vulnerability drives land-use and land cover changes in the Rift Valley dry lands of Ethiopia	2012
7	Hailua, A.; Mammo, S.; Kidane, M.	Dynamics of land use, land cover change trend and its drivers in Jimma Geneti District, Western Ethiopia	2020
8	Gebreslassie, H.	Land Use-Land Cover dynamics of Huluka watershed, Central Rift Valley, Ethiopia	2014
9	Tolessa, T.; Senbeta, F.; Kidane, M.	The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia	2017
10	Alemu, B.; Garedew, E.; Eshetu, Z.; Kassa, H.	Land Use and Land Cover Changes and Associated Driving Forces in North Western Lowlands of Ethiopia	2015
11	Fisseha, G.; Gebrekidan, H.; Kibret, K.; Yitaferu, B.; Bedadi, B.	Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile Basin, Northwest Ethiopia	2011
12	Mussa, M.; Teka, H.; Mesfin, Y.	Land use/cover change analysis and local community perception towards land cover change in the lowland of Bale rangelands, Southeast Ethiopia	2017
13	Alemayehu, F.; Tolera, M.; Tesfaye, G.	Land Use Land Cover Change Trend and Its Drivers in Somodo Watershed South Western, Ethiopia	2019
14	Tolessa, T.; Dechassa, C.; Simane, B.; Alamerew, B.; Kidane, M.	Land use/land cover dynamics in response to various driving forces in Didessa sub-basin, Ethiopia	2020
15	Tefera, M.M.	Land-Use/Land-Cover Dynamics in Nonno District, Central Ethiopia	2011
16	Dinka, M.O.; Klik, A.	Effect of land use–land cover change on the regimes of surface runoff—the case of Lake Basaka catchment (Ethiopia)	2019
17	Othow, O.O.; Gebre, S.L.; Gemeda, D.O.	Analyzing the Rate of Land Use and Land Cover Change and Determining the Causes of Forest Cover Change in Gog District, Gambella Regional State, Ethiopia	2017

Being not yet standardized, the LULC classification method is highly subjective, and can change from one study to the other. Therefore, in the analysis, land classes' name which may have a similar meaning or approach was considered as one. For example, the brushland class cover was taken as a shrubland class cover. Moreover, in some cases, a single class was classified as a combination of both, such as in the case of [19], where the settlement and agricultural land cover classes were classified together as "settlement/agricultural" class. For such a case, we selected only the dominating class. Therefore, the agricultural class was chosen instead of the built-up/settlement one.

For those articles that did not describe the LULCC for each class between the final and initial year, the percentage of LULCC was:

$$LULCC = \frac{(LULC_{t1} - LULC_{t0})}{A} * 100$$

where A is the total area of the study region, while $t0$ and $t1$ are the initial and final year, respectively.

To compare the different articles, the LULCC percentages of each watershed were determined as:

$$LULCC_W = \frac{PLCCC\ in\ P1 + PLCCC\ in\ P2 + PLCCC\ in\ P3 + \cdots + PLCCC\ in\ P17}{total\ number\ of\ articles\ in\ which\ the\ LULC\ was\ used}$$

where W indicates the watershed, while $PLCCC$ and P represent the percentage of land class cover change and the article number (Table 1), respectively.

For example, agricultural LULC was classified in all articles except in the work of Ayana et al. [22]. Therefore, the magnitude of such LULCC was determined depending on the sixteen articles, as:

$$\frac{Ag1 + Ag2 + Ag4 + Ag5 + Ag6 + Ag7 + Ag8 + Ag9 + Ag10 + Ag11 + Ag12 + Ag13 + Ag14 + Ag15 + Ag16 + A17}{16}$$

where Ag is the agricultural land use, while the subscripts indicate the article number.

As another example, the percentage of waterbody LULCC was calculated as:

$$\frac{Wb1\ +\ Wb2\ +\ Wb5\ +\ Wb7\ +\ Wb10\ +\ Wb16\ +\ Wb17}{7}$$

where Wb is the waterbody land use. From this, it can be seen that the waterbody LULCC are addressed in articles 1, 2, 5, 7, 10, 16 and 17 (see Table 1).

4. Article analysis

According to Mariye et al. [2], the maximum likelihood classification method was used to study LULC of the Lege Dadi watershed, for 1995, 1997 and 2013, by using the ERDAS Imagine 9.2 software. The study was aimed to investigate the effects of LULCC on soil erosion potential in the Berhe district, a small portion of the Lege Dadi basin. To achieve the objective of the study, Landsat satellite images were downloaded from the United States Geological Survey (USGS) official website (earth explorer.usgs.gov). The results of classification show six LULC classes: water body (including man-made reservoir), cultivated land, settlement, grazing land, forest (composed mainly of Eucalyptus globules plantation) and bare land. Comparing the different years, the authors observed that cultivated land, settlement and forest increased, while a decrease was observed looking at the areas covered by waterbodies, grazing land and bare land. besides using remote imagery, the authors of this study conducted a series of focus group discussions with farmers, development agents, cabinet members, elders and knowledgeable community representatives to get further information about the long term experience of LULC practices in the watersheds. In their report, the settlement area and cultivated land were increased significantly, whereas grazing land and bare land classes were reduced, confirming what was retrieved from satellite data.

Similarly, in [20], a maximum likelihood classification method was used in combination with a Geographic Information System (GIS) to study the drought vulnerability drives of LULCC in the Rift Valley drylands of Ethiopia using aerial photographs, satellite imagery, rainfall and ground measured data. Specifically, aerial and satellite images refer to 1965, 1986 and 2000, while ground-based measurements were taken in 2010. The inputs data, such as aerial photographs and satellite images, were obtained from the Ethiopian Mapping Authority and Global Land Cover Facility (glcf.umd.edu/data/landsat), respectively. Also in this case, focused group discussions with selected stakeholders and semi-structured interviews with key informants, as well as questionnaires, were considered as a support methodology to assess LULCC in the area. The report shows five LULC classes, such as dense acacia woodland, scattered acacia with grass undergrowth, grassland, cultivated land and bare lands. Both dense acacia vegetation and scattered acacia were consistently decreased from 1965 to 2010; grassland cover was increased from 1965 to 2000 years and slightly decreased from 2000 to 2010 years; bare land was increased from 1965 to 1986 and then decreased from 1986 to 2010 years. The cultivated land was increased from 1986 to 2010 years. From this analysis, it is clear that agriculture is becoming the predominant LULC class in the basin.

Gebreslassie [9] studied the LULC dynamics of the Huluka watershed, Central Rift Valley, Ethiopia from 1973 to 2009. In this research, both supervised and unsupervised classification was used to classify LULC via the ERDAS Imagine 8.4 software. During the study, key informant interview, focal group discussion and field data collection were combined to validate the results. The finding shows six LULC classes, namely cultivated land, woodland, open land, grassland, shrubland, continuous NF, fragmented NH and plantation forest. Of these LULC classes, only cultivated and open lands had shown continuous and progressive expansion, mainly at the expense of grass, shrub and forest lands. In detail, the 25% and 0% of cultivated and open land of the watershed in 1973 expanded to 84% and 4% in 2009, respectively; while the 29%, 18% and 22% of grass, shrub and forest land of the watershed in 1973 decreased to 3.5%, 4% and 1.5% in 2009, respectively.

To evaluate the trends and drivers of LULC in Western Ethiopia, Betru et al. [19] classified the region into four classes (forest, agriculture, shrub/grass and settlement), comparing the years 1978, 1986, 1991, 1999, 2010, 2013 and 2016. They adopted a hybrid method, combining the outputs of supervised classified and intensive on-screen digitizing (visual image interpretation) techniques to produce LULC maps. To determine LULCC, multi-sensor and multi-temporal Landsat images were accessed freely from the USGS website. To validate the results, key informants interviews and focal group discussion was conducted to collect historical information of the last decades. The report shows that 74% of forest was maintained, while the remaining was changed to shrub/grassland (21%) and agriculture (5%) to 1986 and 1991; nearly 95% of the forest gain in this period was from shrub/grassland. Between 1978 and 1986, most of the forest was degraded to shrub/grasslands for the need of construction materials, fuelwood and charcoal; similar to the period from 1986 to 1991, 32% of forest was lost from 1991 to 2010 and the conversion during this period was to shrub/grass and agriculture. 51.7% and 44.7% of the forest land was converted to agriculture and shrub/grasslands, respectively, due to the large expansion of commercial agricultural practice between 2010 and 2016. In the same period also 25% of the forest land was recovered from shrub/grassland.

In [21], the authors focused on the Fincha watershed. The basin was classified into agricultural land, forest land, grazing land, waterbody, swamp and shrubland classes for the years 1985, 1995 and 2005. The goal of this work was to evaluate LULCC combining remote sensing and Markov Modeling, by using freely available Landsat data. The ERDAS Imagine software and a number of methodologies like supervised maximum likelihood classification, LULC detections and spatial matrix analysis were adopted to evaluate LULCC for the twenty years study periods, analyzing separately the decades 1985-1995 and 1995-2005. The finding shows that agricultural land and waterbodies have increased in the area by around 54% and 93%, respectively, while great losses were observed in the case of forest land, grazing land, swamp area and shrubland, by 51%, 31%, 51% and 25%, respectively.

Looking at the same basin, Dibaba et al. [10] applied a supervised classification with the maximum likelihood classifier in ArcGIS to classify the land classes in the years 1987, 2002 and 2017, combining Landsat images, Digital Elevation Model and field data. The aim of this study was not only to compare the changes between the different years, but also understanding their drivers and implications. The research pointed out that, during the last thirty years, agricultural land, commercial farm, built-up and waterbody classes increase by 16%, 5%, 1.7% and 1.7%, respectively, while forest land, rangeland, grazing land, and swampy areas decreased by 12%, 8%, 3% and 1%, respectively. To support the research outcomes, the authors carried out key informant interviews, focal group discussions and field data collection, focusing on socio-economic aspects.

Likewise, in [22], Ayana et al. classified the LULC of the Fincha watershed for the year 2005, using Landsat ETM+ images, to model the effects of LULCC and management practices on the runoff and sediment yields in the Fincha watershed. The authors combined supervised classification based on the minimum distance algorithm method, a Digital Elevation Model, LULC data, soil information, and weather data. Their results show six classes: agricultural land, forest, grazing land, waterbody, swamp area and shrubland. In accordance with evidence pointed out by other authors ([10,21]), more than half of the watershed was covered by agricultural land and the remaining was covered, in decreasing order, by waterbody, grazing land, forest, shrubland and swamp.

Hailu et al. [23] studied the dynamics and drivers of LULCC in the Jimma Geneti District, Western Ethiopia, from 1973-2019, using satellite images from the USGS website. A supervised maximum likelihood classification method was adopted to classify LULC change within the period, while key informant interviews and focal group discussions were carried out to validate the results. In total, the authors classified six LULC classes: bare land, cultivated land, forest, settlement area, waterbody and wetland. During the study period, cultivated land, settlement area and waterbodies increased, whereas forest land, bare land and wetlands decreased.

In his work, Tolessa et al. [24] studied the impact of LULCC on ecosystem services in the central highlands of Ethiopia, from 1973 to 2015, by using multispectral Landsat imaginary (Landsat MSS, TM, ETM+ and Land OLS). Analyzing these satellite images via the maximum likelihood classification method, they were able to classify the region into five classes (settlement, cultivated land, bare land, shrubland and forest). The authors performed ground control points to assist the supervised image classification. The report shows the cultivated land and shrubland expanded significantly between 1973 and 2015, while the forest decreased. No significant changes were observed on both settlement area and bare land.

Alemu et al. [25] analysed the LULCC implications and drivers in the North-Western Lowlands of Ethiopia during the period 1985-2010, by combining supervised and unsupervised methods of remotely-sensed images. Similarly to other studies, key informant interviews, group discussions and ground control points were performed to validate the classification results. The study areas were classified into six LULC classes, namely agricultural land, bare land & settlement, woodland, shrubland, grassland and waterbody. By comparing three reference years (1985, 1995, 2010), the authors pointed out an increment of the area covered by agriculture, bare land & settlement, grassland and waterbodies, while woodland and shrubland declined.

In [26], the authors concentrated on the Debre-Mewi watershed, which is the upper catchment of the Blue Nile Basin, in Northwest Ethiopia. In this case, three reference years were observed (1957, 1982 and 2008), and aerial photographs and multi-spectral Landsat satellite images were compared to assess LULCC. To validate the outcomes, information derived from key informant groups and focal group discussions, as well as field data, were collected. The report shows that the area was classified into four LULC classes: natural forest, shrub and bushland, grazing land and cultivated & settlement land in 1957. Additional classes were added for the 1982 (Eucalyptus plantation) and 2008 (Eucalyptus plantation, rock outcrop) analyses. In fact, after the 1960s, most individual farmers started cultivating plantation around their homesteads, as a source of fuelwood, construction material and income generation and some of the severely degraded cultivated and grazing lands were converted to rock outcrops. For this reason, during the last decades cultivated & settlement areas increased significantly, whereas natural forest, shrub & bushland and grazing land declined rapidly.

According to [27], a combination of unsupervised and supervised classification methods were employed to classify Landsat images of the Bale rangelands, in Southeast Ethiopia, to study LULCC at the regional scale, and how the local community perceive such changes. The authors performed key informant interview and field data collection to support and validate the results. In this case, the study area was classified into seven LULC classes: woodland, bushland, shrubby grassland, grassland, cultivated land, bare land and settlement, using 1986, 2001 and 2016 as reference years. During these 30 years, cultivated land, settlement, bushland and bare land expanded by 14%, 15%, 13% and 22% respectively, while woodland, grassland and shrubby grassland declined by 34%, 24% and 3%, respectively.

Alemayehu et al. [3] studied the trend of LULCC in the Somodo Watershed South Western, Ethiopia, trying to address the main drivers of such changes. They applied both unsupervised and maximum likelihood supervised classification method using ERDAS imagine 9.1. Landsat images, freely obtained from the USGS website, and key informant, focal group discussion and field data techniques were combined to derive coherent information. The Somodo watershed was classified into four LULC classes: agriculture, forest, grass and home garden agroforestry. The study addressed the changes that occurred between 1985 and 2017, pointing out that the area covered by forest and agriculture decreased by 61ha (13%) and 5 ha (1%), respectively. In contrast, home garden agroforestry/settlement and grassland increased by around 50 (7%) and 16 (6%), respectively. The authors calculated that, assuming the same existing rate of LULCC, in 2029 agriculture and forestland are predicted to increase by 91 ha and 21 ha, respectively, while grassland and home garden agroforestry/settlement will decrease by 100 ha and 11.79 ha, respectively.

The study in [5] was conducted on LULC dynamics in the Didessa sub-basin, trying to understand the various driving forces that shaped the landscape in the period 1974-2014, looking at decadal changes. The analysis was performed via both the unsupervised and supervised classification methods, using the ERDAS Imagine 2010 classifier within the ArcGIS software. As made in similar studies, the imagery data used for land cover change were obtained freely from the USGS website, while key informant interviews and focal group discussions were carried out for better understanding the observed dynamics and validate the satellite data. In this case, the study area was classified into seven LULC classes: wetland, shrubland, settlement, grassland, forest, cultivated land and commercial land. The authors' analysis shows that, during the four decades (1974-2014), agricultural land, settlement and commercial land increased, while wetland, grassland, forest and shrubland rapidly decreased.

Tefera [7] studied LULC dynamics in the Nonno district, located in Central Ethiopia, for the period 1987-2007. The research combined three satellite datasets: Landsat Thematic Mapper with 30 m of spatial resolution (image of 1984), Landsat Enhanced Thematic Mapper Plus with 30 m resolution (image of 2002), and SPOT image of 2007 with 5 m resolution. Key informant interviews, specifically made with older peoples, focal group discussions and field data were combined to validate the satellite-derived LULCC analysis. The Nonno district was classified into woodland, shrubland, grassland, cultivated land, settlement site and town. During the observed period, woodland and grassland decreased their extension, while shrubland, cultivated areas and settlements expanded. In particular, woodland and farmland were the two most decreased and increased land use types in the district, respectively.

Focusing on the Lake Basaka catchment, Dinka and Klik [11] studied how LULCC affected the regimes of surface runoff during the period 1973-2015. To do that, they adopted a common methodology, processing Landsat data with the ERDAS Imagine software, and using both unsupervised and supervised classification methods. The catchment area was classified into seven classes: farmland, forest (comprising dense woods), shrubland, grassland, bushy woods (open) land, wetland and waterbody. The report indicates that the Lake Basaka catchment experienced significant LULCC: about 86% of forest coverage and 46% of grasslands were lost over, at the territory was transformed to open bushy woodlands, farms, lakes and wetlands.

To analyze the rate of LULCC during the period 1990-2017, and determining the causes of changes in forest coverage in the Gog district, Gambella Regional State, Othow et al. [12] used the maximum likelihood technique of the supervised classification of the ERDAS Imagine 2014 software. The area was classified into six classes: waterbody, forest, farmland, bushland, bareland and grassland. The authors used free thematic maps (USGS website) and performed key informant interviews, focal group discussions and field data collection to validate the result. Between 1990 and 2017, bareland, forest and waterbody declined, whereas farmland, brushland and grasslands increased.

Table 2 summarizes the results reported above and allows for a comparison between the outcomes reported in the different articles.

Table 2. Land Use Land Cover change considered in the reviewed articles.

Land use Class	*Article*																	*Total*	*Percentage (%)*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
agricultural land	+	+		+	+	+	+	+	+	+	+	+	-	+	+	+	+	15+, 1-	94%+, 6%-
forest	-	-		-	+	-	-	-	-	-	-	-	-	-	-	-	-	1+, 15-	6%+, 94%-
grazing	-	-		-	-	+		-		+	-	-	+	-	-	-	+	4+, 10-	28%+, 71%-
waterbody	+	+			-		+			+						+	-	5+, 2-	71%+, 28%-
swamp/wetland	-	-					-							-		+		1+, 4-	20%+, 80%-
shrub	-			-				-	+	-	-	-		-	+	+	+	4+, 7-	36%+, 64%-
commercial farm		+												+				2+	100%
built-up/settlement		+		+	+		+			+	+	+		+	+			9+	100%
rangeland		-							C									1+	50%+, 50%C
bare/rock outcrop					-	C	-		C	+	+	+					-	3+, 2-, 2C	43%, 28%-, 28%C

In Table 1, + indicates an increased land cover class, - indicates a decreased land cover class, and C indicates a constant land cover class, while the free space indicates that no LULCC were considered in the specific article.

Following the methodology reported in Section 3, it is possible to observe that, among Ethiopian basins, there is a clear increment in areas devoted to agriculture, commercial farms and settlements, as well as waterbodies (Figure 2). The increment of this latter class is due to the construction of new man-made reservoirs, mainly for hydropower and agricultural use. During the last decades, the increasing human pressure affected negatively the natural environment, as visible in the significant decline of forest, swamps and wetlands.

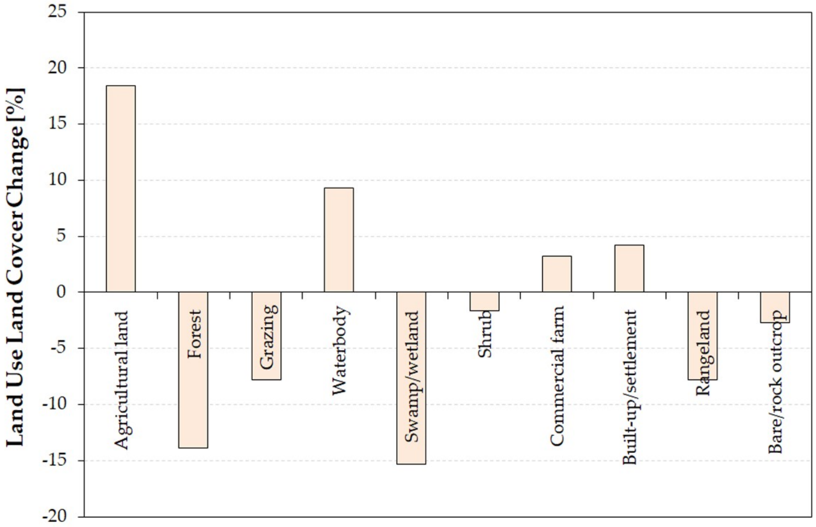

Figure 2. Land use land cover changes percentage in Ethiopia.

Agricultural land use increased in all the analysed studies except in [23], while forest land use decreased in all the study cases, except for the increment pointed out by [9]. In detail, agricultural land, waterbody, commercial farm and built-up/settlement increased by 94%, 57%, 100 and 100%, respectively. On the contrary, forest, grazing land, swamp/wetland, shrubland, rangeland and bare/rock outcrop land decreased by 94%, 71%, 80%, 60%, 100% and 57%, respectively (Figure 2).

The reviewed articles results indicate that LULCC for the past decades, as derived from the analysis of satellite imagery, are in accordance with field evidence (e.g., ground truth data and focus group discussion). In fact, most of the authors used techniques such as key informant interviews, focal group discussions and field data collection to study the socio-economy and to validate the results obtained from Landsat data. In the majority of the analysed works, the key informant interviews were conducted involving the elder peoples, aged greater than 60 years, to derive more consistent information on the history of the study area. Focal group discussions were performed with household farmers and local peoples, regardless of their age and social position. During the field data collection, the authors GPS information to validate the results.

5. Conclusions

The review of seventeen very recent articles on LULCC in Ethiopia pointed out that the predominant methods to classify lands are unsupervised and maximum likelihood supervised classification, generally performed via GIS and ERDAS Imagine software. To validate the information retrieved from satellite images, the majority of the studies used key informant interview, focal group discussions ground truth data. Among the classes analysed there is a large variability, but the most common ones are agricultural land, forest, grazing land, waterbody, swamp area, shrubland, barren land and other lands.

A comparison between the articles indicates that, in most of the studied basins, agricultural land, waterbody, commercial farm, built-up/settlement and bare/rock outcrop increased during the last decades, while the area covered by forest, grazing land, and shrubland decreased. Such changes are mostly connected with increasing human pressure on the Ethiopian environment, driven by the needs of improving the socio-economic situation of the local population.

The reviewed articles addressed LULCC with high detail, providing significant evidence on past variations at the regional scale. However, they are lacking in forecasting future trends of LULCC, needed for adequate management planning to develop a sustainable Ethiopia for the next decades.

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