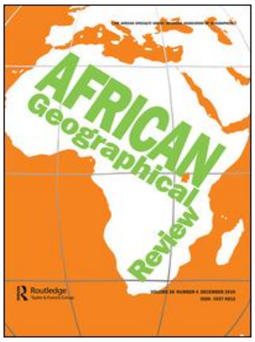

African Geographical Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rafg20

Impacts of land use and land cover change in response to different driving forces in Uganda: evidence from a review

Justine Kilama Luwa , Yazidhi Bamutaze , Jackson-Gilbert Majaliwa Mwanjalolo , Daniel Waiswa , Petter Pilesjö & Espoir Bagula Mukengere

AFRICAN GEOGRAPHICAL REVIEW
https://doi.org/10.1080/19376812.2020.1832547

Routledge
Taylor & Francis Group

Check for updates

Impacts of land use and land cover change in response to different driving forces in Uganda: evidence from a review

Justine Kilama Luwa[a], Yazidhi Bamutaze[b], Jackson-Gilbert Majaliwa Mwanjalolo[b], Daniel Waiswa[b], Petter Pilesjö[c] and Espoir Bagula Mukengere[d]

[a]Department of Biology, Faculty of Science, Gulu University, Gulu, Uganda; [b]Department of Geography, Geo-Informatics and Climatic Sciences, Makerere University, Kampala, Uganda; [c]Centre for Geographic Information Systems, Lund University, Lund, Sweden; [d]Faculté d'Agronomie et Environnement, Université Evangélique en Afrique, Bukavu- R, D. Congo

ABSTRACT

This reviewe of Land Use Land Cover Change (LULCC) studies in Uganda indicate agriculture, forest, grassland, and woodland as the major land use and land cover types. Central Uganda is the most studied region (15%), followed by western (14), eastern (10), and northern Uganda (3). District scale studies were (48%), catchment (19%), forest (17%), national (10%), and park (7%). Landsat 30 m and remote sensing was most used (93%) . Population is the leadingdrivers of LULCC. The impacts of LULCC are site specific and includes reduction of: tree cover and species composition; water quality and quantity; and soil quality.

ARTICLE HISTORY
Received 13 November 2019
Accepted 27 June 2020

KEYWORDS
Uganda; middle income economy; fastest growing population; livelihood; environment

1. Introduction

Land use and land cover change (LULCC) can result from both intentional and non-intentional human activities or as a result of natural causes. However, human forces are now known to be altering the natural global landscape at unprecedented magnitudes and at different spatial-temporal scales (Turner et al., 2009). LULCC also induced changes in ecosystem goods and services which are vital for livelihoods (Maitima et al., 2009). In the twenty-first century, LULCC is a topic of global concern because it affects sustainable development and human wellbeing (Turner et al., 2009). In many developing countries, land degradation as a result of undesired LULCC has led to reduction in food production, and threatened livelihoods (Maitima et al., 2009).

Many studies on LULCC change have been conducted in Uganda at different spatial and temporal scales for different reasons. For example, Anaba et al. (2017) focused on the impacts of LULCC on water quality in the Murchison Bay of Lake Victoria. Wadembere and Kobugabe (2017) investigated urbanization and its effects in western Uganda. In northern Uganda Gorsevski et al. (2012) assessed the effect of armed conflict on forest ecosystem while Nyeko (2010) looked at land use change and water resources management in Aswa basin of northern Uganda. In eastern Uganda, Frank Mugagga et al. (2015) were interested in land use change, carbon stocks, and climate variability in Mt. Elgon region while F Mugagga et al. (2012) investigated LULCC and implications to landslides occurrences in Mt. Elgon, eastern Uganda. On the other hand Li et al. (2016), Zhou et al. (2017), Jagger and Kittner (2017), and Mwanjalolo et al. (2018) LULCC on a national scale. What emerges from literature is that LULCC is complex and driven by both natural and anthropogenic factors that interact in space and time.

CONTACT Justine Kilama Luwa kilamaluwa@gmail.com

Uganda is geared to attain a middle income economy by 2040 in the background of a young and rapidly growing population (growth rate of above 3.03% per annum). The total population was 34 million in 2014 and is projected to reach 80 million by 2040 (UBOS, 2014). But environmental resources such as forest, wetlands, water, grassland to mention but a few, provided direct sources of livelihoods to over 80% of the population (UBOS, 2014). Population pressure and other socio-economic and natural drivers are leading to unprecedented LULCC changes at different spatial and temporal scales in Uganda (UBOS, 2014). It is also important to note that Uganda is so divers in terms of the landscapes, sociocultural, and economic settings which compound LULCC. Given the above background, government agencies and policy makers may need to invest in redesigning current land use policies and/or develop new approaches so that the policies meet specific local context with specific drivers, causes and impacts. To provide a basis to rethink the old and current approach to land resources management, this study systematically reviewed 42 LULCC studies conducted in Uganda from 1998 to 2018. The aim was to document and synthesis the findings to shed more light on the impacts and the drivers of LULCC at regional and local scales. Such information is needed to provide decision support to stakeholders at different levels regarding land use planning and management.

2. Country profile and framework of the review

2.1 Country profile

Uganda is a landlocked country in East Africa located in Southeast Africa between 1° N and 4° N latitude and 30° E and 35° E longitude. The country has a total surface area of about 241,500 km^2 of which land occupies 194,000 km^2 and the rest is open water and wetlands (UBOS, 2014). Uganda has equatorial type of climate with mean annual temperatures ranging from 16° C to 30° C (UBOS, 2014). Two rainy seasons are experienced in the central, western, and eastern regions from March to May and September to November. The northern region receives one long rainy season (April-October) in a year. Average annual amount of rainfall received in most parts of the country ranges between 750 mm and 2,100 mm (UBOS, 2014). Uganda's vegetation varies, with the south having tropical rain forest and savannah, while woodlands and semiarid vegetation dominate the other parts of the country. Uganda has one of the highest population growth rates (>3%) in the world and over 80% of its 34,6 million people (Table 1) derived their livelihoods from services of agriculture (UBOS, 2014). The actual (1991–2014) and projected (2020–2030) population is highest in the central region, followed very closely by western, eastern and northern region respectively. However, northern region is the largest in area followed by central, western, and finally eastern Uganda as seen from Table 1.

2.2 Framework within which the review was conducted

The current study focuses on review of LULCC studies within Uganda and it was restricted to only electronically available literature. The review was conducted within the framework of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (Figure 1).

Table 1. Actual (1991–2014), projected (2020–2030) population, and areas of Uganda by region.

Regions	Census 1991	Census 2002	Census 2014	Projected 2020	Projected 2025	Projected 2030	Area in (Km^2)
Central	4,843,594	6,575,425	9,575,425	11,562,900	13,608,500	15,836,200	61,403.20
Western	4,547,687	6,298,075	8,874,862	10,577,900	12,238,000	13,987,500	55,276.60
Eastern	4,128,469	6,204,915	9,042,422	10,836,500	12,503,100	14,137,400	39,478.80
Northern	3,151,955	5,148,882	7,188,139	8,606,300	9,967,700	11,449,300	85,391.70
National	**16,671,705**	**24,227,297**	**34,634,650**	**41,583,600**	**48,317,300**	**55,410,400**	**241,500**

Source: UBOS, (2018)2018)

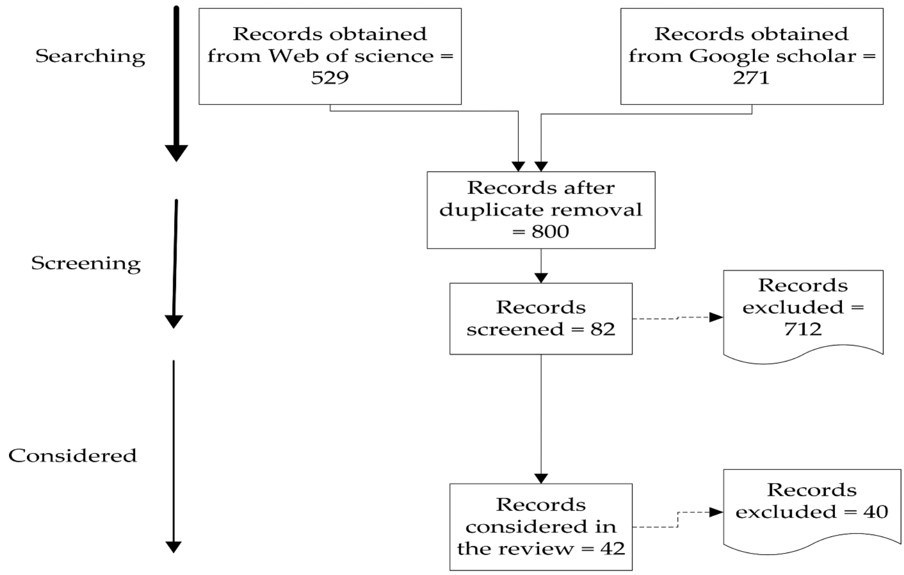

Figure 1. Framework within which the review was conducted (Modified from PRISMA 2009).

PRISMA is an evidence-based minimum set of items for reporting systematic reviews and meta-analyses. It was developed for use in the medical field (Von Elm et al., 2007) but its applications have evolved to many fields, especially the environment. The PRISMA approach was preferred over the ordinary review because of its advantages (allowing researchers to identify common themes and trends based on both qualitative and quantitative approach without bias under guidance of pre-defined inclusion and exclusion criteria). Only English language journals were searched and selected from Web of Science and Google Scholar collections. The first keywords used was 'Uganda Land use,' and then the result was refined with another keyword 'cover change.' The study also considered 3 PhD theses, 4 master dissertations giving a total of 42 case studies on LULCC in Uganda. The selected (42) materials from which categories and subcategories were defined for reanalysis are presented in (Table 2). The findings from the selected 42 literatures were supplemented with data from the Uganda Bureau of Statistics (UBOS) and the World Bank.

Information extracted from the reviewed articles was entered in Microsoft Excel 2016 sheet and analyzed using descriptive approach. Key categories of extracted information includes: author/s-date, where/when the study was conducted, what time frame was covered, what method and data was used by the authors, the key findings in terms of what land use and land cover type decreased/increased, what major drivers and impacts were reported.

3. Results and discussion

3.1 The study locations in Uganda

The review revealed that central Uganda is the most studied region with (15) of the case studies, followed by western region (14), eastern region (10), while northern region registered (3) case studies see (Figure 2). The studies in western Uganda have mainly been conducted in and around Kibale national Game Park and the Albertine region. In eastern Uganda, the studies have mainly been conducted in the Mt. Elgon area and the rangelands of the cattle corridor mainly for conservation purposes. Additionally, some of the studies in eastern Uganda have been motivated by concerns related to landslides disaster (F Mugagga et al., 2012), floods, and droughts. In central Uganda, the studies have mostly been driven by the desire to protect the health of Lake Victoria and

Table 2. Selected and reviewed case studies 1998–2018.

S/ No.	Author(s) and date	Focus of the studies
1	Akello et al. (2016)	Status of Awoja catchment.
2	Anaba et al. (2017)	Water quality under various land use
3	Barasa et al. (2011)	Land use/cover changes dynamics
4	Berakhi (2013)	Land use/cover and human activates
5	undo (2013)	Land-Use and Forest-Cover Change in Kibaale District
6	Byenkya et al. (2014)	Extent of land use and cover change and their impacts on livestock management under drought induced pasture
7	Ebanyat et al., (2010)	Land use change and drivers
8	Egeru and Majaliwa (2010)	Effect of Land use/cover change on Biomass Stock
9	Egeru et al., (2014)	Spatial-temporal dynamics of forage and land cover changes
10	Fura (2013)	Land cover modeling
11	Gorsevski et al. (2012)	Effect of armed conflict on forest ecosystem
12	Hartter and Southworth (2009)	Forest change
13	Hatter (2013)	Impacts of land use and cover change on livelihoods
14	Isunju and Kemp (2016)	Wetland change
15	Jacob et al. (2014)	Resolving land cover misclassification
16	Jagger and Shively (2014)	Biomass supply, consumption and land use change
17	Jagger et al., (2018)	Conservation management impacts
18	Kiggundu et al. (2018)	Land use/cover changes
19	Kizza et al., (2017)	Land use/cover change
20	Li et al. (2016)	Historical and future land use changes in Uganda
21	Lindblade et al., (1998)	Land use change, farm management and impacts
22	Lung & Schaab (2010)	Land cover dynamics and drivers
23	Maitima et al., (2010)	Land use change, impacts and opportunities
24	Majaliwa et al. (2010)	Land-use/cover change effects on properties of soils
25	Mwanjalolo et al. (2018)	Assessed the extent of historical, current, and future land use systems in Uganda
26	Mbazira (2014)	Effects of land use and cover change on rangeland ecosystem
27	F Mugagga et al. (2012)	Land use changes and landslides occurrences
28	Frank Mugagga et al. (2015)	Land use change, carbon stocks and climate variability.
29	Mwavu and Witkowski (2008)	Land use/cover change
30	Mwavu et al. (2018)	Commercial agriculture vs food security
31	Nakakaawa et al. (2011)	Quantify and map major land use and land cover (LULC) change patterns
32	Nakalembe et al. (2017)	Land use change and drivers
33	Nyeko (2010)	Land use changes and water resources management
34	Otukei & Blaschke (2010)	Land cover change detection using combination of methods
35	Sassen et al. (2013)	Forest cover change and drivers
36	SSentongo et al. (2017)	Forest cover change and ecosystem services
37	Tolo, Majule & Perfect (2012)	Trend of natural resources degradation
38	Twongyirwe et al., (2011)	Forest change and drivers
39	Twongyirwe et al., (2015)	Spatial and temporal heterogeneity of the land cover changes
40	Wadembere and Kobugabe (2017)	Urbanization and its effects
41	Wandera (2014)	Causes of land use changes and stakeholders perceptions
42	Zhang et al. (2017)	Carbon stocks and land cover

surrounding wetland ecosystems (Anaba et al., 2017; Kiggundu et al., 2018). On the other hand, those in northern Uganda have been conducted to investigate the impacts of past armed conflicts in the region (Nyeko, 2010; Gorsevski et al., 2012).

3.2 Major land use and land cover types

Generally, ten major land use and land cover types were addressed in the case studies. Of the different land use and land cover types, agriculture, forest, grassland, and woodland were the most commonly reported (Figure 3). It is also important to note that beyond the documented ten major

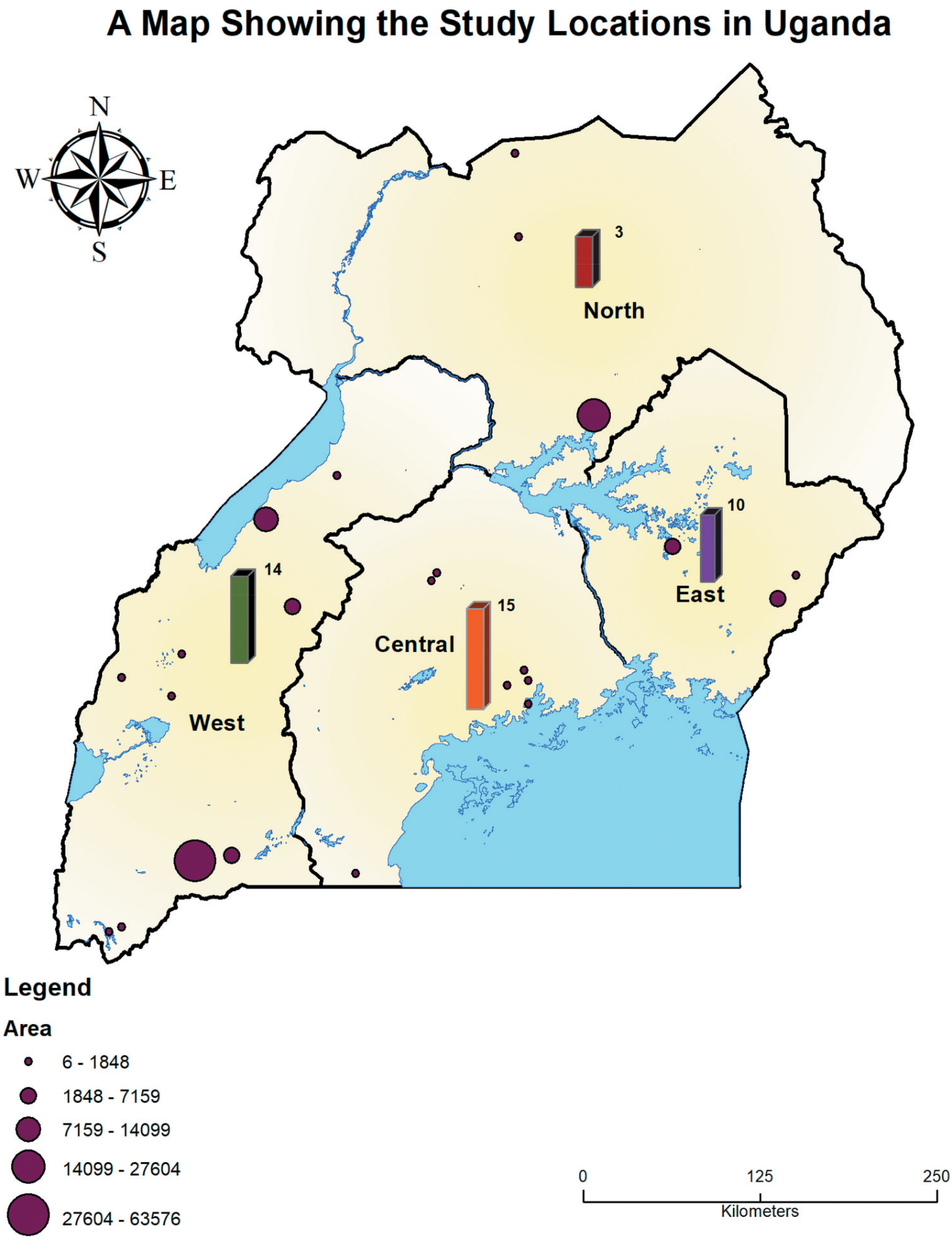

Figure 2. Map of Uganda showing locations of the reviewed case studies (extracted and developed based on the review 1998–2018).

land use and land cover types, there were other small/detailed breakdown in some land use and land cover types. For example, F Mugagga et al. (2012) adopted three broad land-use and land cover classes namely: forest cover, woodlands, and agriculture. Forest was further clustered into plantation coniferous, plantation deciduous, tropical encroached, and tropical well stocked. Woodland meanwhile consisted of riparian vegetation, shrubs, and bushes. Finally, all cultivated and fallow land was designated as agricultural fields. The review therefore indicates a lack of adoption of a standard land use and land cover classification scheme for Uganda.

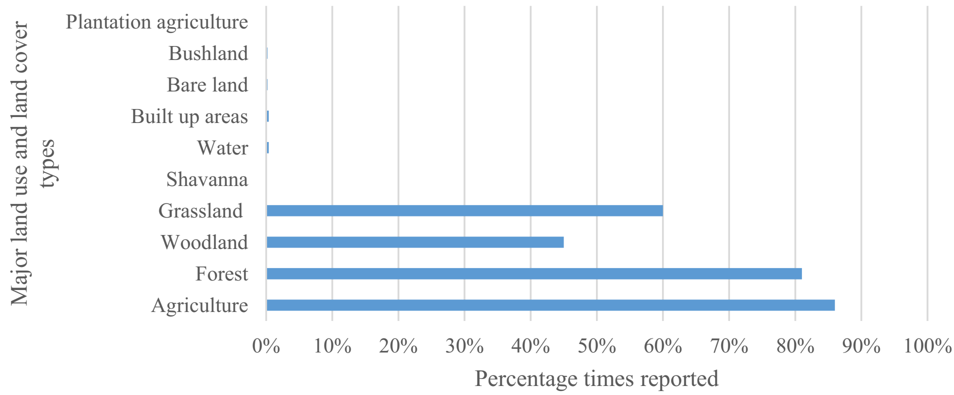

Figure 3. Major land use land cover types reported in case studies (extracted from the reviewed literatures 1998–2018).

3.3 Publication trend

In research, the number and growth rate of scientific publications are taken as important science productivity or output indicators (Alvarado, 2015). The current study found that a total of 42 publications were produced in Uganda by 35 first authors (Table 1) over a twenty-year period (1998–2018) as seen in (Figure 4). The lower end is 1 and the upper end is 8 giving a range of 1 to 8 publications over the two decades. Grouped in decades, (7%) of the publications were made in the first decade (1998–2008) while (93%) of the publications came in the second decade (2009–2018). Statistically, each author is producing 1.2 publication every twenty years equivalent to 0.6 publication per decade. The mean of publication over the two decades is 3 while the median is also 3 with a variance of 4.6 document published and standard deviation of 2.1. The growth in number of publication fits an exponential curve with $R^2 = 0.42$. The pattern of growth of literature on LULCC in Uganda agrees with the scientifically documented pattern in studies of literature production over a long period of time (Alvarado, 2015; Larsen & von Ins, 2010). The growth in LULCC literature in Uganda is comparable to that reported by Pham et al. (2015) in northern upland of Vietnam where the authors found that the topic was only 12 years old with only 17 articles published between 2001 and 2013. In Nepal, similar review by Paudel et al. (2016) reported that LULCC studies in Nepal was

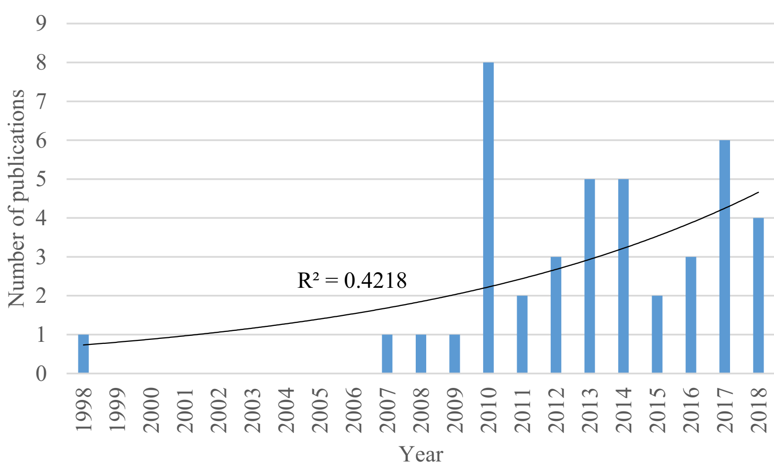

Figure 4. Number of publications per year in Uganda (extracted from the reviewed literatures 1998–2018).

30 years old dating back from 1985 to 2015. The authors also reported 10 country scale LULCC studies between 1985 and 2015 and 16 regional and local scale studies from 1990 to 2014.

3.4 Intensity of the studies

The intensity of the studies (Figure 5) depicts sigmoid growth curve with period of accelerated growth from 1980 to 1985 and peaked off from 1995 to 2005 before starting to decline from 2005 to 2015. The period of accelerated growth coincides with the coming to power of the current government in 1986 and the new constitution in 1995. The decline from 2005 to 2015 and especially 2015 being the last year is because 95% of studies used the earth observation, particularly Landsat imagery (30 m resolution) available for downloads for past years not future time period.

3.5 Time frame of case studies

It is noted from Figure 6 that the case studies covered different time periods with overlaps in some cases. The shortest time frame covered was 5 years, the longest was 47 years, the average is 23 years while, the mode is 29 years which is almost a climatological period. The earliest time period ever studied in Uganda was 1945 while the latest is 2015. Figure 6 also indicates that the most studied time frame rages from about 1980 to 2010. The observed concentration of study time frame starting from 1980 to current can locally be linked with the coming of the National Resistant Movement (NRM) into power in 1986. The NRM government brought in new Constitution in 1995 which resulted into many policies and laws relating to environmental conservation being developed and implemented. In other parts of the world, Paudel et al. (2016) in Nepal and Pham et al. (2015) in upland northern Vietnam found that most LULCC studies covered the period between 1985 and 2005.

3.6 Scales of the studies

Uganda is divided into administrative units: the first is national, second is regional, third is district, forth is county, fifth is subcounty, sixth is parish, seventh is village. In addition to the administrative

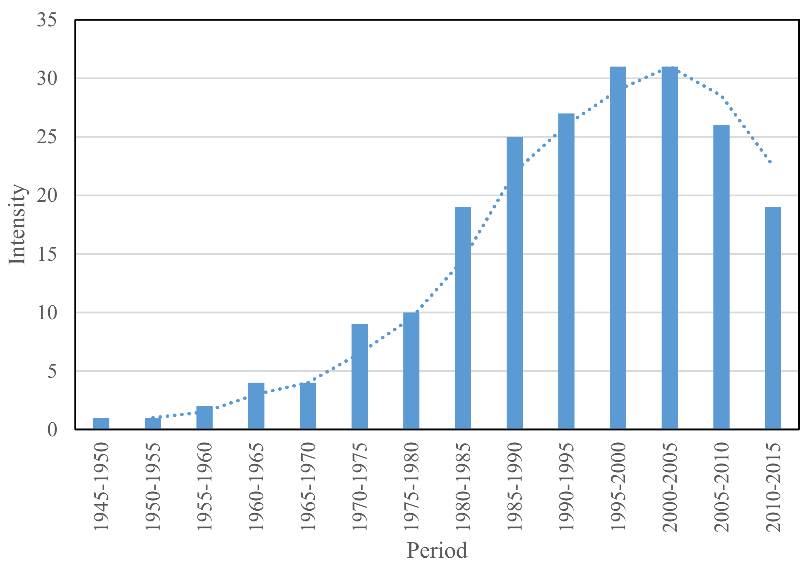

Figure 5. Intensity of the studies (extracted from the reviewed literatures 1998–2018).

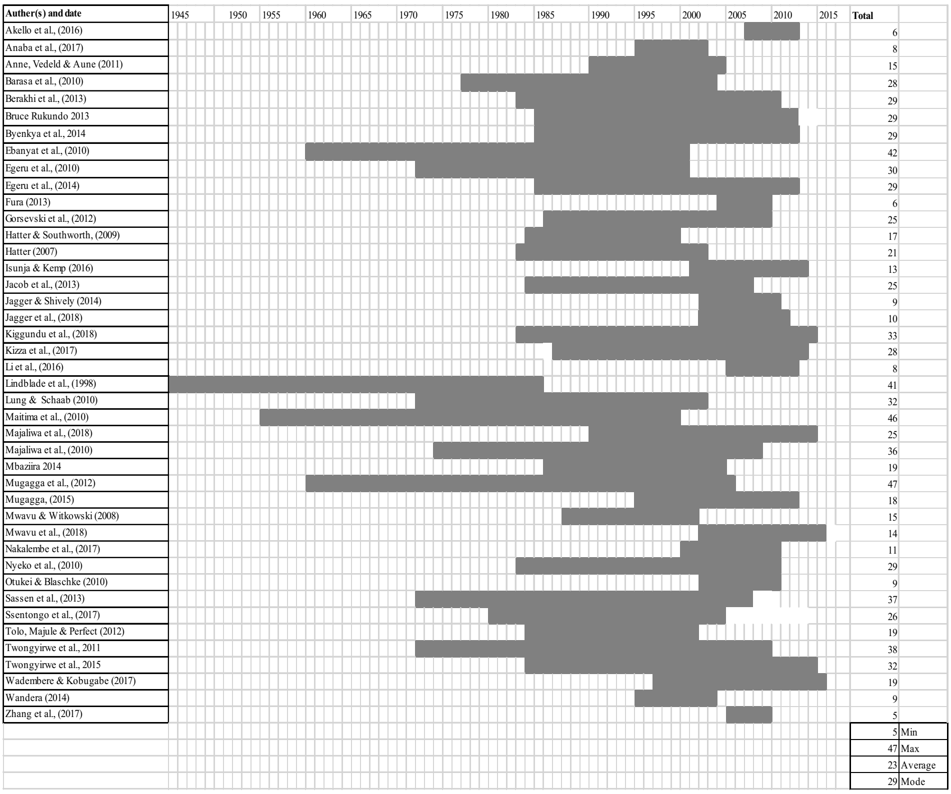

Figure 6. Time frame of the case studies (extracted from the reviewed literatures 1998–2018).

units, this study also dealt with catchment 'an area drained by a water body,' forest, and national parks respectively. Results indicate that the most preferred scale of studies was the district (48%), followed by the catchment (19%), forest (17%), and national and national park scales (10%) and (7%) respectively (Figure 7). District scale studies have been motivated by many reasons including but not limited to land use change and drivers (Nakalembe et al., 2017), extent and trend of LULCC (Egeru & Majaliwa, 2010), and commercial agriculture against food security (Mwavu et al., 2018). On the other hand, all catchment scale studies have directly or indirectly focused on impacts of LULCC on water resources. For example, Anaba et al. (2017) looked at water quality under various land use changes, Isunju and Kemp (2016) investigated the spatiotemporal encroachment on wetlands in Nakivubo wetland in Kampala, Uganda. Forest and National park scales studies have been related to conservation efforts (Sassen et al., 2013; Sentongo et al., 2017; Gorsevski et al., 2012) . The reasons for the national scale studies have been to: understand the spatial and temporal land use and carbon stock changes in Uganda (Nakakaawa et al., 2011), assess the extent of historical, current, and future land use systems in Uganda (Mwanjalolo et al., 2018), assess the impacts of land use and land cover change on terrestrial carbon stocks in Uganda (Zhang et al., 2017), and examine historical and future land use changes in Uganda (Li et al., 2016).

3.7 Methods/data employed

The review has indicated that the most used method/data was earth observation, particularly Landsat imagery (30 m resolution) employed in 95.2% of cases and then MODIS (250 m and

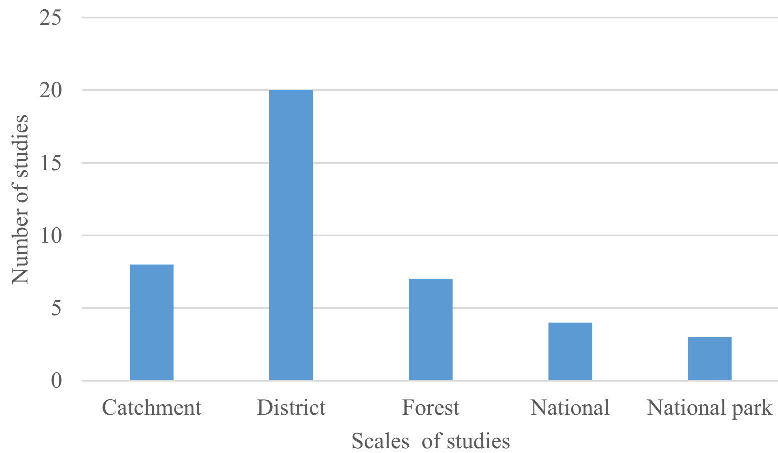

Figure 7. Scales of the case studies (extracted from the reviewed literatures 1998–2018).

500 m) employed in 2.4% of cases, and transect walk plus interview in 2.4% of studies (Figure 8). This might be because Landsat 30 m was the highest resolution until 2017, when the Sentinel 2 Satellite data became available for free downloads.

3.8 Land use and land cover change statistics in Uganda

The review points that generally, agriculture and built up areas (from here on used interchangeably with settlements) have increased while forest and woodland have decreased over the period (1998–-2018). This trend is also supported by data from UBOS (2019) see (Table 3). The table indicates that built up areas increased from about 365 km^2 in 2005 to 670 km^2 in 2010 and to 1360 km^2 in 2015. Agriculture meanwhile increased from 84,695 km^2 in 1990 to 95,211 km^2 in 2000 then to 100,000 km^2 in 2005–2010, and finally to 105,317 km^2 in 2015; Forest decreased in area from 49,334 km^2 in 1990 to 36,655 km^2 in 2005, and finally to 19,535 km^2 in 2015; Wetland change however, has been case specific with local studies reporting a mixed of increasing and decreasing trend as later discussed. However, on a national scale, wetland area appears generally stable. According to the Ministry of Water and Environment (MW&E), 2015 Uganda lost on average 122,000 ha/year of forest between 1990 and 2015, in favor of agricultural area expansion. Similarly the Ministry of Water and Environment (MW&E) (2016), indicated that national area of wetlands

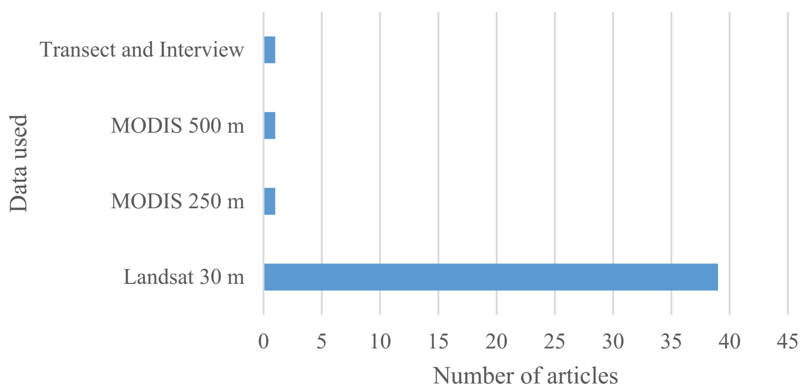

Figure 8. Data/methods used in the case studies (extracted from the reviewed literatures).

Table 3. National land cover statistics (1990–2015).

Type of land cover	1990	2000	2005	2010	2015
Built-Up Areas	365.7	365.7	365.7	969.79	1360.02
Bush-lands	14,223.90	12,624.50	11,893.60	23,776.05	19,723.25
Agriculture	84,694.50	95,211.20	99,703.10	99,219.98	105,317.21
Commercial Farmlands	684.5	684.5	684.5	1343	2567.46
Cultivated Lands	84,010.00	94,526.70	99,018.60	97,877	102,749.75
Grasslands	51,152.70	51,152.70	51,152.70	50,859.25	51,051.57
Impediments	37.1	37.1	37.2	114.21	78.56
Forest	49,333.60	40,416.40	36,654.80	21,943.20	19,535.30
Woodlands	39,740.90	32,601.40	29,527.80	14,449	12,144.78
Plantations – Hardwoods	186.8	153.3	138.6	213	442.98
Plantations – Softwoods	163.8	80	121.5	442	635.68
Tropical High Forest	2,740.60	2,248.20	2,036.30	5637	1,020.00
Tropical High Forest Normal	6,501.50	5,333.50	4,830.60	1202	5,291.86
Water Bodies	36,902.80	36,902.80	36,902.90	36,581.00	36,864.01
Wetlands	4,840.40	4,840.40	4,840.60	8,087.00	7,620.76
Total	**241,550.70**	**241,550.70**	**241,550.70**	**241,550.70**	**241,550.70**

declined by 30% between 1994 and 2008, and slightly increased by 0.03% between 2008 and 2014. The numbers of urban centers increased from 67 in 1991 to 259 in 2014, while urban population increased from 0.6 million people in 1969 to 6.4 million people in 2014 (UBOS, 2014). The implication is that the interaction of population growth and other drivers of LULC change is favoring agriculture and built-up/urban areas expansion at the expense of forest, woodlands, wetlands, as later discussed in Section.

On local scales, Barasa et al. (2011) reported increase in agriculture and decrease in forest between 1975 and 1999 in western Uganda. Similar trend was also reported in the same region by Majaliwa et al. (2010) between 1973 and 2009. In eastern Uganda, Frank Mugagga et al. (2015) reported increased agriculture at the expense of forest between 1960 and 2006. Increase in agriculture and urban areas expansion was also reported between 1987 and 2005 by Mbazira (2014), and between 2007–2013 by Akello et al. (2016) in eastern Uganda. In central Uganda, a similar trend was reported between 1995 and 2003 by Anaba et al. (2017), while in northern Uganda Nyeko (2010) reported a decrease in agriculture over the period 1986–2001. The reported trends also confirm what is observed at national level, except for the Acholi subregion (northern Uganda).

Note that the trends of forest cover and agriculture in northern Uganda are different from the national trend and those in other regions. First, only 9.5% of the reviewed LULCC studies were from northern Uganda. Fewer studies meant less representation of the actual situation on the ground. Northern Uganda also experienced armed conflict from 1986 to mid-2000s. During the period of the armed conflict, people were restricted to live in Internally Displaced Person's camp (IDP's). The people had little or no access to their land, and could therefore not exploit the resources therein. With return of peace in northern Uganda, IDP's life ended in the late 2008. There are now good roads linking all parts of the region to the grater markets within Uganda, and with South Sudan and DR. Congo. There has also been rapid expansion of commercial farming (by the so-called 'investors') in the northern districts of Nwoya and Amuru in the last ten years. The dynamics and the trajectory of LULCC in northern Uganda have thus changed. It is not surprising that the study of Gorsevski et al. (2012) found high rate of deforestation in northern Uganda coinciding with the time after life at the IDPs camps.

3.9 Reported major drivers of land use and land cover change

Only 38% of the studies analyzed the drivers of LULCC. However, even articles that did not analyze LULCC drivers have alluded to some or all the drivers in (Figure 9) as responsible for observed

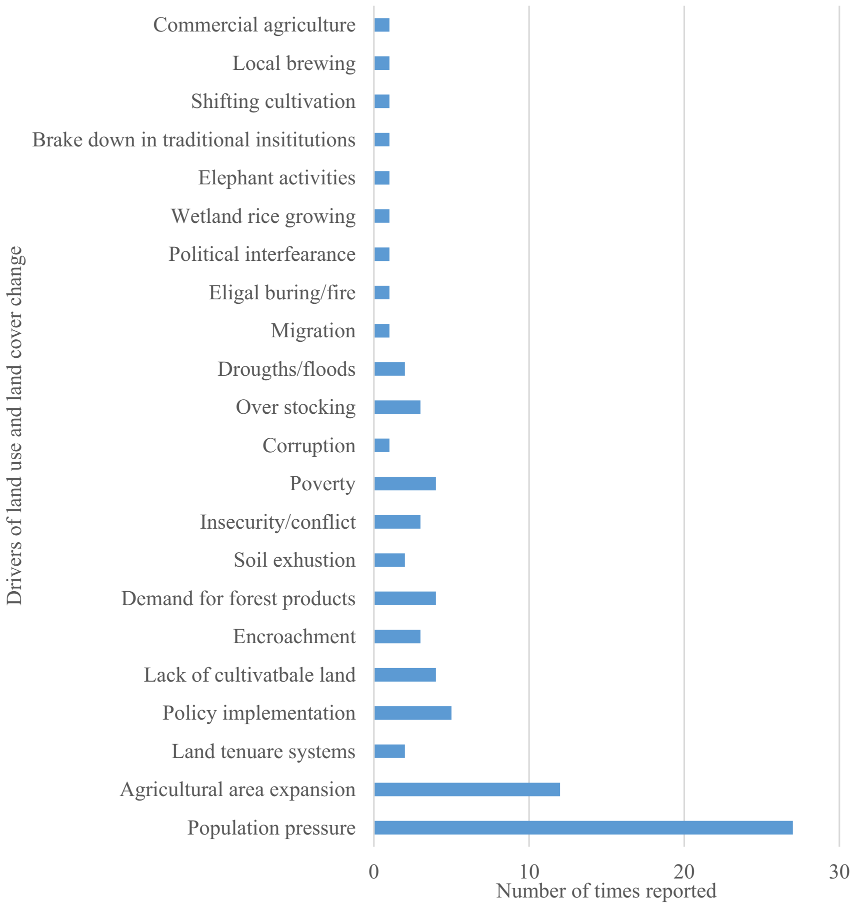

Figure 9. Reported major drivers of land use and land cover change (extracted from the reviewed literatures 1998–2018).

change. Figure 9 also indicates that population and agricultural area expansion are the most reported major drivers of LULCC in Uganda. For example, Anaba et al. (2017) and Wandera, (2014) in central, Wadembere and Kobugabe (2017) and Hartter and Southworth (2009) in western, and Gorsevski et al. (2012) in northern Uganda all emphasized population as the main driver of LULCC. However, Nakalembe et al. (2017) found that it was lack of policy implementation but not population driving LULCC in northern Uganda. On the other hand, Nyeko (2010) reported insecurity as the major driver of LULCC in northern Uganda and not population or policy implementation. In eastern Uganda, Place and Otsuka (2000) discussed unemployment to be the key driver of LULCC, whereas according to Frank Mugagga et al. (2015), it was population and lack of cultivatable land driving LULCC in eastern region. On a national scale, however, increased demand for forest products, lack of policy implementation, and agricultural area expansion have been reported as major drivers of LULCC in addition to population Li et al. (2016), Zhang et al. (2017), and Jagger and Kittner (2017).

3.10 Interactions between drivers of LULCC

The review indicates that the major drivers of LULCC do not operate in isolation but rather combined. For example, the population of Uganda grew from 6.8 million people in 1960 to

34.6 million people in 2014, and it is projected to reach 80 million people by 2040 (UBOS, 2014). With a growth rate of 3% per annum, Uganda has the third fastest growing population in the world (United Nations Population Fund (UNFPA), 2017). Increased population led to increased demand for natural resources, which affected LULCC in different ways. For instance, increased population meant more food, housing, jobs, and other environmental resources required. Forest and woodland therefore got cleared for reasons such as agriculture, settlement, biomass products, etc. as reported by F Mugagga et al. (2012), Frank Mugagga et al. (2015), and Barasa et al. (2011). In general terms, it explains why increased agriculture and built up areas have been reported at the expense of forest, wetland, woodland etc. on local and national levels in the reviewed articles. Similarly, increase in population was accompanied by increased unemployment. Unemployment increased from 1% in 1991 to 3.6% in 2003 where it again dropped to 1.9% in 2005 before increasing to 3.6% in 2009 although the current figure is 1.7%). With unemployment, rural to urban migration increased as people search for better livelihoods opportunities in urban areas. Consequently, Anaba et al. (2017), Akello et al. (2016) and Wandera, (2014) reported increased built-up areas in different places and times. When the resources get over constrained, especially in urban areas, people (especially the poor) are forced to settle in or cultivate wetlands. Wetland decline has been reported in western, central, and eastern Uganda. In the above regions population are higher and total land areas are smaller compered to northern Uganda (Table 1).

In Uganda, agriculture is a key sector to the livelihoods of the rural population (79% of total population) and to the economy of Uganda (UBOS, 2018). Accordingly, in the year 2013/14 and 2015/16, agriculture employed 74.7% and 73% of total rural labor force respectively and the sector's contribution to total GDP increased from 23.7% in 2015/16 to 25% in 2016/17 (MAAIF, 2017). No doubt, agriculture is making tremendous contributions to the livelihoods of the rural population and total GDP of Uganda. The rapid population growth and economic drivers have increased demand for forest products, agricultural and urban areas expansion, manufacturing and construction industries among others (Mwanjalolo et al., 2018). The demographic and socio cultural, economic and diversity in the landscapes have accelerated LULCC in many parts of Uganda. Additionally, land available for agriculture has become increasingly scarce in many parts of the country and has forced subsistence farmers to encroach on marginal lands and protected areas (Mugagga & Mukadis, 2013 and Buyinza & Mugagga 2010).

As already discussed, the population of Uganda is projected to more than double by 2040. In simple term and based on analysis of drivers of LULCC, this can be translated as more pressure on the fixed land resources by 2040. The demographic trend and desire for socioeconomic growth in Uganda may continue to drive LULCC in the country. Similarly, Mwanjalolo et al. (2018) discussed in detail the projected land use systems in Uganda in 2040. Most importantly, their key finding indicates that agricultural land area will generally increase in 2040 withS commercial agriculture increasing by 1.19% and irrigated agriculture by 0.04%. The study reported that subsistence agriculture will still remain the most dominant land use system increasing by 45.45% in 2040. Woodland/unprotected forest will decrease from 867.25 km^2 in 2015 to only 287.27 km^2 in 2040, representing a drop of 0.12%. Li et al. (2016) meanwhile found that agricultural land will increase while forest land will decrease in the country in 2025 under both business as usual and deforestation scenarios.

3.11. Impacts of land use and land cover change

LULCC is having a wide range of impacts on the environment and the people of Uganda at different spatial and temporal scales. For example, Barasa et al. (2011) reported that decrease in forest, wetland, and woodland as a result of increased agriculture between 1975 and 1999 resulted in reduced tree species diversity in western Uganda. In the Mt. Elgon area in eastern Uganda, Frank Mugagga et al. (2015) noted that increased farmland at the expense of forest has led to land with high carbon stocks and reduced the potential of Mt. Elgon areas as a carbon sink. Similarly, Akello et al. (2016) reported that between 2007 and 2013 deforestation, wetland encroachment, poor attitudes, population pressure, and political interference led to poor water quality and lack of formal jobs in Ngora district in eastern Uganda. On the other hand, Egeru and Majaliwa (2010) reported decline in forage quality, reduced grazing area, and increased floods and drought in Teso in eastern Uganda between 1973 and 2001. In the Machismo bay, central Uganda, Anaba et al. (2017) reported increased flooding, water quality decline, and reduced crop yield between 1995 and 2003. Between 1973 and 2009, Majaliwa et al. (2010) reported changes in soil properties as a result of increased agriculture, increased demand for fuelwood, and population pressure in western Uganda. In other parts of Uganda, LULCC was reported to have had negative effects on total fuel consumed (Jagger & Shively, 2014), as well as reduced slope stability affected by hydrological conditions triggering debris flows (F Mugagga et al., 2012), threatened conservation and chimpanzees (Mwavu & Witkowski, 2008). LULCC also increased water quality degradation and increased water treatment cost (Anaba et al., 2017), led to increased waterborne diseases and reduced ecosystem benefits (Jagger & Kittner, 2017).

4. Summary of findings

The review has indicated that that LULCC studies in Uganda have only been conducted for 20 years 1998–2018. The studies mostly used Landsat 30 m data and covered different spatial and temporal scales. Generally, agriculture and built up areas are increasing at the expense of forest, wetland and woodland. Although, the major drivers of LULCC interact with one another, population pressure stands out of all the key drivers of LULCC at both national and local scales. The magnitudes and impacts of LULCC differs in both space and time within Uganda. The historical to current trend of LULCC change and related impacts are likely to significantly increase in (2040); as the projected population is likely to double by 2040 in Uganda.

4.1. Limitations

Our study mainly focused on electronically published articles available in Web of Science and Google scholar. Hard copies of documents in university libraries and ministerial achieves were not considered. This could have increased the number of materials selected and analyzed. However, most probably this would only have a positive impact on the sampling space, but not affecting the findings.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported in part by the Swedish International Development Agency (Sida) and Makerere University under Sida contribution N0: 51180060

Notes on contributors

Luwa is a Lecturer in the Department of Biology, Faculty of Science, Gulu University-Uganda. Luwa holds a Bachelor of Science in Industrial Chemistry of Makerere University, and MSc Water Resources and Livelihoods Security of Linkoping University in Sweden. He is currently a PhD student in the Department of Geography, Geo-Informatics and Climatic Sciences, Collage of Agriculture and Environmental Sciences, Makerere University, Uganda. Luwa's PhD research focuses on Modeling the impacts of climate and land use/cover change on water quality in Sironko catchment, Mt. Elgon, Uganda. Luwa is interested in stakeholders' participation for sustainable natural resources management and utilization for improved livelihoods.

Bmutaze is Associate Professor in the Department of Geography, Geo-Informatics and Climatic Sciences, Collage of Agriculture and Environmental Sciences, Makerere University-Uganda. He holds a PhD in Geography, MSc in Geo-Information Sciences and Earth Observation, Master in Geography and Bachler of Arts in Geography. He has over 20 years' experience in research, teaching, mentorship and scientific leadership in Makerere University. He has been involved in capacity building development and collaborative projects. He is a member of many International Associations and has over 20 scientific publications.

*Majaliwa*is a Professor in the Department of Geography, Geo-Informatics and Climatic Sciences, Collage of Agriculture and Environmental Sciences, Makerere University-Uganda. Holds a 5 years degree in applied physics of ISP-Bukavu/DRC, 2 years in applied physics, a Master degree in Environmental science, and PhD in soil Science of Makerere University. He is interested in remote sensing, hydrology, environmental modeling.

Waiswa is a senior Lecturer in the Department of Geography, Geo-Informatics and Climatic Sciences, Makerere University where he has worked for over a decade. He holds BSc Forestry (Hons) First Class and MSc in Computer Science from Makerere University and PhD in Forest Biometrics and Geomatics from Virginia Polytechnic Institute and State University, USA. His areas of teaching, research and community outreach are Forest Resource Assessment and Management, Geographic Information Systems and Remote Sensing among others. He is the Focal Point and Manager for the European Commission/ African Union Commission supported Environmental Station which provides up to date data for Monitoring Environment and Security in Africa. He has a record of over 13 publications.

Professor Petter Pilesjö is the Director of Lund University GIS Centre, Sweden.His research is mainly focusing on hydrological and topographical modelling, as well as disaster management. Pilesjö has been involved in research and capacity building projects in Africa since the late 1980ies.

Espoir holds a BSc in Agricultural Engineering and MSc in Land Resources Management. Currently he is a PhD student in the Collage of Agriculture and Environmental Sciences, Makerere University-Uganda. His PhD research focuses on Soil Water Conservation. Espoir is interested in areas of Environmental Analysis and Modelling, Geo-informatics and Precision Agriculture.

ORCID

Espoir Bagula Mukengere http://orcid.org/0000-0002-8237-9100

References

Akello, S., Turyahabwe, N., Okullo, P., & Agea, J. G. (2016). Land use/cover change and perceived watershed status in Eastern Uganda. *African Journal of Environmental Science and Technology*, *10*(11), 406–414. https://doi.org/10.5897/AJEST2016.2136

Alvarado, R. U. (2015). Growth of literature on Bradford's law. *Investigación Bibliotecológica: Archivonomía, Bibliotecológica e Información*, *30*(68), 51–72. https://doi.org/10.1016/j.ibbai.2016.06.003

Anaba, L. A., Banadda, N., Kiggundu, N., Wanyama, J., Engel, B., & Moriasi, D. (2017). Application of SWAT to assess the effects of land use change in the murchison bay catchment in Uganda. *Computational Water, Energy, and Environmental Engineering*, *6*(01), 24–40. https://doi.org/10.4236/cweee.2017.61003

Barasa, B., Egeru, A., Okello, P., & Mutuzo, F. (2011). Dynamics of land use/cover trends in Kanungu District, South-western Uganda. *Journal of Applied Sciences and Environmental Management*, *14*(4). https://doi.org/10.4314/jasem.v14i4.63260

Berakhi, R. O. (2013). Implication of Human Activities on Land Use Land Cover Dynamics in Kagera Catchment, East Africa. Graduate School Southern Illinois University Carbondale. Southern Illinois University Carbondale. Retrieved from https://siu.edu/

Buyinza, M., & Mugagga, F. (2010, August). Economics of land degradation in mid-hills of mt. elgon watershed, eastern uganda. *J. Soil Nature*, *4*(1), 1–6. (Online) & -2075-1672 (Optical). https://doi.org/org/SSN-1994-1978

Byenkya, G. S., Mugerwa, S., Barasa, S., & Zziwa, E. (2014). Land use and cover change in pastora; systems of Uganda: Implications on livestock management under drought induced pasture. *African Crop Science Journal*, *22*(1986), 1013–1025

Ebanyat, P., de Ridder, N., de Jager, A., Delve, R. J., Bekunda, M. A., & Giller, K. E. (2010). Drivers of land use change and household determinants of sustainability in smallholder farming systems of Eastern Uganda. *Population and Environment*, *31*(6), 474–506. https://doi.org/10.1007/s11111-010-0104–2

Egeru, A., & Majaliwa, M. (2010). Landuse/cover change trend in Soroti District Eastern Uganda. *Journal of Applied Sciences and Environmental Management*, *13*(4), 77–79. https://doi.org/10.4314/jasem.v13i4.55426

Egeru, A., Wasonga, O., Kyagulanyi, J., Majaliwa, G., MacOpiyo, L., & Mburu, J. (2014). Spatio-temporal dynamics of forage and land cover changes in Karamoja sub-region, Uganda. *Pastoralism: Research, Policy and Practice*, 4(1), 6. https://doi.org/10.1186/2041-7136-4-6

Fura, G. D. (2013). Analysing and Modelling Urban Land Cover Change for Run-Off Modelling in Kampala, Uganda. University of Twente. Retrieved from https://www.utwente.nl

Gorsevski, V., Kasischke, E., Dempewolf, J., Loboda, T., & Grossmann, F. (2012). Analysis of the impacts of armed conflict on the Eastern Afromontane forest region on the South Sudan - Uganda border using multitemporal Landsat imagery. *Remote Sensing of Environment*, *118*, 10–20. https://doi.org/10.1016/j.rse.2011.10.023

Hartter, J., & Southworth, J. (2009). Dwindling resources and fragmentation of landscapes around parks: Wetlands and forest patches around Kibale National Park, Uganda. *Landscape Ecology*, *24*(5), 643–656. https://doi.org/10.1007/s10980-009-9339-7

Hatter, J. N. (2013). Landscape change around Kibale National Park, Uganda: Iimpacts on land cover, land use and livelihoods. Journal of Chemical Information and Modeling. https://doi.org/10.1017/CBO9781107415324.004

Isunju, J. B., & Kemp, J. (2016). Spatiotemporal analysis of encroachment on wetlands: A case of Nakivubo wetland in Kampala, Uganda. *Environmental Monitoring and Assessment*, *188*(4), 17. https://doi.org/10.1007/s10661-016-5207-5

Jacob, A. L., Bonnell, T. R., Dowhaniuk, N., & Hartter, J. (2014). Topographic and spectral data resolve land cover misclassification to distinguish and monitor wetlands in western Uganda. ISPRS Journal of Photogrammetry and Remote Sensing, 94, 114–126. https://doi.org/10.1016/j.ISPRS Journal of Photogrammetry and Remote Sensing.2014 2014 94.05.001 doi:10.1016/j.isprsjprs.2014.05.001

Jagger, P., & Kittner, N. (2017). Deforestation and biomass fuel dynamics in Uganda. *Biomass & Bioenergy*, *105*, 1–9. https://doi.org/10.1016/j.biombioe.2017.06.005

Jagger, P., Sellers, S., Kittner, N., Das, I., & Bush, G. K. (2018). Looking for Medium-term Conservation and Development Impacts of Community Management Agreements in Uganda's Rwenzori Mountains National Park. Ecological Economics, 152(April), 199–206. https://doi.org/10.1016/j.ecolecon.2018.06.006

Jagger, P., & Shively, G. (2014). Land use change, fuel use and respiratory health in Uganda. *Energy Policy*, *67*, 713–726. https://doi.org/10.1016/j.enpol.2013.11.068

J.R. Otukei, T. Blaschke, (2010). Land cover change assessment using decision trees, support vector machines and maximum likelihood classification algorithms, International Journal of Applied Earth Observation and Geoinformation, Volume 12, Supplement 1, 2010, Pages S27-S31,ISSN 0303-2434, https://doi.org/10.1016/j.jag.2009.11.002. (http://www.sciencedirect.com/science/article/pii/S0303243409001135)

Kiggundu, N., Anaba, L. A., Banadda, N., Wanyama, J., & Kabenge, I. (2018). Assessing land use and land cover changes in the Murchison Bay catchment of Lake Victoria Basin in Uganda. *Journal of Sustainable Development*, *11*(1), 44. https://doi.org/10.5539/jsd.v11n1p44

Kizza, C. L., Tenywa, M. M., Kansiime, F., Magunda, M., Nakileza, B., Barasa, B., … Nampijja, J. (2017). Land use/cover change patterns in highland ecosystems of Lake Bunyonyi catchment in western Uganda. African Crop Science Journal, 25(S1), 43–58. https://doi.org/http://dx.doi.org/10.4314/acsj.v25i1.4S

Larsen, P. O., & von Ins, M. (2010). The rate of growth in scientific publication and the decline in coverage provided by science citation. Scientometrics (2010) 84:575–603. https://doi.org/10.1007/s11192-010-0202-z

Li, J., Oyana, T. J., & Mukwaya, P. I. (2016). An examination of historical and future land use changes in Uganda using change detection methods and agent-based modelling. *African Geographical Review*, *35*(3), 247–271. https://doi.org/10.1080/19376812.2016.1189836

Lindblade, K. A., Carswell, G., & Tumuhairwe, J. K. (1998). Royal Swedish Academy of Sciences Mitigating the Relationship between Population Growth and Land Degradation: Land-Use Change and Farm Management in Southwestern Uganda. Source: Ambio, 27(7), 565–571. Retrieved from http://www.jstor.org/stable/4314792%0Ahttp://www.jstor.org/stable/4314792?seq=1&cid=pdf-reference#references_tab_contents

Lung, T., & Schaab, G. (2010). A comparative assessment of land cover dynamics of three protected forest areas in tropical eastern Africa. *Environmental Monitoring and Assessment*, 161(1–4), 531–548. https://doi.org/10.1007/s10661-009-0766-3

MAAIF. (2017). *The Republic of Uganda Ministry of agriculture, animal industries and fisherise: Performance review report*. Government of Uganda, Kampala. Retrieved from https://www.agriculture.go.ug/

Maitima, J., Olson, J., Mugatha, S., Mugisha, S., & Mutie, I. (2010). Land use changes, impacts and options for sustaining productivity and livelihoods in the basin of lake Victoria. *Journal of Sustainable Development in Africa*, *12*(3), 1520–5509

Maitima, J. M., Mugatha, S. M., Reid, R. S., Gachimbi, L. N., Majule, A., Lyaruu, H., … Mugisha, S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa. *African Journal of Environmental Science and Technology*, *3*(10), 310–325. https://doi.org/ 1991-637X © 2009 Academic Journals

Majaliwa, J. G. M., Twongyirwe, R., Nyenje, R., Oluka, M., Ongom, B., Sirike, J., … Barasa, B. (2010). The effect of land cover change on soil properties around Kibale National Park in South Western Uganda. *Applied and Environmental Soil Science*, *2010*(May2010), 1–7. https://doi.org/10.1155/2010/185689

Mbazira, J. (2014). *The effects of land use cover change on rangeland ecosystems in Kakooge sub-county Nakasongola district, Uganda*. Makerere University.
Ministry of Water and Environment (MW&E). (2015). *State State of of Uganda ' S Forestry*. Government of Uganda, Kampala. Retrieved from https://www.mwe.go.ug/
Ministry of Water and Environment (MW&E). (2016). *Uganda Wetlands Atlas* (Vol. 2). Governmet of Uganda. http://www.mwe.go.ug/sites/default/files/Uganda/Wetlands/Atlas/Volume/II_Popular/Version.pdf
Mugagga, F., Kakembo, V., & Buyinza, M. (2012). Land use changes on the slopes of Mount Elgon and the implications for the occurrence of landslides. *Catena*, *90*, 39–46. https://doi.org/10.1016/j.catena.2011.11.004
Mugagga, F., & Mukadis, B. (2013, October). Land tenure and soil conservation practices on the slopes of Mt Elgon National Land tenure and soil conservation practices on the slopes of Mt Elgon National Park, Eastern Uganda. *Journal of Geography and Regional Planning*, *6*(7), 255–262. https://doi.org/10.5897/JGRP2013.0398
Mugagga, F., Nagasha, B., Barasa, B., & Mukadsi, B. (2015). The effect of land use on carbon stocks and implications for climate variability on the slopes of Mount Elgon, Eastern Uganda. *International Journal of Regional Development*, *2*(1), 58. https://doi.org/10.5296/ijrd.v2i1.7537
Mwanjalolo, M. G. J., Bernard, B., Paul, M. I., Joshua, W., Sophie, K., Cotilda, N., Bob, N., John, D., Edward, S., & Barbara, N. (2018). Assessing the extent of historical, curreent, and future land use systems in Uganda. *Land*, *7* (132), 1–17. https://doi.org/10.3390/land7040132
Mwavu, E. N., Kalema, V. K., Bateganya, F., Byakagaba, P., Waiswa, D., Enuru, T., & Mbogga, M. S. (2018). Expansion of commercial sugarcane cultivation among smallholder farmers in Uganda: Implications for household food security. *Land*, *7*(73), 1–15. https://doi.org/10.3390/land7020073
Mwavu, E. N., & Witkowski, E. T. (2008). Land-use and cover changes (1988–2002) around Budongo forest reserve, NW Uganda: Implication for forest and woodland sustainability. *Land Degradation and Development*, *20* (October), 587–588. https://doi.org/10.1002/ldr
Nakakaawa, C. A., Vedeld, P. O., & Aune, J. B. (2011). *Spatial and temporal land use and carbon stock changes in Uganda : Implications for a future REDD strategy*. Forest Policy and Economics-01253 No. of pages 11. https://doi.org/10.1007/s11027-010-9251-0
Nakalembe, C., Dempewolf, J., & Justice, C. (2017). Agricultural land use change in Karamoja Region, Uganda. *Land Use Policy*, *62*, 2–12. https://doi.org/10.1016/j.landusepol.2016.11.029
Nyeko, M. (2010). *Land use changes in Aswa Basin-Northern Uganda: Opportunities and constraints to water resources management*. PhD thesis, University of Naples, Italy. Retrieved from https://www.researchgate.net/institution/University_of_Naples_Federico_II
Paudel, B., Zhang, Y. L., Li, S. C., Liu, L. S., Wu, X., & Khanal, N. R. (2016). Review of studies on land use and land cover change in Nepal. *Journal of Mountain Science*, *13*(4), 643–660. https://doi.org/10.1007/s11629-015-3604-9
Pham, T. T. H., Turner, S., & Trincsi, K. (2015). Applying a systematic review to land use land cover change in Northern Upland Vietnam: The missing case of the borderlands. *Geographical Research*, *53*(4), 419–435. https://doi.org/10.1111/1745-5871.12133
Place, F., & Otsuka, K. (2000). Population pressure, land tenure, and tree resource management in Uganda. *Land Economics*, *76*(2), 233–251. https://doi.org/10.2307/3147226
Sassen, M., Sheil, D., Giller, K. E., & Ter Braak, C. J. F. (2013). Complex contexts and dynamic drivers: Understanding four decades of forest loss and recovery in an East African protected area. *Biological Conservation*, *159*, 257–268. https://doi.org/10.1016/j.biocon.2012.12.003
Sentongo, A., Darkey, D., & Mutyaba, J. (2017). Detecting forest cover and ecosystem service change using integrated approach of remotely sensed derived indices in the Central Districts of Uganda. *South African Journal of Geomatics*, *7*(1), 46–63. https://doi.org/org/http://dx.doi.10.4314/sajg.v7i1.4
Tolo, C. U., Majule, E. A., & Perfect, J. (2012). Changing Trends of Natural Resources Degradation in Kagera Basin: Case Study of Kagera Sub-Basin , Uganda. *Natural Resources, 2012*, ,95–106 https://doi.org/http://dx.doi.org/10.4236/nr.2012.33014
Turner, B. L., Meyer, W. B., & Skole, D. L. (2009). Change : Global integrated study towards an. *Ambio*, *23* (1), 91–95. http://www.jstor.org/stable/4314168
Twongyirwe, R., Majaliwa, J., Ebanyat, P., Tenywa, M., Sheil, D., Heist, M., . . . Kumar, L. (2011). Dynamics of forest cover conversion in and around Bwindi impenetrable forest, Southwestern Uganda. *Journal of Applied Sciences and Environmental Management*, *15*(1). https://doi.org/10.4314/jasem.v15i1.68439
Twongyirwe, Ronald, Bithell, M., Richards, K. S., & Rees, W. G. (2015). Three decades of forest cover change in Uganda's Northern Albertine Rift Landscape. *Land Use Policy*, *49*, 236–251. https://doi.org/10.1016/j.landusepol.2015.07.013
UBOS. (2014). 2014 census population. *Uganda National Population and Housing Census Resulte*.Government of Uganda, Kampala
UBOS. (2018). *Uganda Bureau of Statistics. The 2018 statistical abstract*. Government of Uganda, Kampala. Retrieved from https://www.ubos.org/
UBOS. (2019). Statistical Abstract, 2019. Uganda Bureau of Statistics - Statistical Abstracts, *47*, 56. Retrieved from http://www.ubos.org/onlinefiles/uploads/ubos/pdf documents/abstracts/Statistical Abstract 2019.pdf

undo, B. (2013). *Implications of Land Governance on Natural Resources Management: The Case of Land-Use and Forest-Cover Change in Kibaale District, Uganda*. TECHNISCHE UNIVERSITÄT MÜNCHEN.

United Nations Population Fund (UNFPA). (2017, March). Uganda Population Dynamics. Issue Brief, 01, 1–4. Retrieved from https://uganda.unfpa.org/enUnited Nations Population Fund (UNFPA). (2017, March). Uganda population dynamics. *43*, 1–4. https://uganda.unfpa.org/en

Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., & Vandenbroucke, J. P. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. *PLoS Medicine*, *4*(10), 1623–1627. https://doi.org/10.1371/journal.pmed.0040296

Wadembere, I., & Kobugabe, M. (2017). Geospatial assessment of uncontrolled urbanization and its deviation from an intelligent city: A case study of Fort Portal, Uganda. *Journal of Geography, Environment and Earth Science International*, *12*(1), 1–12. https://doi.org/10.9734/JGEESI/2017/36362

Wandera, P. (2014). The Political Ecology of unplanned land use changes in Kampala City, Uganda. A case of selected parishes of Kawempe Division. *Norwegian University of Science and Technology*. Retrieved from https://www.ntnu.edu/

Zhang, F., Zhan, J., Zhang, Q., Yao, L., & Liu, W. (2017). Impacts of land use/cover change on terrestrial carbon stocks in Uganda. *Physics and Chemistry of the Earth*, *101*, 195–203. https://doi.org/10.1016/j.pce.2017.03.005

Zhou, Z., Ouyang, Y., Qiu, Z., Zhou, G., Lin, M., & Li, Y. (2017). Evidence of climate change impact on stream low flow from the tropical mountain rainforest watershed in Hainan Island, China. *Journal of Water and Climate Change*, *8*(2), 293–302. https://doi.org/10.2166/wcc.2016.149