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Original Research Article

Land use/cover change and transformations in Upper Runde Sub-catchment area in Zimbabwe

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ABSTRACT: The study assessed land use/cover changes in the Upper Runnde sub-catchment in Zimbabwe between 2000 and 2020 using GIS and remote sensing techniques with the support of interviews and field observations. Faster land use/cover changes were experienced within the 2000–2010 decade when compared to the 2010–2020 decade; for instance, bare land increased by 92.1% between 2000–2010 compared to 16.5% between 2010–2020. Major land cover transformations included change from forest land to bare land, grassland and shrub land, and change from grassland to bare and shrub land to grassland. The results confirmed conversion of forests to agricultural lands and settlements following the fast-track land reform program in 2000, and livestock increase induced overgrazing as major human activities driving land cover changes. There is a need for serious attention from resource management stakeholders before depletion of critical resources like water and woodlands. Therefore, the Ministry of Lands, Agriculture, Water, and Rural Resettlement and the Zimbabwe National Water Authority may consider strict auditing of land uses and water resource use in catchment areas to guard against encroachment of agriculture and other land uses in protected lands and fragile ecosystems like water bodies and wetlands.

KEYWORDS: land use/cover; drivers; land cover change; catchment; resources

1. Introduction

Changes in the global landscape have been a constant phenomenon since the existence of humanity on earth[1]. This has been attributed to increasing pressure on land resources on the verge of meeting the demands of an exponentially surging global population through various development activities[2–4]. Resultantly, changes in the natural earth's panorama had myriad negative impacts on ecosystems as well as surface water availability on the earth's surface[4]. In this context, anthropogenic activities and their concomitant modification of the landscape culminated in an inevitable risk of environmental degradation around the world[5].

Since the early 1980s, a lot of changes have taken place on the global landscape, as exhibited by the persistent expansion of cultivated land and the decline in natural land cover across the globe. Studies confirmed accelerated rates of land cover changes in recent decades compared to previous decades[6–10].

The world's forest decline was estimated at about 129 million hectares between 1990 and 2015, approximately the size of South Africa's land mass, signifying 1.3% loss of earth's forest land[3]. On a

regional scale, it has been confirmed that Africa had the largest annual rate of forest loss, estimated at about 0.49%, with reports from African countries showing that about 82 million hectares of forest have been converted into other land uses between 1990 and 2015. Globally, rates of agricultural expansion showed a declining trend, though an increase has been noted in Latin America and Sub-Saharan Africa[2,11,12]. It was estimated that 70% of the grasslands, 50% of the savanna, 45% of the temperate deciduous forests, and 27% of the tropical forests have been cleared for agriculture[2].

Sub-Saharan Africa witnessed an area covered by agriculture increasing by 2.3% between 1975 and 2000, which took place at the expense of vegetation and surface water. This implied that sub-Saharan Africa lost natural vegetation equivalent to 8% of 1975 forest cover in 25 years[13]. Some studies confirmed that countries in West Africa have lost and are still losing large extensions of their natural land coverage that is being replaced by a landscape with strongly human influence dominated by agriculture[14,15]. In this sense, Kiros[16] indicated that in response to the growing demand for food production, agricultural land is expanding at the expense of natural vegetation and grasslands. Studies in the Ethiopian highlands indicate that land use and land cover changes were promoted mainly by human actions like agriculture[17,18].

Research findings in Zimbabwe by Chenje et al.[19] attributed scarcity of undisturbed land to the vicious agricultural and demographic pressures born significantly out of the Fast Track Land Reform program. The Fast Track Land Reform Program (FTLRP), which occurred between 2000 and 2009, saw commercial farmers being replaced by small-scale farmers, which resulted in changes in natural resource exploitation in these areas, which have been coined resettlements. Agriculture is invading most of the virgin lands in Zimbabwe, as evidenced by the forest cover reduction by 10.46% between 1992 and 2008, land shrubs by 1.9%, and wood pastures by 0.53%, while the cultivated areas are increasing by 13.76%[20]. A study conducted by Matsa and Muringaniza[20] showed that significant changes were experienced in the Shurugwi district, where important changes included a decrease of 9.4% on the cover of the vegetation between 1991 and 2000 and an accelerated decrease of 11.6% between 2000 and 2009, while agriculture gained more land. Similarly, a study in ward 32 of Mazowe District revealed a significant loss in the cover of forest, pastures, and water, yet cultivated and bare land experienced an increase between 2000 and 2018[21].

Upper Runde Sub-catchment was no exception to changes in land use/cover over the past years as it was exposed to similar land cover driving scenarios. Changes in land use/cover in this sub-catchment have the potential of affecting water resources as well as natural vegetation and other natural scenes. Studying changes in land use/cover changes in this area was significant to stir action for environmental conservation following the realization of the increased magnitude of resource loss. This will enhance achievement of sustainable development goals 14 and 15 on life below water and life on land. Against this background, this study seeks to analyze changes in land cover change and transformations between 2000 and 2020 and assess drivers of changes in land use/cover in Upper Runde Sub-catchment in Southern Zimbabwe.

2. Description of the study area

Upper Runde is a sub-catchment (**Figure 1**) of Runde catchment area that covers the southern part of Gweru District, Shurugwi District, and Zvishavane District, part of Matebeleland south province, the northern part of Mberengwa District, Chivi District, and the northern part of Masvingo District. The sub-catchment covers 10,668 km^2 of land.

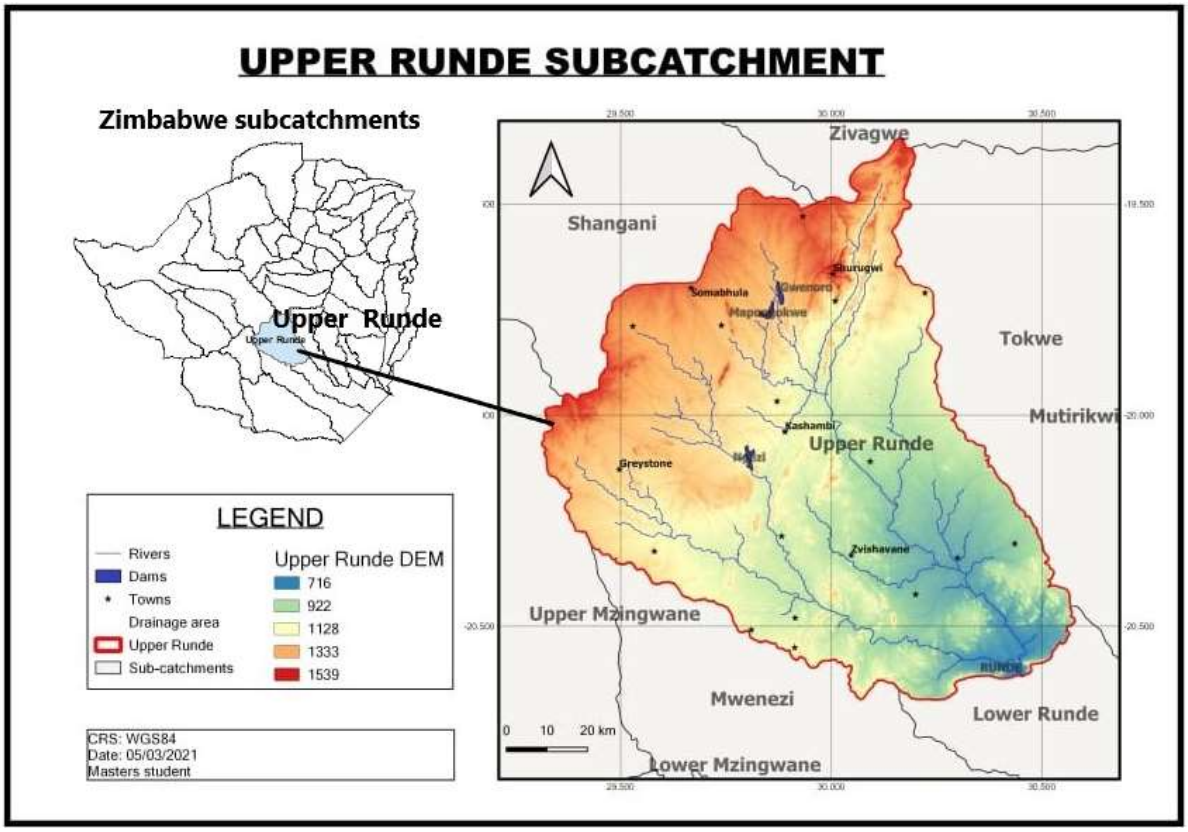

Figure 1. Upper Runde Sub-Catchment area map.

Aridity increases with distance from the north to the southern part of the catchment; hence, precipitation and temperatures decrease and increase, respectively, in this direction. Mean annual runoff spatially varies between 23 mm in the south-west of the catchment and about 113 mm in the northern part of the catchment around the Shurugwi area[22]. Upper Runde sub-catchment covers agro-ecological regions II, III, IV, and V and experiences yearly precipitation ranging between 900 mm and 450 mm in the wettest and driest areas of the catchment, respectively. The average maximum recorded temperature is 30 ℃ whereas the minimum is 5 ℃. Evaporation in this catchment ranges from 2000 mm to 1800 mm per annum[22].

The geology of the catchment is related to the Great Dyke, consisting of mate intrusions in layers that are related to economically essential metals such as platinum, nickel, chromium, vanadium, iron, titanium, copper, and tin. Upper Runde Sub-Catchment Area is a savanna woodland characterized by species such as Mopane, Brachystegia, Julbernadia, and Acacia. Most of the fauna native to the savanna woodland ecosystem in the Upper Runde Sub-Catchment area encompasses kudus, hares, monkeys, baboons, barks, and wild pigs, inter alia. A lot of bird species are also native to the conducive savanna woodlands[23] as well as enumerable smaller animal species.

Major towns in the study area include Gweru, Shurugwi, Zvishavane, and Masvingo, which provide employment to a considerable number of people. The majority of people in this area are Shona, with a considerable proportion being Ndebele speaking. According to ZimStats[24], the Upper Runde Sub-Catchment area has an estimated population of 402,978 people, of whom 211,260 (52.4%) are female and 191,718 (47.8%) are male. The dominant livelihood activities in the sub-catchment area are crop farming, livestock rearing, and artisanal mining. These activities have the potential to significantly change the land cover and introduce conditions that are ideal for accelerated soil erosion, such as overgrazing,

vegetation clearance, and open pits surrounded by loose soils. Economic activities in the area of study are predominantly agriculture, mining, and vending. Since the mineral-rich Great Dyke passes through the study area, several mines are located in this area, and they include Unkie and Mimosa mines, which are some of the major chrome mines in the country.

3. Methodology

This study used remote sensing techniques and GIS statistics. However, a combination of quantitative and qualitative data collection methods was employed to complement and expand research findings[25]. Qualitative data like interview responses complemented quantitative remote sensing data through explanations, which improved the scientific strength of the research more than it would be using one method. The study required detection and quantification of land use/cover changes in Upper Runde Sub-catchment between 2000 and 2020; hence, GIS and remote sensing techniques were adopted for a synoptic analysis of land use/cover changes. Remote sensing and GIS in this research were adopted due to their ability to provide a synoptic spatial and temporal visualization of phenomena.

The research targeted the Vungu, Shurugwi, Zvishavane, Mberengwa, Masvingo, and Chivi Rural District Councils (RDCs), Zimbabwe National Water Authority (ZINWA), and Environmental Management Agency (EMA). Vungu, Shurugwi, Zvishavane, Mberengwa, Masvingo, and Chivi Rural District Councils were targeted to provide information pertaining to land uses that influenced land cover changes between 2000 and 2020 in the catchment, especially in their respective areas of jurisdiction. From ZINWA, the upper-Runder sub-catchment manager was targeted for the provision of information pertaining to land cover modifications in the catchment and their impacts on water resources in the area. Ecosystems officers from EMA departments in Gweru, Shurugwi, Zvishavane, Mberengwa, Masvingo, and Chivi districts were targeted to provide information on land cover changes in the catchment area.

Face-to-face interviews were conducted with community development officers from RDCs, EMA ecosystem officers, and the sub-catchment manager. Audio recording was also used during interviews for the collection of all reported information after seeking consent from the interviewees. Direct field observations were conducted to confirm remote sensing data as well as the collection of ground truthing coordinates for image classification accuracy assessment.

Landsat 4-5 and 8 satellite images were acquired freely from the USGS website (https://earthexplorer.usgs.gov/) for the mapping of land use/cover changes in the Upper-Runde sub-catchment between 2000 and 2020. Landsat 4-5 images were downloaded for 2000 and 2010, and Landsat 8 image was downloaded for 2020. These paths and rows for all the adopted images were 170 and 73-74, respectively. All images had the same acquisition date, which was 21 September for the years 2000, 2010, and 2020. The study maintained use of Landsat images throughout the study period to ensure comparison of images of the same spatial resolution (30 m^2).

In this case, Landsat 4-5 was effectively operational during the first study decade, and Landsat 8 was the best functional platform, which was operational during the last study decade. All images had cloud cover below 10% to ensure better classification accuracy. All images were acquired in September, when cloud cover is at its minimum and maximum insolation is experienced on target phenomena to ensure enhanced spectral response of land covers.

Image pre-processing, processing analysis, and map production were done using ArcMap 10.5 software. Image pre-processing included data cleaning through the removal of no data value regions of

each of the images, area of interest masking using the Upper Runde sub-catchment shapefile, as well as correction of geometric and radiometric errors (**Figure 2**).

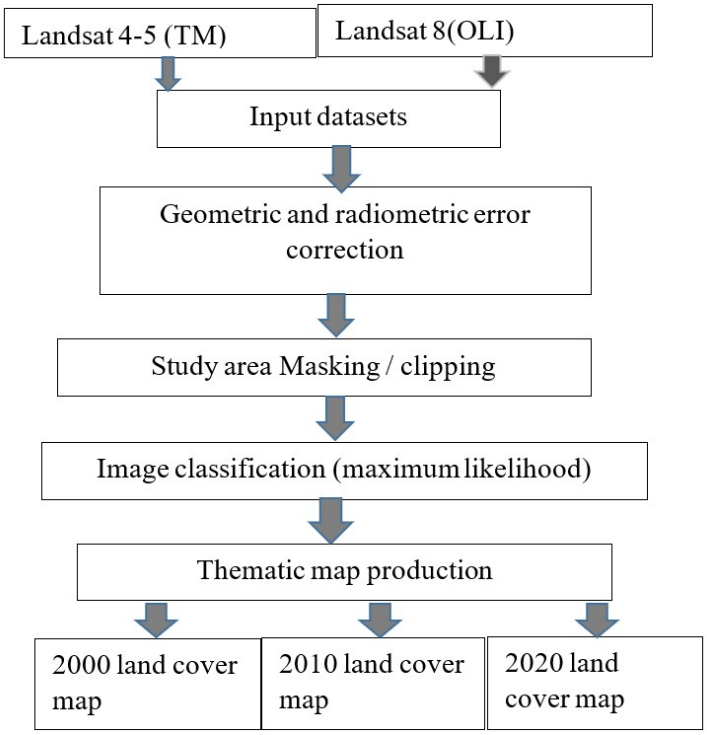

Figure 2. Land cover map production procedures.

Geometric errors were corrected through re-projection to ensure that the image and Upper Runde sub-catchment shapefiles used the same projection (Universal Mercator Projection), and radiometric errors were corrected through radiometric calibration. To solve radiometric noise problems, image enhancement (improving image contrast and brightness using the image analysis function) as well as using the reflectance rescaling coefficients given in the metadata files of the images were used. Image classification using the maximum likelihood classification algorithm was part of the processing protocol. During this process, training samples were developed, and regions of interest were selected to group all regions with similar spectral signatures into one class. The maximum likelihood classification algorithm was used because the researchers had good knowledge of the study area; hence, they could identify and distinguish land covers that appeared in respective categories. Bare rock surfaces showed a spectral signature that could be categorized as grass or water; hence, the researchers took note of that and classified them under bare lands. The same classification algorithm was adopted by a number of scholars for the same reason[21,26–28]. Following image classification, the confusion matrix was used to determine accuracy to see whether the classified images matched the ground reality. Attribute tables of classified images were exported to the Microsoft Excel package for statistical calculation of change.

Land cover statistics were exported from an attribute table in ArcMap 10.5 software to a Microsoft Excel spreadsheet for percentage calculations and the development of thematic maps showing land cover changes in Uppr-Runde sub-catchment. Qualitative data was evaluated for relevance using content analysis and screened to ensure that only valid data was adopted, which could be used to validate or endorse quantitative data presented in graphs and thematic maps. Since the interviews were conducted with reliable government offices with experts in the research domain, most of the information was relevant. The data collected during field observations was also used to supplement the quantitative data.

4. Results

4.1. Classification accuracy

Classification accuracy of the results indicated overall accuracy of 84.8% for the 2000 image and 90.4% for the 2010 and 2020 images. The lowest accuracy was recorded on grassland and scrubland (**Table 1**) due to the confusion of the spectral signature of scrublands and grasslands. However, the classification accuracy was good enough to report meaningful results.

Table 1. Land cover classification accuracy.

		2000						
		REFERENCE						
		Water	**Cultivated/ Bare**	**Grassland**	**Shrubland**	**Thick woodland**	**Total**	**User accuracy (%)**
CLASSIFIED	Water	23	0	0	1	1	25	92
	Cultivated/bare	0	22	3	0	0	25	88
	Grassland	0	1	20	4		25	80
	Scrubland	0	0	5	18	2	25	72
	Thick woodland	0	0	0	2	23	25	92
	Total	23	23	28	25	26		
	Producer accuracy	100	95.7	71.4	72	88.5		Overall Acc 84.8%
		2010						
		REFERENCE						
		Water	**Cultivated/ Bare**	**Grassland**	**Shrubland**	**Thick woodland**	**Total**	**User accuracy (%)**
CLASSIFIED	Water	25	0	0	0	0	25	100
	Bare	0	21	2	2	0	25	84
	Grassland	0	1	23	1	0	25	92
	Scrubland	0	0	3	20	2	25	80
	Forest	0	0	0	1	24	25	96
	Total	25	22	28	24	26		
	Producer accuracy (%)	100	95.5	82.1	83.3	92.3		Overall Acc 90.4%
		2020						
		REFERENCE						
		Water	**Cultivated/ Bare**	**Grassland**	**Shrubland**	**Thick woodland**	**Total**	**User accuracy (%)**
CLASSIFIED	Water	25	0	0	0	0	25	100
	Bare	0	24	1	0	0	25	96
	Grassland	0	3	19	3	0	25	76
	Scrubland	0	0	2	22	1	25	88
	Forest	0	0	0	2	23	25	92
	Total	25	27	22	27	24		
	Producer accuracy (%)	100	88.9	86.4	81.5	95.8		Overall Acc 90.4%

4.2. Land use/cover changes in Upper Runde sub-catchment between 2000 and 2010

Between 2000 and 2010, significant changes in the land cover occurred in the upper Runde sub-catchment area. The area covered by dense forest declined from 135,050.76 hectares in 2000 to 117,793.53 hectares in 2010, which represents 12.8% loss in dense forest over this decade (**Table 2**). Scrubland cover declined from 295,088.13 hectares in 2000 to 225,727.2 hectares in 2010, which shows 23.5% loss in scrubland cover during this 10-year period.

Table 2. Land use/change statistics between 2000 and 2020.

Land cover	2000 land cover (ha)	2010 land cover (ha)	% Change	2020 land cover (ha)	% Change
Forest	135,050.76	117,793.53	−12.8	112,698.41	4.3%
Grassland	446,570.37	405,517.5	−9.2	367,902.27	−9.3
Bare	146,838.15	282,109.14	92.1	328,654.7	16.5
Scrubland	295,088.13	225,727.2	−23.5	2,230,000	−1.2
Water	9427.77	1827.81	−80.6	719.91	−60.61

Over the same period of time, bare land cover, including rock outcrops, significantly increased from 146,838.15 hectares in 2000 to 282,109.14 hectares in 2010 (**Figure 3)**, which signifies a 92.1% gain in bare/rock outcrop land cover. Grassland experienced a decline from 446,570.37 hectares in 2000 to 40,5517.5 hectares in 2010, which is 9.2% loss in grassland cover between 2000 and 2010. Water cover also experienced a decrease from 9427.77 hectares in 2000 to 1827.81 hectares in 2010, which is tantamount to 80.6 loss in surface water cover between 2000 and 2010.

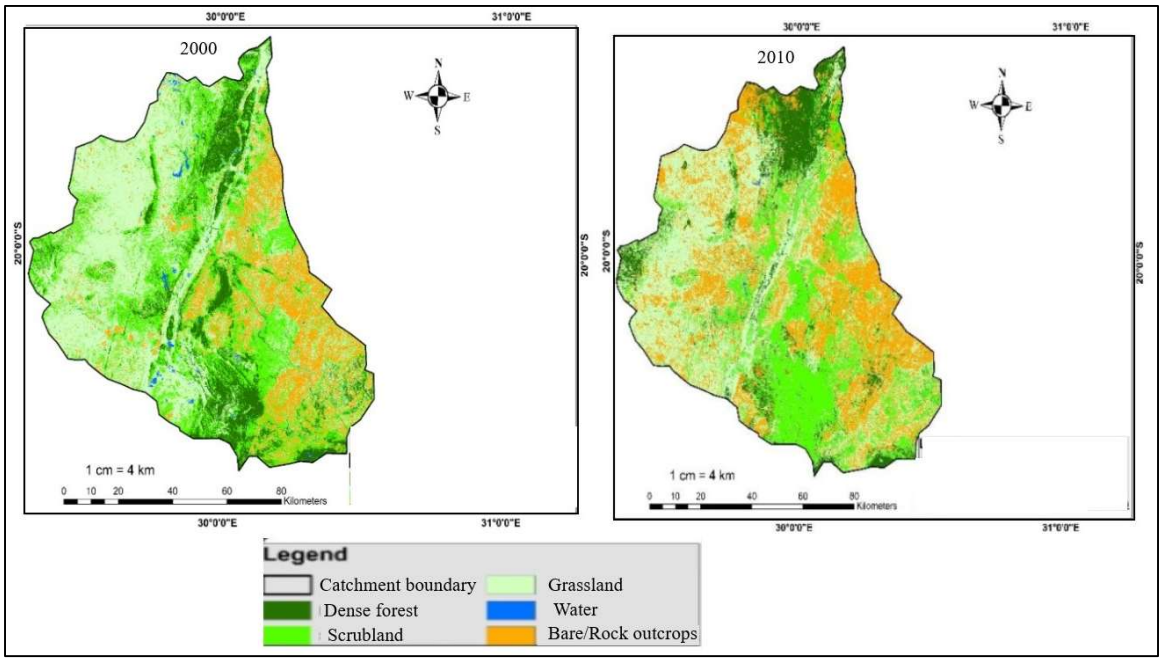

Figure 3. Upper Runde sub-catchment land cover in 2000 and 2010.

Environmental Management Agency (EMA) officers from Gweru, Zvishavane, and Mberengwa offices agreed that densely forested areas in the catchment experienced accelerated decline according to their findings during their mapping exercises. The Shurugwi EMA officer from the ecosystems department and the RDC community development officer from the Mberengwa office supported the decline in forested land, grassland, and water cover in Shurugwi and Mberengwa, respectively,

immediately after the land redistribution in 2000, which concurs with the findings of this study, whereby densely forested areas around Shurungwi experienced a loss between 2000 and 2010 (**Figure 4**). Sentiments from the ZINWA officer from the Gweru office indicated that the Gwenhoro dam, among other water bodies, experienced a decline in water quantity between 2000 and 2010, a submission that concurred with information from officers from ZINWA Shurugwi, Zvishavane, and Northern Mberengwa.

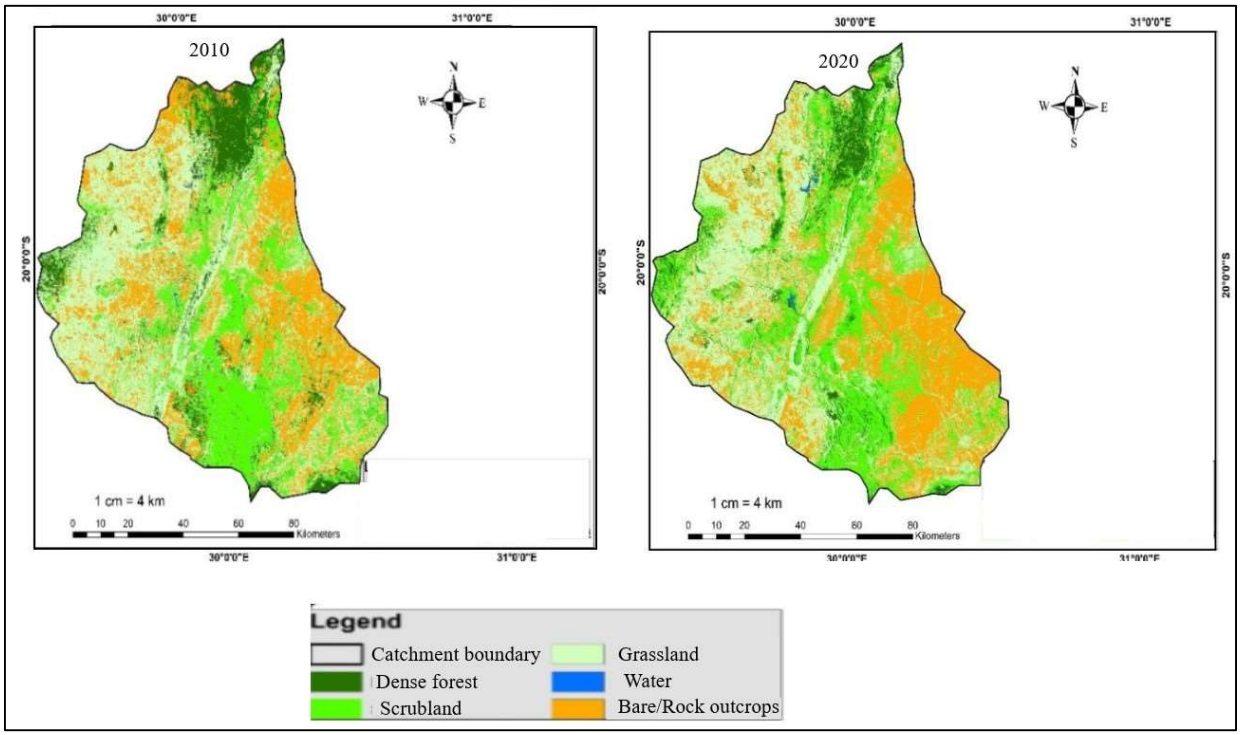

Figure 4. Upper Runde sub-catchment land cover in 2010 and 2020.

Between 2010 and 2020, dense forest further reduced to 112,698.41 hectares from 17,793.53 hectares in 2010, a loss that represents 4.3% loss in dense forest cover between 2010 and 2020. During this decade, scrubland changed from 225,727.2 hectares in 2010 to 2,230,000 hectares in 2020, which is equivalent to 1.2% loss in scrubland cover during this period. Over this period, bare land, including rock outcrops, increased from 282,109.14 hectares in 2010 to 328,654.7 hectares in 2020, a gain that represents 16.5% more bare land in 2020 compared to 2010. Between 2010 and 2020, grassland cover lost 9.3% of its 2010 area, as indicated by a drop from 405,517.5 hectares in 2010 to 367,902.27 hectares in 2020. Water cover was no exception to the changes, as these changes in catchment land cover influenced its quantity; hence, it dropped from 1827.81 hectares in 2010 to 719.91 hectares in 2020, which is a loss of 60.61% of its 2020 area coverage. These changes during the decade were confirmed by the findings by the ecosystems officer from EMA Gweru, who indicated that, in their study of ecosystem and wetland degradation in the Midlands Province between 2000 and 2015, they found that the period between 2010 and 2015 was marked by accelerated rates of water and vegetation loss as well as bare land gain. These findings by EMA research agreed with the findings from this study, as water experienced a sharp decline between 2010 and 2020, whilst at the same time all other land covers experienced loss except for bare land and rock outcrops, which increased due to an increase in canopy cover loss emanating from deforestation. The findings from this research indicated that the major driver that initiated most of the factors that led to changes in land use/cover in the Upper Runde sub-catchment is the Fast-Track Land Reform program

of 2000. Interviews with most key informants agreed that the transformation of land covers since 2000 was initiated by a change in land ownership, which was a function of the land redistribution process that came immediately after the land reform program. The EMA ecosystems officer highlighted that natural forests were under protection before 2000, when white farmers were landowners in most areas within the catchment, especially areas in lower Gweru, Matebeleland south, and parts of Mberengwa and Shurugwi districts. Dense forests in Shurugwi were under protection, but after the land reform program, most areas were cleared as new black farmers, who succeeded the white commercial farmers, started clearing tracts of land for the establishment of settlements as well as for farming, as some of them were allocated plots in grasslands or bushlands. This resulted in higher rates of conversion of forests, bushland, and grasslands to farms and settlements between 2000 and 2010, as shown by classified maps of the Upper Runde sub-catchment.

4.3. Land use/cover change and transformation between 2000 and 2020 and their drivers

All land covers except Bare/rock outcrops experienced negative changes throughout the study period (**Figure 5**).

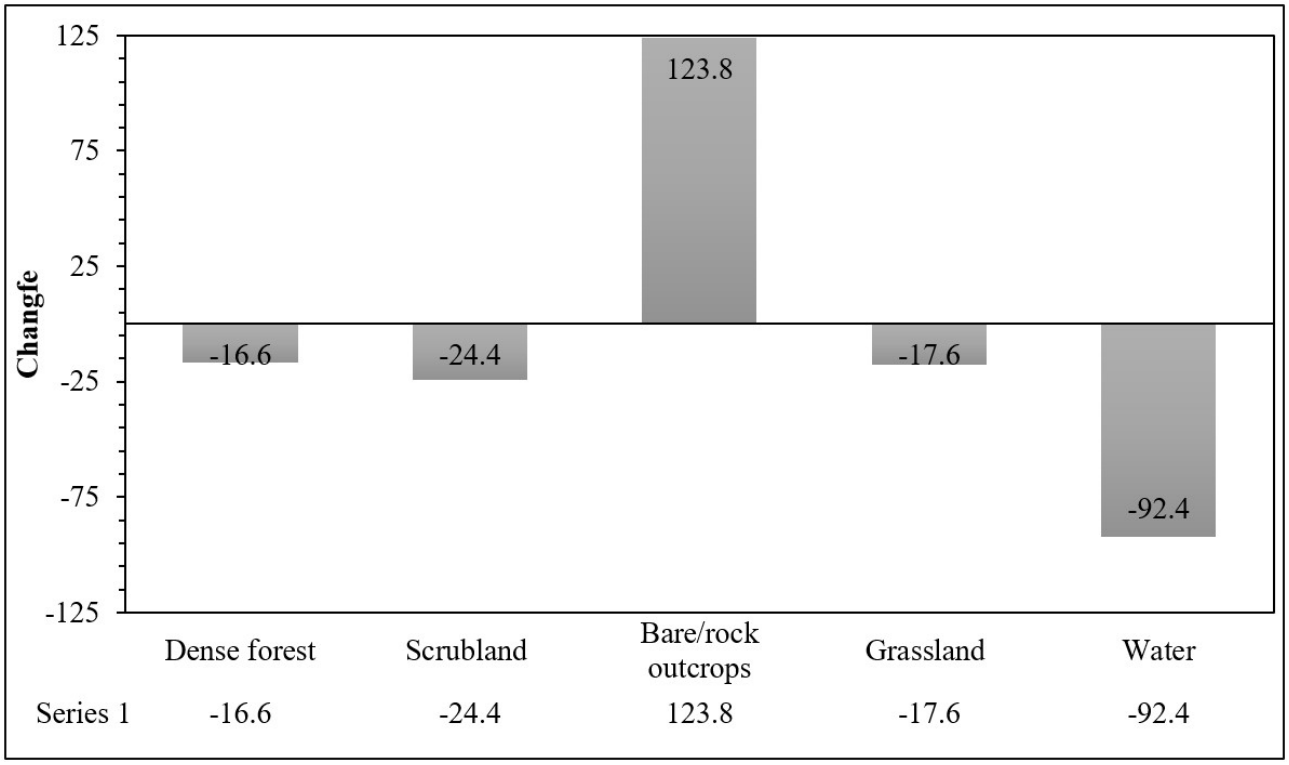

Figure 5. Overall land use/cover change rates between 2000 and 2020.

This was so mainly because the increase in bare land was at the expense of other land covers, including impacts on water bodies through increased siltation due to possibly increased erosion. The rates of increase in bare/rock outcrop land cover between 2000 and 2010 were faster compared to the rates of increase between 2010 and 2020, as indicated by an accelerated rate of 92.1% between 2000 and 2010 compared to 16.5% between 2010 and 2020. This shows that the bare land increase between 2000 and 2010 was 75.6% more than the rate for the last study decade. This was mainly because land clearance after the land redistribution was so sudden and faster, as it marked an abrupt change of land cover from grassland, forest, and scrubland to bare, with small-scale farmers dominating land clearance for agriculture and settlements.

Water cover experienced the fastest negative changes both between 2000–2010 and 2010–2020 compared to other land covers. This land cover experienced −80.6% change between 2000 and 2010 and then −60.6% change between 2010 and 2020. This indicated faster loss in water cover during the first study decade compared to the last study decade. This accelerated rate of water loss was mainly due to the increased incidence of climate change-induced droughts as well as siltation due to increased erosion on bare ground in the catchment area. However, faster rates in the first decade correspond to faster loss of vegetation and an increase in bare ground, which implies more siltation of water bodies.

Scrubland experienced second-fast negative changes during the study period. This is shown by −23.5% and −1.2% change in area under scrubland cover between 2000–2010 and 2010–2020, respectively, with faster change rates experienced in the first study decade compared to the later decade. The reason behind this accelerated loss of scrubland between 2000 and 2010 was faster conversion of land to settlements and farmlands during this decade, as shown by a faster increase in bare land cover as well.

Grassland experienced almost uniform rates of change throughout the study period, as indicated by −9.2% and −9.3% loss between 2000–2010 and 2010–2020, respectively. However, the last study decade experienced a slightly higher rate of grassland loss, most probably due to continued conversion of grasslands to farmlands as well as overgrazing in the catchment as well as heightened global warming and associated water deficits. Dense forest cover experienced faster negative change in the first study decade compared to the last study decade, as shown by losses of −12.8% and −4.3% during the first and last decade, respectively, due to the contribution of the above-described factors.

Based on an overall assessment of land use/cover changes in the Upper Runde sub-catchment between 2000 and 2020, it was shown that most of the land in the catchment experienced changes from one land cover to the other. It was revealed that the major transformations experienced over the 20-year period include conversion of grassland into bare land (23%), dense forest into scrubland (12%), scrubland into bare land (9%), and scrubland into grasslands (6%) (**Figure 6**).

These findings indicate that the increase in bare land took place at the expense of grassland and scrubland the most, which shows that grassland and scrubland were the most targeted land covers for farming. This confirms that overgrazing is among factors of land use/cover changes in the upper Runde sub-catchment, though the underlying major cause seems to be changes in land use and ownership due to land redistribution. Mining activities, especially in Shurugwi and Zvishavane, have also been mentioned as drivers of vegetation loss as well as wetland degradation by all interviewed EMA ecosystem officers. Mining activities that are being carried out in Shurugwi and Zvishavane are leading to increased clearance of tracts of land during mineral extraction, especially by small-scale artisanal miners. The change of grassland to bare land might also have been contributed by overgrazing, as indicated by some key informants during the study. It was shown that despite grassland declining in coverage between 2000 and 2020, it also gained some portions of scrubland and dense forest, most probably due to the abstraction of wood for domestic use by resettled farmers as well as the commercialization of firewood, which resulted in the removal of tree canopy, thus exposing grasslands and bare surfaces. Both the EMA officer and the Forestry Commission officer agreed that an increase in bare land and associated loss of grasslands, wetlands, and vegetation are partly due to global warming-induced high temperatures and associated water deficits, as well as increased overgrazing as a result of increased herds of cattle in some parts of Gweru, Matebeleland, and Zvishavane Districts. The EMA officer reported that one cattle that weighs 500 kg requires 3 hectares of pastureland to ensure sustainable utilization of pastureland, but the

number of cattle in most areas is far beyond the recommended capacity, which might be contributing to overgrazing.

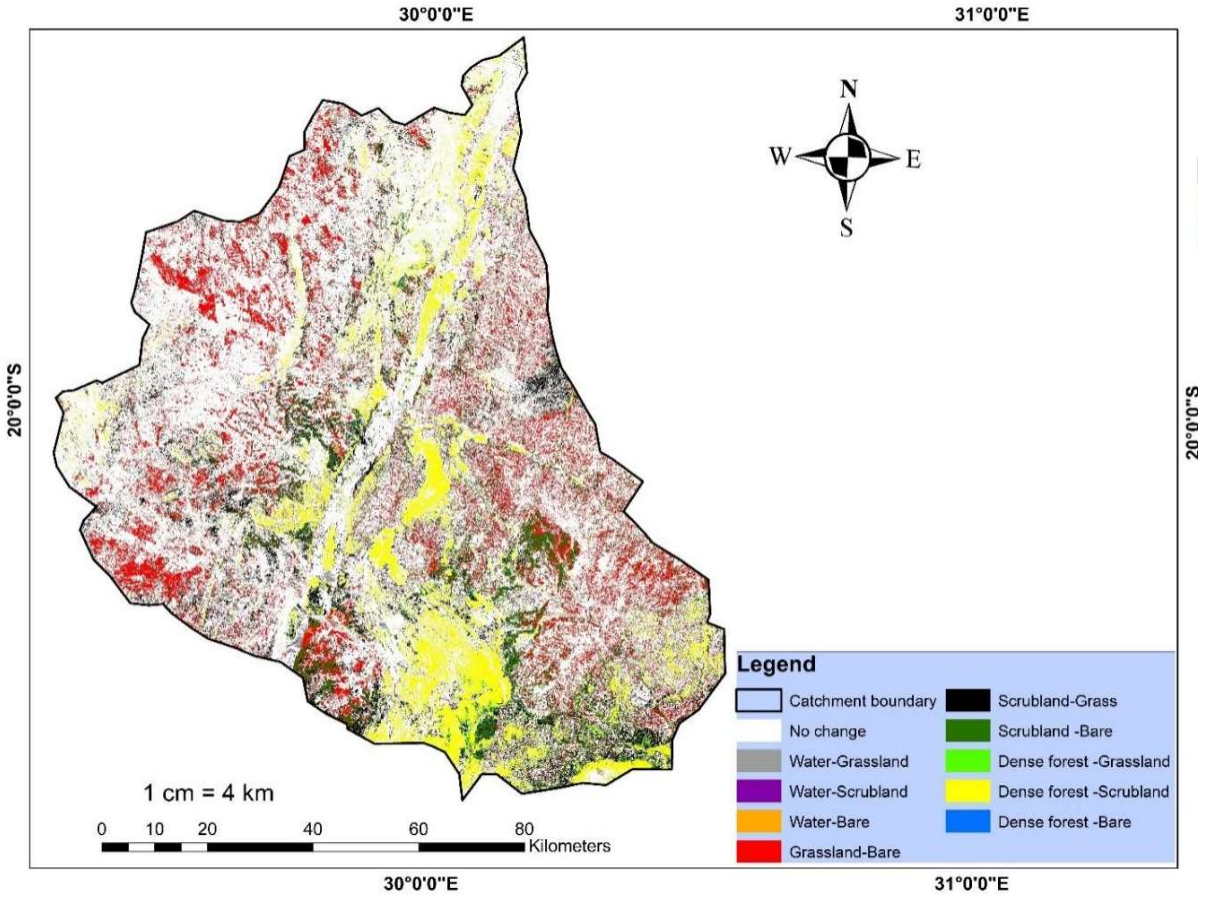

Figure 6. Land use/cover transformation map for Upper Runde sub-catchment area.

It was also confirmed that some areas that were covered by water in the catchment were transformed into grasslands, bushland, and bare land, though this change is not much visible on images due to the spatial resolution of the images used. This was confirmed by an interview with Shurugwi RDC community development officer, who highlighted that agriculture and mining have dominated clearance of forests. He further stipulated that increased livestock ownership by small-scale farmers is leading to overgrazing, which is also contributing to the loss of pasturelands and the increase of bare land cover. An interview with the ZINWA sub-catchment manager confirmed that forests that existed in 2000 and prior to this year were crucial in ensuring the sustainability of wetlands or surface water resources. He further remarked that dams, rivers, and lakes that used to be perennial became intermitted, and some are now ephemeral due to siltation emanating from increased erosion in the catchment area. It was also highlighted by the Gweru and Shurugwi EMA officers that Runde river water level has declined, which in turn resulted in declining water levels in Ngezi-Palawani dam.

The ZINWA Sub-catchment Manager attributed declined water levels in both Gwenhoro and Ngezi Palawani to increased abstraction for supply to Gweru and Zvishavane urban areas, respectively, and declined precipitation and associated frequent droughts, which are almost occurring on a yearly basis since 2015. However, the EMA Officer from Zvishavane pointed out that water levels in most dams within the Upper Runde Sub-catchment have reduced as a significant volume of these reservoirs is occupied by sand or silt. These submissions by the key informants indicate that water cover decline in

the catchment was due to a combination of siltation emanating from erosion and increased incidence of droughts in the Midlands province. Interviews with key informants from RDC, EMA, and the Forestry Commission confirmed that cutting down trees for various uses led to exposure of grasslands and bare land, a phenomenon that resulted in changes from scrubland and dense forests into grassland and bare land. The ZINWA catchment manager also indicated that reduced levels of water in surface reservoirs and streams are usually accompanied by exposure of bare land surfaces as areas that were once covered by water become uncovered or develop into grasslands. He further outlined that some wetlands, which used to be waterlogged, have been converted to agricultural lands or have dried up, leaving grass as the succeeding cover. These sentiments from the ZINWA sub catchment manager support the change of land cover from water to grassland and bare land.

5. Discussion

Land cover change and transformation has been and continues to be one of the major phenomena associated with increasing human populations and activities related to livelihoods. Therefore, changes in land ownership and use as a result of land use policy and management to accommodate changes in human need and demands have been key in driving modifications of natural landscapes in rural communities. Findings from this study indicate significant negative changes in floral natural and water resources since the time when land uses changed around 2000. The findings from this study concur with the findings from a study conducted by Matsa and Muringaniza[20] on land use/cover changes in Shurugwi District, which revealed that the Fast Track Land Reform program accelerated the increase in bare land between 2000 and 2011. Their results also indicated that grassland and forested lands as well as water cover declined due to an increase in the conversion of wetlands and once protected natural vegetation into croplands or settlements. Given that their study area is part of the Upper Runde sub-catchment under scrutiny in this study, it can be deduced that the findings from this research are also representative of activities taking place in Shurugwi District. This was supported by a study by Matsa et al.[21], which showed a significant decline in vegetation and a decline in water quantity in water resources in resettlement areas of Ward 32 of Mazowe District, including the Mwenje Dam. Their findings indicated that this was accelerated by increased land under cultivation between 2000 and 2019, which concurs with the results of this study.

More so, climate change-induced precipitation inadequacy for pasture replenishment, especially in agro-ecological regions 4 and 5a, which include parts of Mberengwa, Matebeleland south, and Zvishavane, is also contributing to grassland loss. At sub-catchment level, human activities have tremendous impacts on the availability of surface water resources. The contribution of bio-climatic variables like precipitation and temperature is difficult to measure due to the complexities of land use change drivers; however, reports suggest that these variables contribute significantly to water and other land cover changes. This cannot be doubted since water supply and loss are determined by these variables. Rural communities are characterized by various human activities like brick molding, crop cultivation, and mining activities, which can control land cover changes and transformation; hence, accounting for the contribution of climate change is difficult, though it massively deserves mention. A study by Matsa and Muringaniza[20] on drivers of land cover changes in Shurugwi indicated that Unki mine and small-scale artisanal mining have contributed to the destruction of vegetation. This confirms the finding from this study, as their study area was part of the focus area in this study.

Another study by Hailu et al.[18] on drivers of land use/cover changes in Jimma Genetti District in Ethopia showed that the highest increment in the percentage of cultivated land and associated

diminishing of wetland and forestland has been observed between the years of 1987 and 1995, which they attributed to the spike in small-scale farming in the district. This shows that crop cultivation is having significant impacts on forested lands and wetlands, which disturbs the hydrological processes of catchments. Another study by Gumindoga et al.[29] on effects of land cover/land use changes on water availability in and around Ruti Dam in Nyazvidzi catchment in Zimbabwe indicated that the increase in population who rely on firewood in rural communities of Gutu and Buhera contributed to the decline in forest cover in Nyazvidzi catchment. This supports findings from this study, where wood abstraction was confirmed to be one of the major drivers of forest loss. investigated the effects of land use/cover changes on water resources in the Nile Basin and noted that deforestation and expansion of agriculture have significant impacts on hydrological processes in the region. In Europe, studies indicated the impacts of land use changes on watershed hydrology in the Carpathian Mountains[30] and the catchment area of the Rhine River[10] and results suggest that urbanization and expansion of agriculture altered hydrological processes and led to increased runoff and flooding in the region. In America, studies have explored the drivers of land use/cover changes in hydrological catchments. For example, Pacheco et al.[31] investigated the impacts of land use changes on water resources in the Amazon Basin[9] and in the Mississippi River catchment, which indicated that deforestation and conversion of forests to agriculture have significant impacts on hydrological processes, such as increased sedimentation and altered streamflow patterns. This literature points towards more impacts of urbanization in developed regions and more impacts of agriculture and wood abstraction in developing regions. In Asia, Wang et al.[32] and Wang et al.[33] studied the impacts of land use changes on watershed hydrology in the Yangtze River Basin and found that urbanization and expansion of agriculture had significant effects on hydrological processes, including increased flood risk and water scarcity. Generally, it can be noted that human activities are responsible for land use/cover changes being experienced in different parts of the world, with agricultural activities being found in both developing and developed countries, while urbanization is significant in developed countries. However, there is still room for developing countries in Africa to urbanize and cause similar land cover changes being experienced in Europe and Asia. In this regard, there is a need to ensure the sustainability of human activities through robust legislation implementation, as regulations are already there.

6. Conclusion

The study assessed land use/cover changes in the Upper Runnde Sub-catchment area between 2000 and 2020. Findings from this study indicated significant changes in land use/cover in the catchment area, with the decade 2000 to 2010 having experienced more changes than the decade 2010 to 2020. The changes during the 20-year study period included the loss of dense forests, grasslands, water, and shrubland, as well as an increase in bare lands and exposed rock outcrops. Major land cover transformations that took place included change from forest land to bare land and grassland and shrub land, change from grassland to bare and shrub land to grassland. These changes indicate the implications of tree canopy clearance for wood and agriculture as well as tillage of grasslands and shrublands for crop cultivation. Though water resources are not much visible on the transformation map, some water areas were transformed to bare land, grassland, and scrubland, which indicates the impacts of land cover changes on surface water hydrology in the catchment. The results from this study showed that changes in land cover in the Upper Runde sub-catchment emanated mainly from conversion of naturally vegetated lands to agricultural lands and settlements following the fast-track land reform program in 2000, overgrazing due to an increase in livestock ownership in areas in the catchment, increased pressure on water resources, as well as climate change-induced precipitation deficits. In light of the findings from

this study, the Environmental Management Agency strongly encourages to vigorously implement punitive measures against illegal land developers to reduce unreasonable exploitation of wood and water resources in the Upper Runde sub-catchment area, while the Ministry of Lands, Agriculture, Water, and Rural Resettlement may consider strict auditing of land uses in catchment areas to guard against encroachment of agriculture and other land uses in protected lands and fragile ecosystems like water bodies and wetlands.

Author contributions

Conceptualization, OM and RC; methodology, OM; software, OM; validation, OM and RC; formal analysis, OM; investigation, OM; resources, RC; data curation, RC; writing—original draft preparation, OM and RC; writing—review and editing, OM and RC; visualization, OM. All authors have read and agreed to the published version of the manuscript.

Data availability statement

Data will be made available upon reasonable request from the authors.

Conflict of interest

The authors declare no conflict of interest.

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