Understanding land use and land cover change in a prolonged conflict affected farming system: the case of Tuban district, Yemen

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Abstract

A growing body of evidence suggests the worsened decline in the productivity of land resources is cascading risks on vulnerable populations in Yemen, but recent research rarely focuses on this geographical area. This study uses the most extended space-based dataset, Landsat, to evaluate land use and land cover change from 1993 to 2023 in Tuban district, a threatened biodiversity hotspot in Yemen. The paper also assessed the drivers of the change and suggested recommendations. Based on the information obtained from the field observations, the study adopted six land use types (annual cropland, perennial farmland, shrubland, riverine trees, settlement, and bare land). Results showed that between 1993 and 2023, the yearly cropland and the riverine vegetation decreased by 30.19% and 52.55%, respectively. Likewise, the shrubland showed a 63.35% decrease. On the other hand, the settlement area and bare land increased by 574.12% and 15.81%, respectively. Population growth, shortage of rain, desert locusts, lack/shortage of agricultural inputs, and the impacts of the ongoing conflict and civil war have contributed to land use and land cover change. To halt the harmful effects of land use and land cover changes, awareness development, development of locally adaptive improved seeds, afforestation, and institutional capacity development interventions are suggested as likely solutions.

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Introduction

Essentials such as food, fibre, clean water, and air that ensure the wellbeing of humanity are obtained because of the proper ecological functions of land resources. This includes the production of goods and services that ensure environmental development and protection, formation and recycling of nutrients, decomposition of wastes, aesthetic value, and the protection and conservation of genetic diversity that ensures the survival of humanity (Nowak *et al*., 2007; Östlund *et al*., 2004). However, land use and land cover change (LULC), habitat modification, population growth, climate change, and over-exploitation of natural resources are causing the degradation of goods and services of land resources (Arora, 2018; Kopittke *et al*., 2023).

Although the degradation of land resources is a global challenge (Nkonya *et al*., 2016), its impact on food security, environmental hazards, and biodiversity loss are more precarious in war-torn developing countries (Saxena, 2023) such as Yemen. Remote sensing and integrated modelling studies have also shown that land degradation driven by land use and land cover change is usually higher in conflict regions because of unregulated development pursuits, which led to urbanization, illegal quarrying, and overall challenges with solid waste disposal (Reuveny *et al*., 2010). The impacts of armed conflicts on land degradation are seen in cases such as the 1975-1990 civil war in Lebanon (Hourani, 2015) and the Tripoli clashes of 2008-2013 (Mitri *et al*., 2014), which resulted in severe losses in vegetation cover (Kallio, 2015) and contributed for land use and land cover changes. War's multifaceted impacts on land resources range from direct biophysical damage to other ripple effects, such as changes in peoples' ordinary practices and their use of land resources (Mitri *et al*., 2014). This is especially true considering that military operations heavily rely on solvents and similar toxic chemicals that leach into the land and can remain there for years (Shebanina *et al*., 2023), thus causing transboundary environmental pollution impacts.

Like other conflict affected countries in the Middle East, Yemen is facing a considerable challenge by compromising local food availability. The protracted civil war that erupted in 2011 resulted the collapse of governmental structures that ensure the efficient utilization and development of land resources and its subsequent impact on land use and land cover changes (World Bank, 2020). The armed conflict worsened the decline in the productivity of land resources due to the lack and decrease of agricultural input provisions such as improved farming skills development, improved seeds, and fertilizer supply. Caused by the ongoing conflict, the collapse in the functioning of public services has also led for uncontrolled deforestation and the inefficient soil and water management and conservation practices which in turn caused widespread flooding during farming seasons that invariably damage cultivated land (World Bank, 2017). This situation has directly impacted the land use and land cover patterns of Yemen. As a result of this, the ongoing armed conflict compounded by climate change hazards has made Yemen to be one of the food and nutrition insecure countries of the world. If the remaining land resources are to be conserved and used in an integrated and sustainable manner; sustainable utilization, conservation, and maintenance of land cover from degradation are some of the vital issues that need to be addressed by decision-making authorities of Yemen.

Thus, sustainable land management requires a better understanding of the interrelationships and linkages among the resources' ecological, social, cultural, political, and economic dimensions. Despite wide recognition that understanding these interrelations is necessary for sustainable land management, studies focussing on this area of scientific inquiry still need to be expanded and fragmented across much of Yemen.

Therefore, this study is aimed at utilizing the conventional remote sensing techniques and explore the dynamics of land use and land cover changes in the Tuban district of Yemen across time (1993-2023) and identify the possible drivers of the land use and land cover change and suggest policy and strategic related actions.

Materials and Methods

Study area

Tuban district is found on the southwestern coast of Yemen (Figure 1). The district is in the Lahj governorate of the country. The governorate is the fifth largest known for its agricultural production potential. The altitude of Lahj varies from 2500 meters above sea level to one of the most fertile Wadis (valleys) in Yemen, Wadi Tuban, which is less than 600 meters above sea level. The climate varies according to the topography, with temperatures in the coastal plains increasing to 32°C in the summer and decreasing to 20°C in the winter. In the coastal plains, rainfall occurs during the winter and autumn seasons and in spring and summer in the mountainous areas (Thabet *et al*., 2013). Tuban has some of the fastest depleting aquifers in Yemen due to greater reliance on groundwater. Model projections suggest that unless formidable interventions are implemented, the depletion of Tuban's aquifers will reach critical levels by 2025 (United States Agency for International Development, 2016), leading to decreased agricultural productivity and increased livelihood vulnerability and its inevitable impact on land use and land covers of the country.

Data collection

Multi-sensor and multi-temporal Landsat images were captured from the data portal (https://earthexplorer.usgs.gov) of the United States Geological Survey (USGS;https://apps.sentinel-hub.com/) and of Sentinel Hub to quantify the magnitude and direction of LULC change. The following factors were considered when selecting satellite images: (i) the principal events that occurred in the area and image quality that reduces the impact of clouds on land cover mapping. All imageries were obtained during the dry season, where the phonological stages of plant covers were similar between dates. The satellite images were accessed with a minimum cloud cover (<3%) between April and October, before

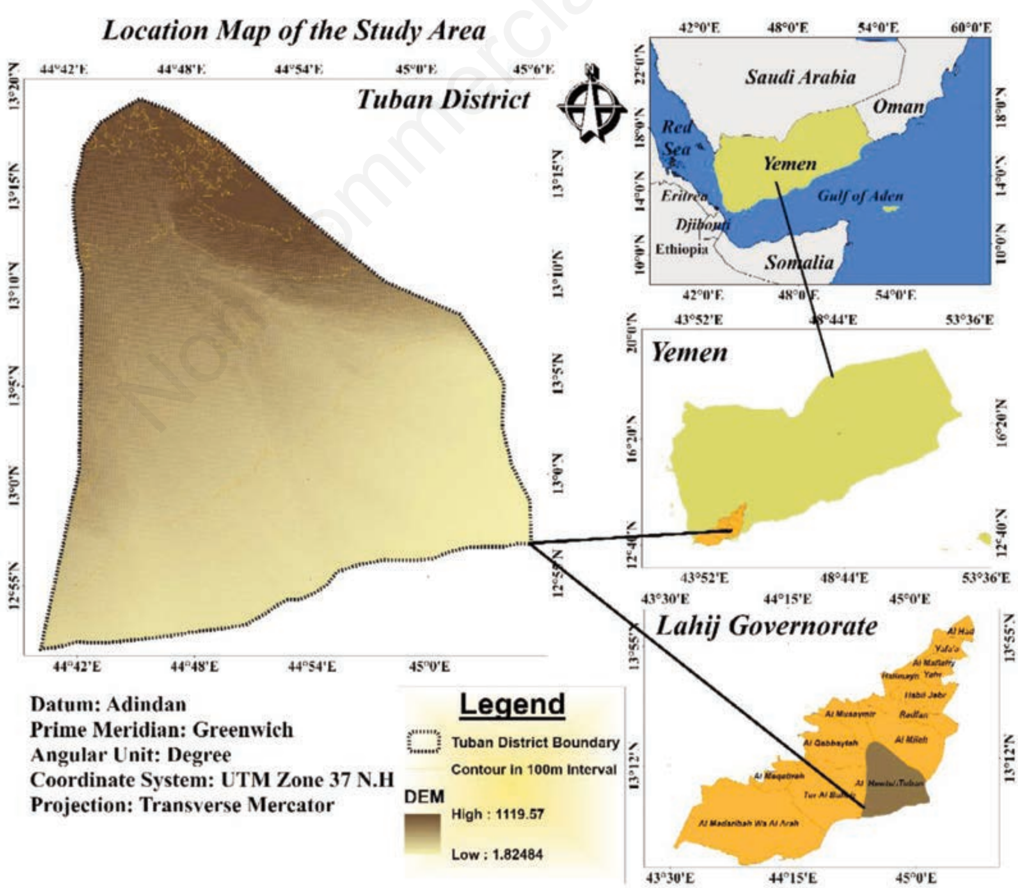

Figure 1. Location map of Tuban district, Yemen.

the mild period from October to May. Moreover, we employed multispectral satellite data (Landsat 5, 7, and 8 with sensors TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus), and OLI-TIRs (Operational Land Imager and Thermal Infrared Sensor) from 1993, 2003, 2013, and 2023, respectively (found in 161 paths and 051-row number), to identify and evaluate satellite images. The reflective Landsat bands with 30-m and 15-m spatial resolution were used to obtain the information on multi-temporal land use land cover classification (LULCC). The LULC classifications were interpreted using the expert visual interpretation capacity integrated with the Google Earth application.

For the identification of the land use and land cover change drivers, the article also used secondary sources of information.

Data analysis

Software for image analysis

Remote sensing and GIS tools were used for image processing and data analysis, including the recent ERDAS Imagine and Arc GIS version. At first, images were geo-referenced using a datum selected by WGS-84 for Tuban district, Yemen. The demarcated study area was also digitized using Arc GIS, which helped to overlay the view on the satellite image.

Image pre-processing

The visible, near-infrared (NIR), and panchromatic bands of Landsat 7 and 8 imageries were stacked using the ERDAS IMAGINE software layer to produce a false color composition image of the study area. The stacked image's digital pixel number (DN) values were converted to radiance (Ziskin *et al*., 2010). Following Lillesand and Kiefer (Lillesand and Kiefer, 1994), the atmospheric correction was done to remove the atmospheric effects on the stacked images.

Post-classification change detection evaluated LULC types on Google Earth Cloud images (Mariye *et al*., 2022). Google Earth images were significant data sources for creating the latest land cover map. LULC trends and dynamics were assessed using Landsat imagery, which provides a range of spatial, temporal, spectral, and multi-resolution capabilities for land cover analysis (Oettera *et al*., 2000). Remotely sensed earth data can be examined to derive meaningful information for various uses. The objective of image classification procedures is to automatically categorize all pixels in an image and into land use/land cover classes or themes.

Image processing and classification

To enhance the quality of the image, different mosaicking, subsetting, and radiometric enhancement techniques (Haze reduction and Histogram equalization) were applied to the raw data. The maximum likelihood algorithm classification (MLC) was applied to create a land use classification of 4 different periods. MLC is typically used as a starting point for remotely sensed data classification. Supervised image classification approaches were used for the classification of semi-automatic algorithms. After the image was processed, signatures were distributed per pixel by identifying the land cover into fixed classes. The training data were used for ten testing samples as a minimum for each LULC category. If the study area is more significant than 1,000,000 ha or has more than 12 classified categories, there should be 75-100 samples for each LULC category (Costa *et al*., 2018). This suggested approach samples small areas thoroughly, while large areas might be under-sampled. Hence, assigning the signature value (training area) in the supervised image classifications, a spatial merging approach was used to achieve a more homogenous appearance of the individual classes. This approach is used to merge neighboring regions based on their spatial features.

Training samples were selected for each of the predetermined LULC categories by delimiting polygons around representative sites. Google Earth extension was employed to reduce confusion in interpreting the pixel. Furthermore, the results obtained from the supervised class with the help of ERDAS Imagine were imported to Arc GIS for map layout preparation, reclassification, and pixel value estimation for all LULC classes. Finally, using ERDAS IMAGINE, the classified images' accuracy was assessed against the Kappa coefficient value where producer and user accuracy align side by side.

The error matrices were created using ERDAS, and the source and destination of each land cover value were evaluated in an Excel spreadsheet (Kindu *et al*., 2013; Meshesha *et al*., 2016; Othow *et al*., 2017). In addition to calculating the area of LULC in hectares and percent, we also calculated the percentage change in LULC between the stated periods (Braimoh, 2006; Pontius *et al*., 2004).

Based on the information obtained from the district, the study adopted the Intergovernmental Panel on Climate Change (IPCC) classification scheme consisting of six land use types (annual crop land, mixed farm, shrub land, riverine trees, settlement, and bare land) (Table 1).

Table 1. Land use/land cover types and definition.

Land cover/land use type	Description
Annual crop land	Areas used to produce annual crops, such as corn, soybeans, vegetables, and cotton. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Mixed farmland	Areas of grasses, legumes, or grass-legume mixtures are planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle, and also perennial woody crops such as orchards and vineyards. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Riverine tree	Areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover. Deciduous nor evergreen species are greater than 75% of total tree cover.
Settlement	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Shrub land	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation.
Bare land	This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions. Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Hence, the article applied standard remote sensing techniques and that is meant to serve as a first glance information whereby other researchers can build on this research findings and make further exploration on the ground whenever the security situation is improved in the country.

Results

Accuracy classification

The overall accuracy of the study's thematic maps varied from 85% to 90%, and the overall Kappa statistics ranged from 0.82 to 0.88 (Table 2). These accuracy and Kappa values of the six classifications are within the acceptable range of accuracy (>80%) and these results are found to be satisfactory for the land use land cover change analysis (Alshari and Gawali, 2022; Solomon *et al*., 2018).

Land cover changes

Six representative land cover classes were extracted from the Tuban district for 1993, 2003, 2013, and 2023. In 1993, the bare land classification was the dominant land classification, covering about 65.96% of the district's total area, followed by shrubland (16.77%) and annual cropland (13.29%). This was again followed by the riverine (3.08%), settlement (0.78%), and mixed farmland cover classes (Table 3).

Furthermore, the 2003 land use and the land cover trend was also dominated by expanding the bare land cover class to 77.59%, followed by annual cropland cover (10.83%). The annual cropland cover class decreased by 3% since 1993, while the bare land increased by 12% from 1993. On the other hand, the riverine land cover also reduced from 3.08% (1993) to 1.36% (2003). The settlement areas and the mixed farmland classes made up 1.04% and 0.33%, respectively, showing an increase from the 1993 coverages (Tables 3 and 4).

The bare land continued to expand in 2013 and remained the dominant land cover of the district (80.62%), followed by the annual cropland cover (12.16%). The shrubland continued to shrink in 2013 (1.87%), while the settlement areas doubled (2.59%) compared to 2003 (Tables 3 and 4).

In 2023, the bare land amounted to 76.39% showing a 4% decrease from 2013. The annual cropland cover decreased by 3%, about 9.28%, in 2023. Contrary to this, the settlement land cover increased from 2.59% (2013) to 5.23% (2023). The mixed farm and the riverine vegetation covered about 1.5% and 1.46% of the district in 2023 (Tables 3 and 4).

Moreover, these results are also in agreement with the detailed spatial representation of the Land Use Land Cover classes from 1993, 2003, 2013, and 2023 as indicated in Figure 2.

Drivers of land use land cover change

Based on the review of related literature and observations by the authors, below are the major driving factors that caused the land use and land cover changes of the study area.

Civil unrest

Yemen has been going through civil unrest over the past decade, and this has caused economic, social, and other crises (Elnakib *et al*., 2021). The ongoing conflict has destabilized public services (AlMunifi and Aleryani, 2021), local and regional livelihood opportunities (Al-Saidi *et al*., 2020), and the subsequent col-

Table 2. Accuracy assessment results.

Class name	Accuracy percentages							
	1993		2003		2013		2023	
	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's
Mixed farm	90	90	90	90	90	90	90	90
Annual crop land	90	90	90	90	82	90	100	90
Riverine tree	80	80	80	80	89	80	90	90
Settlement	80	80	80	80	89	80	90	90
Shrub land	90	90	90	90	80	80	90	90
Bare land	90	90	90	90	82	90	82	90
Overall accuracy	86		87		85		90	
Overall kappa	0.84		0.84		0.82		0.88	

Table 3. Land use and land cover changes in Tuban.

Land cover classes	1993		2003		2013		2023	
	Hectare	%	Hectare	%	Hectare	%	Hectare	%
Annual crop land	19,188	13.29	15,633	10.83	17,564	12.16	13,394	9.28
Bare land	95,239	65.96	112,031	77.59	116,416	80.62	110,299	76.39
Riverine tree	4,453	3.08	1,961	1.36	2,830	1.96	2,113	1.46
Shrub land	24,219	16.77	12,801	8.87	2,707	1.87	8,876	6.15
Settlement	1,120	0.78	1,497	1.04	3,740	2.59	7,550	5.23
Mixed farm	175	0.12	471	0.33	1,136	0.79	2,161	1.5
Total	144,394		144,394		144,394		144,394	

lapse of institutional services and capacities (Sharp, 2020). The civil unrest has also disrupted the proper functioning of local-level natural resource governance systems, which has, in turn, contributed to the degradation of resources such as natural forests and shrubland covers.

Population growth

As elsewhere in the world (Mohamed and Abo, 2023; Struyk, 2005), Yemen has experienced an ever-increasing human population. The population increased from 3.32 million in 1960 to 33.70 million in 2022 (United Nations Population Funds, 2022). Since humans rely directly on land resources for fibre, food, energy, settlement, *etc.*, this increase has led to the expansion of settlement areas and the degradation of resources such as forests and shrublands cover as a major way of satisfying household energy needs.

Climate change

Climate change poses a severe threat to the natural world. Shortage of rain, increased temperature, and other harmful impacts of climate have altered the land use and land cover trends.

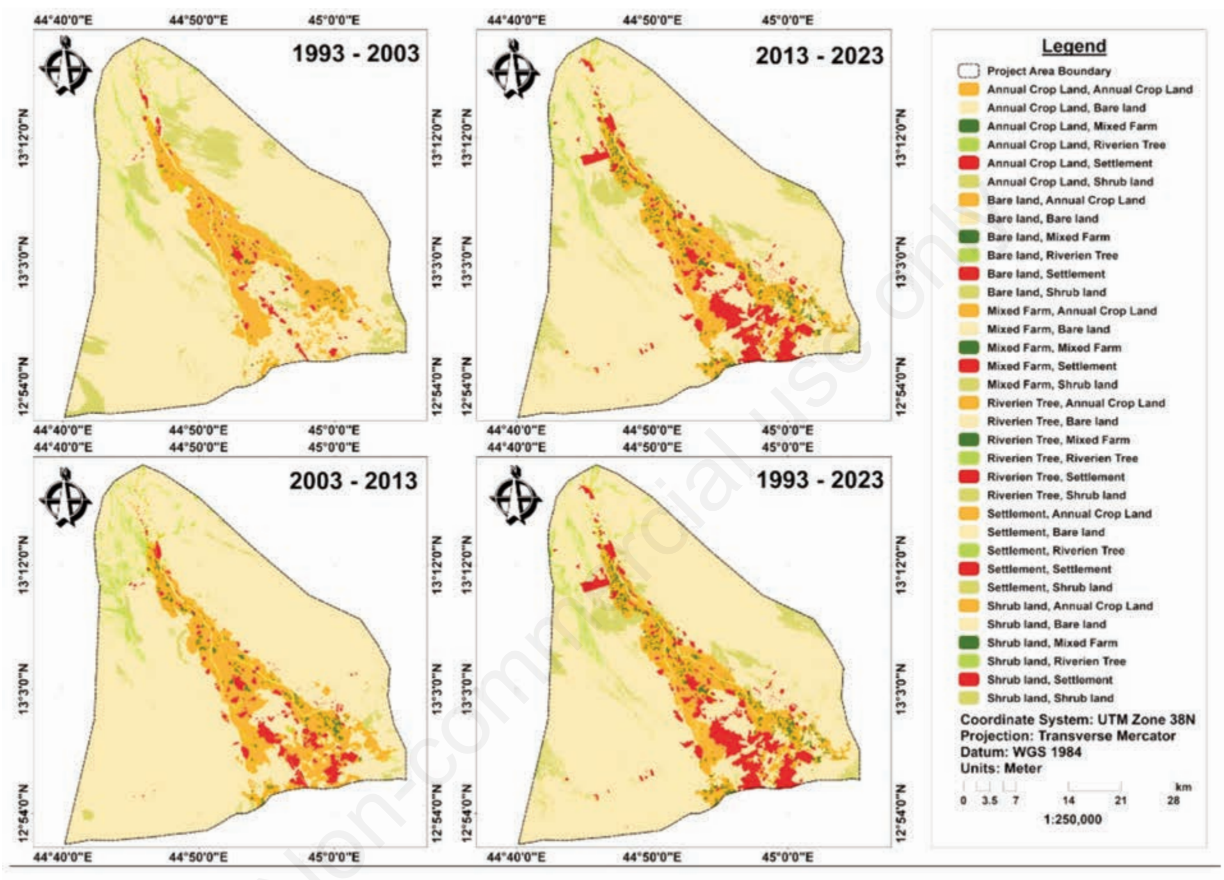

Figure 2. Land cover change detection map.

Table 4. Conversion matrix using change detection result (in square kilometer).

Land cover categories	Land use land cover in 1993						Row total
	Annual crop land	Bare land	Mixed farm	Riverine tree	Settlement	Shrub land	
Land use land cover in 2023							
Annual crop land	114.33	12.34	0.78	0.57	0.89	5.03	133.94
Bare land	35.89	827.38	0.02	33.24	0.96	205.50	1,102.99
Mixed farm	17.91	1.63	0.91	0.03	0.18	0.97	21.61
Riverine tree	0.82	9.60	0.01	10.14	0.08	0.48	21.13
Settlement	18.56	41.87	0.02	0.38	8.94	5.73	75.50
Shrub land	4.37	59.57	0.00	0.17	0.16	24.48	88.76
Class total	191.88	952.39	1.74	44.53	11.20	242.19	1,443.94
Class changes	77.55	125.01	0.84	34.39	2.26	217.71	
Image difference	-57.94	150.60	19.87	-23.40	64.30	-153.44	

Regarding climate vulnerability, the Notre Dame Global Adaptation Initiative ranked Yemen 172 out of 182 countries. According to the UN Office for the Coordination of Humanitarian Affairs's (2022) Humanitarian Needs Overview report, Yemen is highlighted as one of the world's most water-stressed countries, painting a bleak picture for Yemenis and Yemen's agriculture and food systems along with its direct negative impact on land use and land cover changes.

Decreased agricultural productivity and production

The agricultural practices of Yemen in general and the study area in particular faced a considerable challenge due to the increased cost and shortage of agricultural inputs (seed, fertilizer, pesticides, *etc*.). The regional desert locust infestation has also contributed to the decrease in agricultural land use (World Bank, 2020).

Discussion

Land use and land cover changes

Between 1993 and 2023, the bare land coverage of the district increased from 95,239 hectares to 110,299 hectares. Contrary to that, the annual cropland cover that maintains the livelihood of the local population decreased from 19,188 to 13,394 hectares. In the same pattern, the riverine vegetation decreased from 4,453 to 2,113 hectares between 1993 and 2023 (Tables 5 and 6). The shrub land cover also reduced from 24,219 hectares to 8,876. On the other hand, the settlement area has increased from 1,120 hectares in 1993 to 7,550 hectares in 2023. Expansion of the bare land and settlement areas, on the one hand, and the decreasing pattern of shrublands in Yemen are reported by different scholars (Abdlwahed, 2008; Alshari and Gawali, 2022). A significant vegetation cover loss and ecological obliteration is also reported in the Socotra Island of Yemen (Van Damme, 2022). Research also shows that land use and land cover change, the expansion of invasive species, habitat modification, population growth, the severe impact of fertilizers on the environment, climate change, and over-exploitation of natural resources are among the primary causes of the threat (World Wildlife Fund, 2015).

Therefore, all the land cover classes of the study area have gone through considerable changes over the years (Tables 5 and 6). For instance, between 1993 and 2023, about 3,589 hectares of Annual cropland changed to Bare land; 1,856 hectares of Annual cropland cover changed to Settlement; 5,957 hectares of Bare land transformed to Shrub land; 4,187 hectares of Bare land converted to Settlement; and 3,324 hectares of Riverine tree land cover is turned into Bare land.

The protracted civil unrest and the armed conflict that fully erupted in the entire country during the years 2011-2014 has impacted the functioning of the public services, livelihoods, land use patterns, and food systems in general. This also must have caused for the slowdown of crops production activities in the area and hence the decrease of the annual cropland from 13.2 to 12.16% in between the years of 1993-2013. On the other hand, considering the increasing trend of population from time to time, the cropland (agricultural activities) was supposed to increase, however, it is vivid that the ongoing civil war disrupted the agricultural activities and forced people to flee from farmlands. This decrease in agricultural production and productivity has impacted the food systems of the country in general and the study area in particular.

In similar vein, though research findings are very minimal, some research undertakings in the conflict affected areas of Yemen indicated that, land use and land cover changes are observed in different spots of the country. A study done in the year 2008 in Aden governorate for instance indicated that, the greater portion (40.29%) of the shallow sea water of the area is converted to soil filling. In the same governorate 32.49% of the sand / mountain land use types are changed to urban settlement use. It was also indicated that 18.20% of the sand / mountain land use is changed to a vegetation covered area between 1987 and 2003 (Abdlwahed *et al*., 2008). Similarly, a study done in Ibb city of Yemen found out that, in between 1990 and 2020 the vegetation cover of the area decreased from 33.2% to 27.8% while baren land and settlement areas showed a significant increase. Population growth, climate change, weakened national policies and institutional capacities, and the decreased access on the use of advanced agricultural technologies have contributed for the change in land use and land covers of Ibb (Dammag *et al*., 2023).

Table 5. Area and land cover percentage change in Tuban.

Land cover classes	Percentage change of LULC		
	1993-2003	2003-2013	2013-2023
Annual crop land	-18.53	12.36	-23.74
Bare land	17.63	3.91	-5.25
Riverine tree	-55.95	44.28	-25.34
Shrub land	-47.15	-78.85	227.85
Settlement	33.68	149.75	101.9
Mixed farm	168.92	141.48	90.19

LULC, land use and land cover change.

Table 6. Land use and land cover changes of Tuban between 1993 and 2023.

Land cover classes	1993		2023		Net change area in hectare	Percentage change of LULC	Rate of change (hectare/year)
	Hectare	%	Hectare	%			
Annual crops land	19,188	13.29	13,394	9.28	-5,794	-30.19	-579
Bare land	95,239	65.96	110,299	76.39	15,060	15.81	1,506
Riverine tree	4,453	3.08	2,113	1.46	-2,340	-52.55	-234
Shrub land	24,219	16.77	8,876	6.15	-15,343	-63.35	-1,534
Settlement	1,120	0.78	7,550	5.23	6,430	574.12	643
Mixed farm	175	0.12	2,161	1.5	1,986	1135.1	199
Total	144,394		144,394		46,954		

LULC, land use and land cover change.

A land cover change analysis done in Ma'rib city of Yemen also showed similar trend of land cover changes in the area. From 1987 to 2018, water bodies declined by 83.5% while settlement areas and farmlands increased by 365.52% and 324.52% respectively (Al-Akad *et al*., 2019).

In a similar conflict affected country (Afghanistan) a study that evaluated land use and cover change in between 1973-2022 also unveiled that in the city of Kabul significant land use and land cover changes were observed in between 1973-2022. For instance, the barren area showed an expansion from 22.89% (2013) to 29.97% in 2020 while water bodies are reduced from 2.51% in 2003 to 1.30% in 2013 (Hekmat *et al*., 2023).

From these results, field level observations and discussions with local authorities it is striking to observe that improper utilization of natural resources and lack of sustainable land use policy and practices exacerbated by the ongoing conflict in Yemen are contributing for a remarkable land use and land cover change in the country. The food security trend analysis done by development partners indicated as Yemen is already facing acute food insecurity due to the climate change, and the natural resources degradation that is aggravated by land use and land cover changes (FAO, 2023). Despite these basic facts, due to the ongoing conflict and limitations in getting official permits to collect data from the field, the research faced some limitation on furnishing the satellite imagery findings with ground truthing data as well as local community's perception on the land use and land cover change trends of the area. Apart from that, since the study area is among the highly insecure areas of Yemen, field level observations and consultations with the local communities will require a heavy military escort and such movements are found to be costly from financial and security perspectives. However, the satellite imagery findings are believed to inform policy and decision makers in addressing the sever land use and land cover changes and the exacerbated environmental degradation trends that are happening in Tuban and other parts of Yemen.

Major drivers of land use land cover change

The present study aimed to employ quantitative modes of enquiry to unravel the dynamics of land use and land cover change in Tuban, Yemen. The most striking observation to emerge from this analysis is that the district has undergone substantial land cover changes. While the extent and causal factors of these changes were speculative, it is now apparent that civil unrest, population growth, climate change, and decreased agricultural productivity are the primary drivers of land use and land cover change in Tuban. In line with this, considering the current civil unrest in Yemen, properly functioning governance systems are critical to the sustainable utilization of land resources since natural resources governance will influence the practice of efficient utilization and development of available land resources such as forest, agricultural lands and many more resources (Hammelman, 2022; Peng *et al*., 2022). Governance systems are particularly essential if the attendant regulatory services do not impair land and overall ecosystem functions, and this has been shown elsewhere to lead to Land Degradation Neutrality. This concept aims at preserving land resources by ensuring no net loss of productive land (Hannam, 2022). However, in the context of the current conflict in Yemen, due to the prevalence of weak institutional capacities, the efficient governance of natural resources is being challenged because of weak law enforcement on land use practices and lack of efficient land use policies and strategies.

Conclusions

This paper analyzed Tuban district, Southern Yemen's land use land cover changes from 1993 to 2023. High accuracy of the thematic maps and overall Kappa statistics were obtained for the study area (85% to 90% and 0.82 to 0.88, respectively). The district has undergone noticeable land cover changes over the past 30 years owing to the ongoing conflict in the country, population growth, impacts of climate change, and the decrease in agricultural production. The bare land of the district expanded from 95,239 hectares in 1993 to 110,299 hectares in 2023. The riverine vegetation also decreased by half in the last 30 years. The annual cropland cover has also decreased from 19,188 to 13,394. Similar results were also witnessed in the decline of the shrubland. The settlement area on the other hand increased by 7-fold over the past 30 years. Civil unrest, population growth, climate change, and decreased agricultural productivity are the primary drivers of land use and land cover change in Tuban. To counteract the drivers of land cover change, the study recommends that development actors establish functional natural resources governance structures in local communities by analyzing the growing demands of the increasing population, current climate change, and environmental degradation trends. The sustainable utilization, improvement, and management of land resources requires a better understanding of the localities' interrelationships and linkages among ecological, social, cultural, political, and economic dimensions. Hence, the establishment of a cross-sectoral coordination development framework is also likely to play a role in the sustainable management and utilization of land resources. However, it is also worthy to mention that, cognizant of the current collapsed governmental systems and structures of Yemen, the possibilities of establishing efficient natural resources governance mechanisms seems to be a challenging goal to be achieved within a short time span. Owing to the current civil war, this research has some limitations in supplementing the findings of the satellite imagery with household survey and other sources of primary data such as focus group discussions with the local community. Hence, other researchers can build on the findings of this research and make further exploration on the ground whenever the security situation in the country is improved. Apart from this, considering the spatial resolution limitations, future research can consider utilizing higher resolution options for better insights.

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