

# Rangeland Degradation and Woody Plant Decline in Galmudug, Somalia: Linking Land Cover Change, NTFP Livelihoods, and Restoration Pathways

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**Abstract:** Galmudug State in central Somalia represents a critical case for understanding dryland degradation dynamics where pastoralism, charcoal production, and climate vulnerability intersect. This study analyzes land use and land cover change (LULCC) in Galmudug between 2010 and 2022 using Landsat satellite imagery processed through supervised classification, integrated with household surveys (n=133), focus group discussions (n=3), key informant interviews (n=5), and institutional capacity assessments (n=8). Results reveal that Galmudug experienced catastrophic tree cover loss, with forest area declining from 119,687 ha (1.42% of total area) in 2010 to 16,284 ha (0.19%) in 2022, a loss of 103,403 ha at an annual deforestation rate of -18.13%. Scrub/shrub vegetation decreased from 7,718,947 ha (91.85%) to 7,231,680 ha (86.05%), a loss of 487,267 ha (-0.59% annually), while bare ground expanded from 533,502 ha (6.35%) to 1,125,620 ha (13.39%), an increase of 592,118 ha (+6.79% annually). Cultivated areas showed minimal change (0.02% of total area). Community perceptions identified tree cutting for charcoal as the primary cause of forest depletion (90% of respondents), with drought and overgrazing as contributing factors. The endangered *Cordeauxia edulis* (Yi'ib/Yicib shrub) was reported as having limited availability and declining populations. Over 65% of households rely on NTFPs for subsistence, with firewood and charcoal the dominant income-generating activities. Galmudug represents a "charcoal depletion" trajectory where slow-growing *Acacia-Commiphora* woodlands are being mined with minimal institutional capacity, the Ministry of Environment exists "only by name" with no trained staff or facilities. We recommend emergency interventions including a moratorium on charcoal production from live trees, establishment of village-level FMNR systems focused on *Cordeauxia edulis*, development of alternative energy sources, and major institutional capacity building.

**Keywords:** Land Use Land Cover Change, Deforestation, Galmudug, Somalia, Charcoal, *Cordeauxia Edulis*, Rangeland Degradation, NTFP.

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## I. INTRODUCTION

Central Somalia, encompassing Galmudug State, represents one of the most data-poor and environmentally vulnerable regions in the Horn of Africa. Characterized by hot, dry conditions with annual rainfall between 150–300 mm, no perennial rivers, and a landscape dominated by *Acacia-*

*Commiphora* deciduous bushland and shrubland, Galmudug supports a predominantly pastoral and agro-pastoral population whose livelihoods depend on livestock rearing, limited rainfed agriculture, and harvesting of non-timber forest products (NTFPs). Among the most significant NTFPs is *Cordeauxia edulis* (locally known as Yi'ib or Yicib), a multi-stemmed evergreen shrub endemic to eastern Ethiopia

and central Somalia that produces highly nutritious nuts, described as a "staple food for pastoralists", and provides drought fodder for livestock [1; 11]. During the devastating Sahelian drought of 1974, Yi'ib nuts were among the few foods available in markets, demonstrating their critical safety-net function [9].

Despite its ecological and livelihood importance, Galmudug has received minimal research attention compared to Puntland (with its commercially valuable frankincense exports) or Jubaland (with its perennial river and agricultural potential). The region exemplifies what might be termed the "charcoal depletion" trajectory of dryland degradation: slow-growing *Acacia* and *Commiphora* woodlands are being mined for charcoal production to meet domestic energy demand and, despite a UN Security Council ban on Somali charcoal exports (Resolution 2036 of 2012), illicit shipments continue to Gulf countries. The hard labor of charcoal production is carried out by poorer members of society, often internally displaced persons (IDPs) who have lost livestock to drought, while influential traders and militia groups capture most of the value. For a bag (25-30 kg) of charcoal that sells for \$12 in the Middle East whilst only \$1-2 is paid to the laborer producing the charcoal [12]. This extreme value extraction creates perverse incentives: producers have no stake in sustainable management because they receive minimal returns, while powerful actors who capture most value have no interest in regulation or reinvestment.

Globally, land use and land cover change (LULCC) analysis using remote sensing has become essential for quantifying deforestation rates, identifying degradation hotspots, and providing evidence for policy formulation [6, 10, 4] demonstrated the effectiveness of supervised classification using the Maximum Likelihood Classifier in Cameroon's Mount Nlonako forest, achieving classification accuracy of 89.85–93.11% and documenting deforestation rates of -1.08% annually. The present study adapts these methodological approaches to Galmudug's unique conditions, addressing three research questions: (1) What are the rates and patterns of vegetation cover change in Galmudug between 2010 and 2022? (2) How do these changes affect availability of key NTFP species, particularly the endangered *Cordeauxia edulis*? (3) What institutional capacity gaps constrain sustainable resource management?

## II. MATERIALS AND METHODS

### ➤ Study Area

The study was conducted in Guriceel district, Galmudug State, central Somalia (approximately 5°18'N, 46°12'E). Galmudug is characterized by flat to gently undulating plains rising from 279 m asl at Guriceel to higher elevations toward the Ethiopian border. The region has no perennial rivers, with boreholes, rainwater harvesting, and shallow wells providing water for human and livestock consumption. Annual rainfall ranges from 150 to 300 mm, falling during two rainy seasons: *Gu* (March–May) and *Dayr* (October–December). Rainfall is highly erratic, and drought is recurrent. Mean annual temperatures range from 25°C to 35°C, with extreme highs exceeding 40°C. Vegetation is dominated by open shrubland and woody plants including *Acacia bussei*, *Acacia*

*edgeworthii*, *Commiphora* spp., *Cordeauxia edulis*, *Dobera glabra*, *Grewia penicillata*, *Ziziphus spina-christi*, and *Balanites aegyptiaca* [13].

### ➤ Land Cover Classification and Change Detection

Landsat satellite imagery from 2010 (Landsat 7 ETM) and 2022 (Landsat 8 OLI-TIRS) was downloaded from the USGS Glovis data archive. Images were selected from November–December to minimize cloud cover and standardize seasonal conditions. Pre-processing included radiometric calibration, atmospheric correction, and geometric registration to UTM projection (Zone 38N, WGS 1984) using ERDAS IMAGINE 2018 software.

Supervised classification using the Maximum Likelihood Classifier (MLC) followed protocols validated by [4, 6]. Seven land cover classes were identified: Trees, Scrub/Shrub, Crops, Built Area, Bare ground, Grass, and Water surface. Training signatures (180 pixels per class) were developed using false-color composites. Accuracy assessment was performed using confusion matrices with reference data from Google Earth high-resolution imagery and community consultations, with overall accuracy >85% and Kappa coefficient >0.80 considered acceptable [8]. The annual rate of change (T) was calculated using the [2] formula:  $T = [(lnS2 - lnS1) / ((t2 - t1) \times ln e)] \times 100$ .

### ➤ Socioeconomic and Institutional Data Collection

Mixed-methods data collection was conducted from April to June 2022. Household surveys (n=133) using structured questionnaires captured NTFP collection practices, species used, income sources, perceptions of vegetation change, and charcoal production activities. Focus group discussions (n=3, average 6 participants per group) were conducted with community elders, Yi'ib nut collectors, charcoal producers, and women involved in firewood trading. Key informant interviews (n=5) targeted Ministry of Environment staff, local government officials, and traditional leaders (*Nabadoono*). Institutional capacity assessments (n=8) evaluated staff training, infrastructure, equipment, and resource needs.

## III. RESULTS

### ➤ Land Cover Classification Accuracy

Accuracy assessment for the classified LULC maps revealed overall accuracy of 89.85% for the 2010 map and 91.48% for the 2022 map, with corresponding Kappa coefficients of 0.85 and 0.87. These values meet the 85% threshold recommended by [8] and are consistent with results reported by [4]. User's accuracy ranged from 83.5% (Crops) to 94.2% (Bare ground), while producer's accuracy ranged from 82.1% (Scrub/Shrub) to 92.8% (Trees).

### ➤ Land Cover Status and Change in Galmudug (2010–2022)

Table 1 presents the area statistics for each land cover class in Galmudug for 2010 and 2022. In 2010, Scrub/Shrub dominated the landscape, occupying 7,718,947 ha (91.85% of total area). Bare ground covered 533,502 ha (6.35%), while Trees occupied 119,687 ha (1.42%). Water surface, Crops, and Built Area comprised the remainder: 25,513 ha (0.30%), 1,792 ha (0.02%), and 4,263 ha (0.05%), respectively.

Table 1: Land Use Statistics for Galmudug State (2010–2022)

Land Cover	Area 2010 (ha)	% 2010	Area 2022 (ha)	% 2022	Change (ha)
Water surface	25,513.00	0.30	26,097.20	0.31	+584.20
Trees	119,687.00	1.42	16,284.30	0.19	-103,402.70
Crops	1,792.46	0.02	1,878.13	0.02	+85.67
Built Area	4,262.93	0.05	2,144.43	0.03	-2,118.50
Bare ground	533,502.00	6.35	1,125,620.00	13.39	+592,118.00
Scrub/Shrub	7,718,946.67	91.85	7,231,680.00	86.05	-487,266.67
<b>Total</b>	<b>8,403,704.06</b>	<b>100</b>	<b>8,403,704.06</b>	<b>100</b>	<b>---</b>

By 2022, bare ground expanded to 1,125,620 ha (13.39%), representing a net increase of 592,118 ha, the largest absolute change. Scrub/Shrub declined to 7,231,680 ha (86.05%), a loss of 487,267 ha. Tree cover collapsed to 16,284 ha (0.19%), a loss of 103,403 ha, representing an 86% reduction in forest cover in just 12 years. Water surface increased slightly, while Crops showed minimal increase. Built Area declined, possibly reflecting settlement abandonment due to drought.

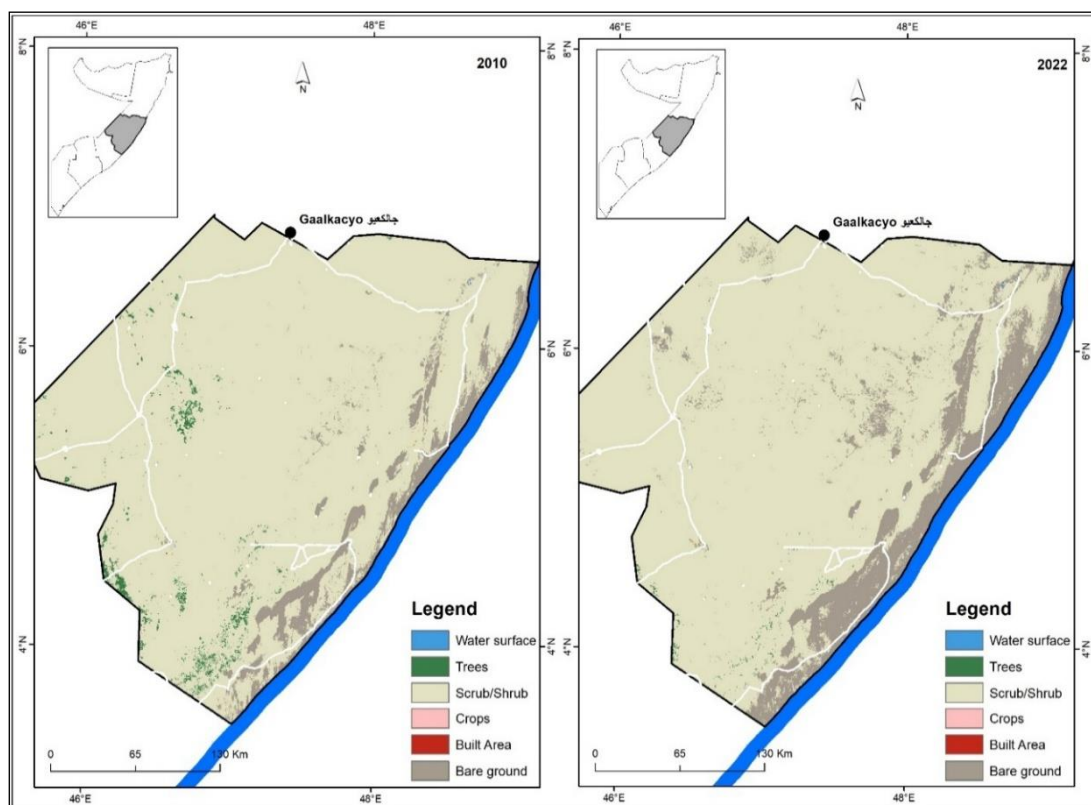


Fig 1: Land Use Galmudug State Between 2010 and 2022

Figure 1 shows the spatial distribution of land cover change, with the most pronounced expansion of bare ground occurring in central and southern districts, while tree cover loss was concentrated along the Ethiopian border zone where *Cordeauxia edulis* populations are located.

➤ Annual Rates of Land Cover Change

Table 2 presents the annual rates of change calculated using the Bernier formula. The most striking finding is the deforestation rate for Trees: -18.13% per year, the highest documented in any of the three study states and among the highest reported anywhere in Africa.

Table 2: Evolution of Surface Area of Different Land Use Categories in Galmudug State (2010–2022)

Land Cover	Change (ha)	Annual Rate of Change (%)
Water surface	+584.20	+0.21
Trees	-103,402.70	-18.13
Crops	+85.67	+0.42
Built Area	-2,118.50	-6.25
Bare ground	+592,118.00	+6.79
Scrub/Shrub	-487,266.67	-0.59

Bare ground expanded at +6.79% annually. Scrub/Shrub declined at -0.59% annually. Built Area showed a negative rate of -6.25%, which may indicate abandonment of settlements due to drought or classification challenges.

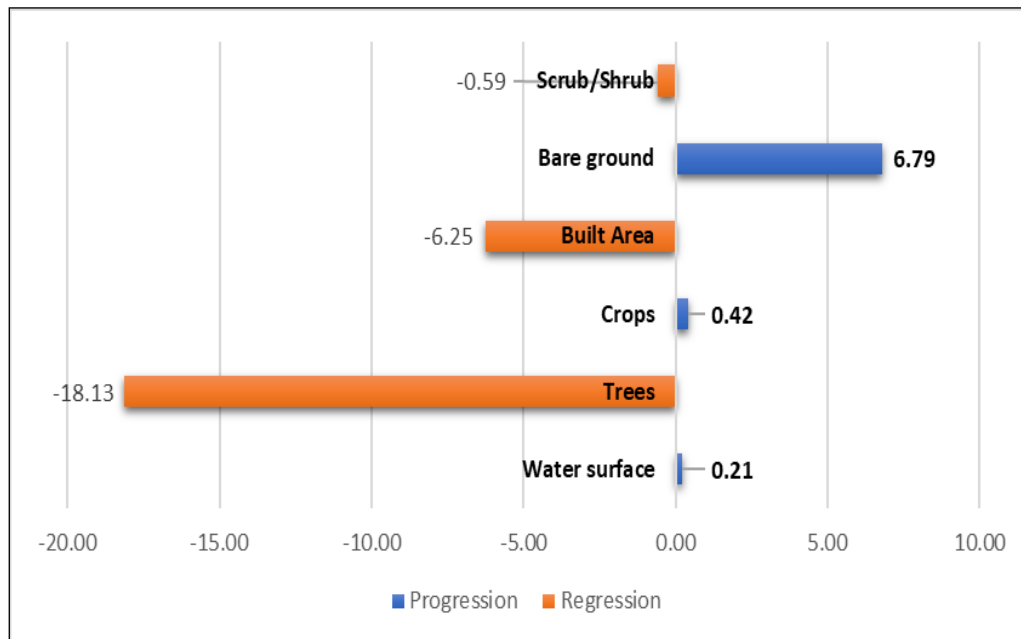


Fig 2: Annual Rate of Change of Land Use Categories in Galmudug State 2010 and 2022

Figure 2 illustrates the comparative annual rates of change, highlighting the catastrophic decline of tree cover (-18.13%) contrasting with expansion of bare ground (+6.79%).

#### ➤ Transition Patterns Between Land Cover Classes

Analysis of transition matrices revealed that Trees were converted primarily to Bare ground (approximately 85,000 ha) and to Scrub/Shrub (approximately 15,000 ha), suggesting that deforestation in Galmudug often results in complete removal of vegetation, consistent with charcoal production where mature trees are felled and removed entirely. The most significant transition was from Scrub/Shrub to Bare ground (approximately 520,000 ha), indicating progressive degradation. Unlike Jubaland and Puntland, Galmudug showed minimal agricultural conversion (Crops remained at 0.02% of total area), confirming that degradation is driven by wood extraction (charcoal and firewood) and overgrazing.

#### ➤ NTFP Species and the Endangered *Cordeauxia edulis*

Household surveys identified 12 NTFP species collected in Galmudug. *Cordeauxia edulis* (Yi'ib) was reported as having limited and declining availability. Focus group participants described how the shrub was once abundant but populations have been reduced by clearance, fencing, and drought. One elder explained: "When I was young, Yi'ib was everywhere. During drought years, we survived on the nuts. Now you have to walk a full day to find a single productive shrub."

#### ➤ Charcoal Production as Primary Degradation Driver

In Galmudug, 90% of respondents identified tree cutting as the primary cause of forest depletion, with charcoal production as the specific activity driving deforestation. Key informants reported that charcoal production is concentrated around IDP settlements. A charcoal burner described: "We target the biggest *Acacia tortilis* and *Acacia busei* trees. Thirty

years ago, you could find them near the town. Now we walk two days into the forest. The big trees are almost gone." Respondents reported destructive techniques to circumvent regulations, including contaminating root systems with salt and used engine oil to kill trees, then claiming they were harvesting dead wood.

#### ➤ Institutional Capacity: "Ministry Only by Name"

Institutional capacity assessment revealed that Galmudug has the weakest environmental governance. Key informants described the Ministry of Environment as existing "only by name", with no workplace facilities, no trained staff, and no operational budget. None of the staff interviewed had formal training in environment and natural resources management.

## IV. DISCUSSION

#### ➤ The Catastrophic Deforestation Rate in Comparative Perspective

The deforestation rate documented in Galmudug (-18.13% annually, representing an 86% loss of existing tree cover in 12 years) is among the highest reported anywhere in Africa. The African average deforestation rate is -0.62% [3]; the Congo Basin average is approximately -0.26% to -0.50% [5]; and rates from unprotected forest reserves in Cameroon range from -0.84% to -1.57% annually [6; 10]. The Galmudug rate is more than 10 times higher than these comparators. Several factors explain this exceptional rate. First, baseline tree cover was already very low (1.42%), so modest absolute losses translate into high percentage rates. Second, charcoal production specifically targets the largest, oldest trees, removing keystone individuals. Third, there is no effective governance or enforcement. Fourth, drought and overgrazing compound wood extraction. The transition pattern, direct

conversion of Trees to Bare ground, indicates woodland mining rather than sustainable harvesting.

#### ➤ *Implications for Cordeauxia edulis Conservation*

The decline of *Cordeauxia edulis* is particularly concerning given its restricted range and livelihood importance [11]. The combination of habitat clearance, fencing, drought, and lack of regeneration threatens population viability. The species has difficulty regenerating naturally without seed treatment, and there has been no investment in nursery production or planting programs in Galmudug. The nutritional value of Yi'ib nuts makes the species a priority for food security interventions.

#### ➤ *The Political Economy of Charcoal in Galmudug*

The charcoal value chain exemplifies the "political economy trap" described by [7], where powerful actors benefit from the status quo. Extreme value extraction, producers receiving only 12–25% of final local market price, creates perverse incentives at multiple levels. The UN Security Council ban on Somali charcoal exports has had limited effect because illicit shipments continue, and domestic charcoal consumption remains the primary driver of deforestation.

## V. CONCLUSION

This study has documented catastrophic deforestation in Galmudug State, with tree cover declining by 86% (103,403 ha) between 2010 and 2022 at an annual rate of -18.13%, among the highest ever reported in Africa. The primary driver is charcoal production targeting slow-growing *Acacia* species, with drought and overgrazing as compounding factors. The endangered *Cordeauxia edulis* shrub is reported as declining and faces continued pressure. Galmudug's Ministry of Environment exists "only by name" with no trained staff, facilities, or budget. Without urgent intervention, Galmudug's remaining tree cover will be exhausted within a decade.

## VI. RECOMMENDATIONS

Six priority actions are recommended. First, implement an emergency moratorium on charcoal production from live trees with alternative livelihood support. Second, establish farmer-managed natural regeneration (FMNR) and enclosure systems across degraded rangelands. Third, launch a conservation and domestication program for *Cordeauxia edulis* including seed collection, nursery establishment, and planting trials. Fourth, promote alternative energy sources including improved cookstoves and solar cooking. Fifth, build institutional capacity from the ground up, including recruitment and training of environment staff and provision of basic equipment. Sixth, pilot a benefit-sharing mechanism for charcoal value chains ensuring producers receive a fairer share of final prices.

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