SPARC
Supporting Pastoralism and Agriculture in Recurrent and Protracted Crises

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TECHNICAL REPORT

LAND USE DYNAMICS AND FARMER–HERDER CONFLICTS

A spatial analysis of case studies from Sudan and Nigeria

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About SPARC

Climate change, armed conflict, environmental fragility and weak governance and the impact these have on natural resource-based livelihoods are among the key drivers of both crisis and poverty for communities in some of the world's most vulnerable and conflict-affected countries.

Supporting Pastoralism and Agriculture in Recurrent and Protracted Crises (SPARC) aims to generate evidence and address knowledge gaps to build the resilience of millions of pastoralists, agro-pastoralists and farmers in these communities in sub-Saharan Africa and the Middle East.

We strive to create impact by using research and evidence to develop knowledge that improves how the UK Foreign, Commonwealth and Development Office (FCDO), donors, non-governmental organisations, local and national governments and civil society can empower these communities in the context of climate change.

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ACRONYMS

FGD	focus group discussion
FHC	farmer–herder conflict
GIS	geographic information system
IDPs	internally displaced people
KII	key informant interview
LGA	Local Government Area (Nigeria)
LULC	land use and land cover

EXECUTIVE SUMMARY

This study investigates how land use and land cover (LULC) dynamics intersect with farmer–herder conflicts (FHCs) in two contrasting contexts within the Sahelian and Sudano-Sahelian belt: Gadarif State in Sudan and Nasarawa State in Nigeria. The study aims to understand how spatial changes in land systems contribute to rising competition over resources and to identify practical strategies for mitigating conflict. Specifically, it seeks to answer the question: what options for mitigating farmer–herder conflicts in Sudan and Nigeria are revealed by the analysis of spatial land use dynamics? Using a mixed-methods approach, combining multi-temporal satellite imagery, geospatial analysis, field surveys, focus group discussions (FGDs), and key informant interviews (KIIs), the research highlights how evolving land systems drive tensions, and offers evidence-based options for reducing conflict through integrated land management and governance reforms. It builds on and complements earlier detailed qualitative analysis in the two geographical contexts on the causes of FHCs, and emphasises the key role land conversion plays.

Key findings

- **Rapid agricultural expansion and shrinking grazing resources:** in both Sudan and Nigeria, agriculture has steadily encroached on traditional grazing lands, forests, and livestock corridors. In the study area in Gadarif, Sudan, agricultural land covers of the area by 2025, while sparse vegetation critical for grazing has fallen to just 11%. In Nasarawa, Nigeria, farmland now occupies over half the landscape, with natural vegetation and grazing reserves reduced to 19%, also under pressure from rapid urbanisation and mining.

- **Fragmented landscapes heightening conflict risks:** as croplands, settlements, and degraded lands spread, pastoralists face shrinking, patchy grazing areas and obstructed migration routes. This forces livestock movements closer to croplands and settlements, raising the risk of crop damage and clashes over water points and seasonal pastures. Field observations and local accounts reveal how livestock are increasingly guided through cultivated fields or charged fees to graze on fallow plots, eroding informal arrangements that once minimised disputes.

- **Governance failures and tenure insecurities fuelling tensions:** in Sudan, state policies and land acts have historically prioritised mechanised agriculture, marginalising pastoralists and weakening customary tenure. In Nigeria, ambiguities in the Land Use Act and inconsistent local enforcement have left pastoral and smallholder communities vulnerable to opportunistic land allocations and tenure uncertainty. Across both contexts, traditional leaders struggle to mediate disputes when state land decisions override local agreements.

- **Gendered impacts and underutilised roles in peacebuilding:** women bear disproportionate burdens – walking longer distances for farming, firewood, and water collection, engaging in charcoal production, and coping with food insecurity – yet often lack a voice in land decisions or local conflict mediation. Nonetheless, women maintain critical social networks across farming and pastoral communities, positioning them as potential anchors for peacebuilding.

- **Worsening pressures under conflict:** in Sudan, the ongoing war since April 2023 has driven large-scale internal displacement into rural zones, where internally displaced people (IDPs) have few options beyond exploiting forests to extract resources and for small-scale farming, intensifying pressures on already contested resources. The war has also weakened institutional capacities, disrupted traditional land management, and heightened insecurity, further constraining pastoral mobility.

Policy and programming implications

1. **Promote conflict-sensitive land use planning and zoning**
    - Delineate and protect livestock corridors, grazing reserves, riparian forests, and seasonal water points through participatory mapping and robust legal recognition.
    - Integrate spatial conflict risk analysis into district and state land use plans to proactively prevent flashpoints.
2. **Advance inclusive and equitable land governance reforms**
    - Secure customary and communal land rights, particularly for grazing areas and mobility corridors.
    - Strengthen local land boards and multi-stakeholder committees to transparently vet land allocations and safeguard shared resources.
3. **Reinforce local dialogue and mediation platforms**
    - Build the capacity of traditional leaders and community institutions and establish clearer linkages with formal governance systems.
    - Support multi-stakeholder land committees and community early warning systems to address disputes before they escalate.
4. **Embed gender-responsive approaches in land and conflict interventions**
    - Ensure women's meaningful participation in land governance bodies and peacebuilding initiatives.
    - Reduce practical burdens – such as distant water points and reliance on degrading forests – to lower risks and create shared incentives for cooperation.

Potential cross-regional learning

The experiences from Sudan and Nigeria echo challenges faced across the Sahel and similar drylands, where expanding agriculture, shrinking grazing spaces, and weak governance heighten tensions. These findings underscore the importance of cross-regional learning, as adapting lessons from participatory land use planning, community-managed grazing reserves, and gender-responsive mediation across the Sahel can inform more flexible and inclusive solutions. Sharing what has worked and where pitfalls emerged can help countries tailor strategies that balance livelihoods and reduce FHCs in fragile landscapes. Comparative work across the Sahelian belt can also shed light on how different policy and tenure regimes shape resilience or conflict. Ultimately, research and policy must also move beyond simplistic divides between farmers and pastoralists to recognise hybrid livelihoods, and design governance systems flexible enough to accommodate this complexity.

Taken together, these insights call for multi-layered strategies that combine conflict-sensitive spatial planning, inclusive and equitable land tenure systems, stronger local dialogue and mediation platforms, and gender-responsive approaches. Such integrated efforts are essential not only for reducing immediate tensions over land and resources but also for building the institutional foundations, social trust, and adaptive capacities needed to sustain peace, secure livelihoods, and enhance resilience across Sudan, Nigeria, and other dryland regions facing similar pressures.

A cattle herd passes by a flock of sheep along a narrow migration route surrounded by agricultural fields in southern Gadarif, Sudan. Credit: Hussein M. Sulieman

1. INTRODUCTION

1.1 Farmer–herder conflicts in Sudan and Nigeria

Farmer–herder conflicts (FHCs) in Sudan and Nigeria are the outcome of intertwined historical, political, socioeconomic, and environmental processes that have destabilised the traditional balance between pastoralism and farming. In both contexts, these conflicts are fundamentally rooted in how land and natural resources are governed, distributed, and accessed (Momale, 2024; Sulieman, 2024).

In Sudan, the root causes of FHCs can be traced to decades of state policies that have systematically prioritised privatised land use systems for crop production – particularly large-scale mechanised agriculture – over communal land use systems. This bias originated during the colonial era, when policies began to favour sedentary cultivation, and was later entrenched by the 1970 Unregistered Land Act, which nationalised vast tracts of land – approximately 90% of the country's territory – effectively stripping pastoralist communities of their customary land rights (Sulieman, 2015). Such policies empowered the state to allocate communal rangelands to large-scale investors, often politically connected elites, who expanded mechanised farming into traditional grazing areas. This expansion, coupled with climate change, recurrent drought and ecological degradation, has severely reduced available pastures, forcing pastoralists and smallholder farmers into increasingly restricted spaces, thereby intensifying competition and friction over resources (Sulieman, 2024). Widespread inflation and rising poverty have further pressured local livelihoods, driving both farmers and herders to diversify their income sources in overlapping ways that contribute to tension. As a result, livestock trespassing on crops and the cultivation of land previously used for grazing have become common immediate triggers for farmer–herder conflicts (ibid.).

In Nigeria, FHCs are similarly driven by a complex mix of demographic, environmental, and political factors, and are shaped by distinct local dynamics. Historically, pastoralists and farmers in regions such as Nasarawa maintained interdependent relations: herders contributed manure to farmers' fields while farmers provided crop residues for livestock feed. However, rising population densities and expanding crop cultivation have increasingly encroached upon traditional grazing routes and reserves, disrupting these complementary exchanges (Usman and Nichol, 2022). Environmental degradation, including soil depletion and declining pasture availability in northern Nigeria, alongside social and political factors, has pushed pastoralist communities to migrate southwards into the Middle Belt and southern regions (Momale, 2024). These migrations have intensified land competition and often placed pastoralists in direct conflict with settled farming populations (Bombom et al., 2024). Compounding these tensions, more local political decisions such as the enactment of the Open Grazing Prohibition and Ranches Establishment Law (2017) in neighbouring Benue State (Gusa and Tijah, 2022) displaced large numbers of pastoralists into Nasarawa State, overwhelming local land resources and inflaming disputes over grazing rights, water access, and land ownership. Weak implementation of Nigeria's 1978 Land Use Act, which vested control over land allocation in state and local governments, has left ambiguities in land tenure that frequently fuel local disputes. Insecure tenure arrangements and ineffective institutions undermine the ability to resolve conflicts peacefully (FGN/World Bank/NESG, 2019; Momale, 2024).

The impacts of these conflicts on rural livelihoods and food systems in both countries are severe and multifaceted. In Sudan, the recurrent destruction of crops by livestock jeopardises farmers' food security and pushes them to adopt coping strategies such as premature harvesting or turning to wage labour. Meanwhile, pastoralists face restrictions on mobility and heavy fines for trespassing, leading to diminished incomes, their own food security challenges, and a weakening of traditional livelihood systems. The traditional complementarity between farming and herding has further eroded, with both groups now increasingly engaging in each other's primary economic activities – farmers raising more livestock and pastoralists cultivating more crops – thereby heightening direct competition rather than fostering mutual support (Sulieman, 2024).

In Nigeria, the consequences are more profound. Violent clashes have resulted in widespread displacement, destruction of property, and persistent poverty across farming and pastoral communities alike. Hausa and Tiv farmers report the loss not only of crops but also of livelihoods and community health, while Fulani herders contend with declining herd productivity, rising food insecurity and erosion of social assets. These conflicts disrupt agricultural production cycles, threaten local food availability and deepen mistrust among communities, which in turn hampers collaborative land and resource management (Momale, 2024; Nwankwo, 2024).

Gender and age dimensions add further layers of complexity to these conflicts. In both Sudan and Nigeria, women play critical roles in farming and pastoral production systems yet face systemic exclusion from land ownership and decision-making bodies that mediate conflicts (Momale, 2024; Sulieman, 2024). The impacts on women include loss of income, increased dependency and workloads, psychosocial distress, and reduced access to education, healthcare, and social services. Young people, who are heavily involved in herding and farming, are often the main victims of violence, yet are rarely engaged in formal conflict resolution or local governance structures. Many are forced to migrate, take up insecure wage labour, or turn to informal economic activities, such as charcoal production in Nigeria or artisanal gold mining in parts of Sudan, to support themselves amid shrinking livelihood opportunities (Momale, 2024; Sulieman, 2024).

Underlying these local dynamics are institutional and governance failures that perpetuate FHCs. In Sudan, land legislation and state-led investment incentives continue to privilege large-scale commercial agriculture, undermining customary land rights and disempowering traditional authorities that once helped mediate access to communal resources. This governance gap enables unchecked land grabbing and resource privatisation, further marginalising pastoral and smallholder communities (Babiker, 2012; Sulieman and Ahmed, 2017). In Nigeria, local governments and traditional leaders often lack the authority or impartiality needed to effectively mediate disputes, while broader security challenges and fragmented policy responses leave conflicts to escalate unchecked. Perceptions of minimal or biased support from state institutions exacerbate grievances, making durable conflict resolution elusive (Nwokike et al., 2023).

1.2 Land use and land cover changes as drivers of farmer–herder conflicts

If not properly managed, land use and land cover (LULC) changes play a pivotal role in driving FHCs by reshaping the availability and distribution of critical natural resources. These changes often intensify competition over increasingly scarce resources, heightening tensions between farming and pastoralist communities. The dynamics of LULC change – shaped by diverse socio-economic, political, and environmental factors – transform landscapes in ways that directly influence the interactions and coexistence of farmers and herders (Brottem, 2016; Legese and Balew, 2021).

In many parts of Africa, agricultural expansion and settlement growth are primary forces behind LULC change. For example, in the Bale lowlands of Ethiopia, increasing farmland and settlement footprints have degraded rangelands, disrupting livestock mobility and heightening competition for dwindling resources (Legese and Balew, 2021). In West Africa, beyond biophysical pressures, economic interests and political decisions are also critical drivers of land use change and associated conflicts. The political ecology perspective highlights how land tenure regimes and resource management policies can deepen inequalities by privileging certain groups, thereby fuelling resource-based conflicts (Brottem, 2016).

These changes have profound consequences. The conversion of rangelands into agricultural fields directly reduces grazing areas, compelling herders to compete more intensely with farmers. In Pakistan's Kurram Valley, declining rangeland availability has necessitated a transition from open grazing to controlled systems, adversely affecting herd sizes and pastoral livelihoods (Hussain et al., 2024). Similarly, LULC changes can undermine traditional land use systems, increase community vulnerability and triggering disputes. In the Butana area of Sudan, altered land use patterns have disrupted established access arrangements, contributing to social tensions as communities adapt to evolving socioeconomic and ecological realities (Sulieman, 2018). Experiences from Tanzania indicate that land use plans can inadvertently aggravate tensions when they favour large-scale agricultural investments at the expense of pastoral interests, underscoring the need for more inclusive and transparent planning processes (Walwa, 2017).

While poor management of LULC changes is a significant driver of FHCs, these issues are deeply intertwined with broader climatic, socioeconomic and governance factors that shape land use dynamics and relations between groups. Addressing these complex challenges requires comprehensive strategies that integrate sustainable land management with conflict resolution, ensuring the diverse needs and perspectives of farmers, herders, and other stakeholders are considered. Such holistic approaches are essential for building more resilient rural livelihoods and reducing the likelihood of conflict (Human Rights Watch, 2025).

1.3 Study rationale

Sudan and Nigeria were selected for examination because they represent contrasting yet comparable contexts in understanding FHCs within the Sahelian and Sudano-Sahelian belt. They also offered an opportunity to use quantitative spatial analysis to complement recent and detailed qualitative analysis exploring the causes of FHCs (Sulieman, 2024; Momale, 2024).

Both countries host substantial populations dependent on pastoralism and smallholder crop farming, sectors that are deeply interlinked with the political economy of land and natural resource use. In Sudan, pastoralism and rainfed smallholder agriculture form the backbone of rural livelihoods, yet decades of state-led promotion of crop production, particularly large-

scale mechanised farming, combined with recurrent drought and weak tenure protections, have reshaped land use systems and exacerbated competition over shrinking grazing and farming areas (Sulieman, 2024). In Nigeria, the Middle Belt zones, such as Nasarawa, exemplify the pressure points where demographic expansion, southward migration of pastoralists in response to resource scarcity and social and political factors in the north, and weak land governance intersect to produce acute and often violent conflicts (Human Rights Watch, 2025; Momale, 2024; Nwankwo, 2024).

Studying Sudan and Nigeria together thus provides a geographically diverse lens across the eastern and western extremes of the Sahelian zone, offering insights into how similar structural drivers – such as climate variability, policy biases favouring crop over livestock production, land grabbing, and demographic pressures – play out under differing political and institutional conditions. This dual focus is highly relevant to the broader Sahelian context, where pastoral and agro-pastoral systems remain vital yet increasingly vulnerable.

1.4 Objective

The objective of this study is to identify options for reducing FHCs by analysing LULC dynamics as an underlying driver of conflicts, in order to provide evidence-based information to guide policy and programming in the promotion of peace and improved land management practices in the respective countries.

1.5 Research questions

This research is guided by one primary and two secondary questions:

Primary research question

What options for mitigating FHCs in Sudan and Nigeria are revealed by the analysis of spatial land use dynamics?

Secondary research questions

1. What are the spatial and temporal patterns of LULC changes in the agricultural and pastoral areas within the case study areas in Sudan and Nigeria?
2. Where are the key hotspots of FHCs, and how are the conflicts in these areas explained by the corresponding spatial and temporal changes in LULC?

2. METHODOLOGICAL APPROACH

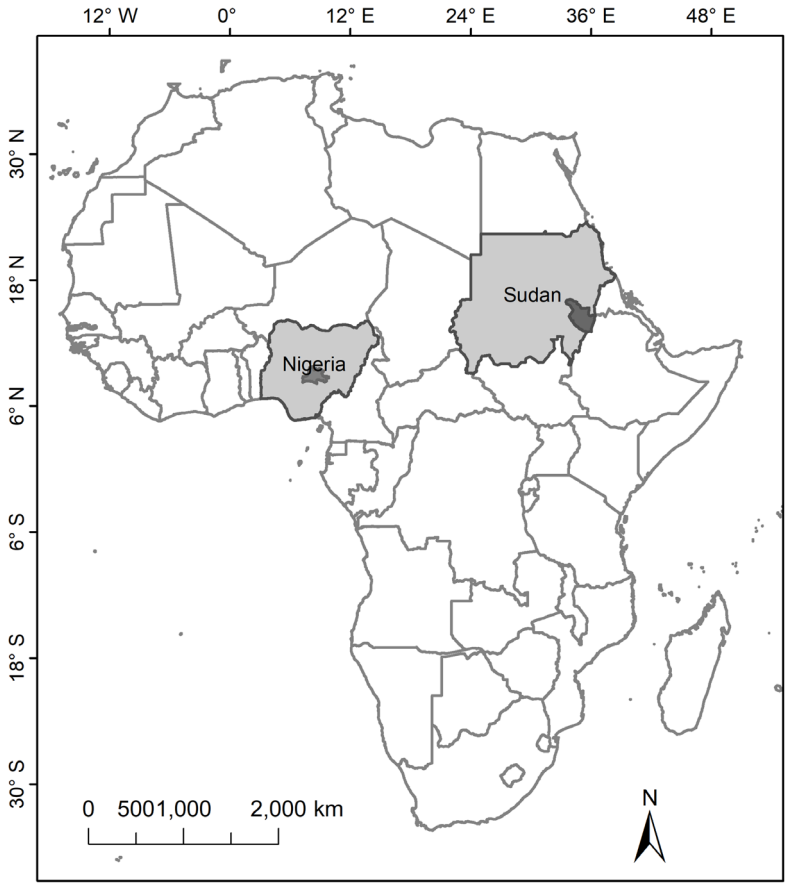
2.1 Study design and approach

This study employs a mixed-methods approach, integrating remote sensing, field surveys, key informant interviews (KIIs), and focus group discussions (FGDs). This combination is used to ensure data triangulation and provide a better understanding of how LULC changes intersect with FHCs. Remote sensing delivers quantitative evidence of LULC trends, while fieldwork captures local realities and community perspectives. The study uses a two-scale spatial analysis: broad-scale LULC change over a larger area and fine-scale analysis focused on FHC hotspots. This layered design helps reveal both long-term transformations and localised conflict dynamics, which are crucial for designing targeted interventions.

2.2 Case study selection

The research is anchored in two key case studies, namely in Gadarif State in Sudan and Nasarawa State in Nigeria (Figure 1).

FIGURE 1. MAP OF THE CASE STUDIES IN SUDAN AND NIGERIA

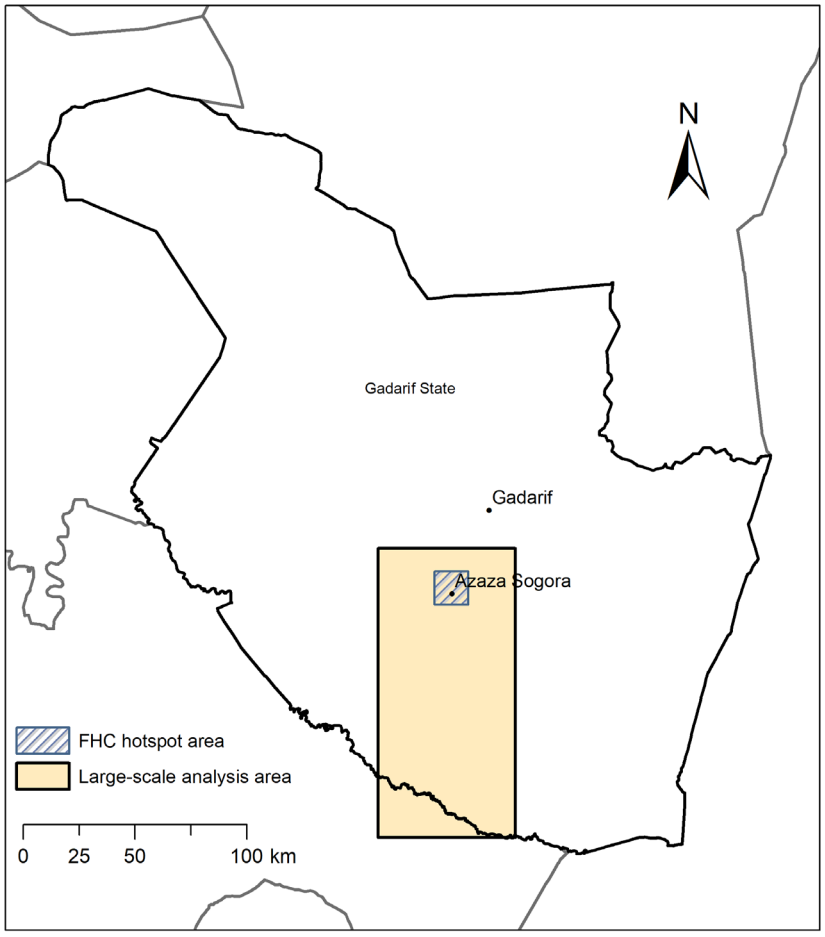


Source: authors' own.

2.2.1 Sudan case study

The case study in Gadarif State, eastern Sudan (Figure 2), examines an area of around 78,000 km² characterised by hot temperatures (from a mean minimum of 22°C in winter to a mean maximum of 37°C in summer), a single rainy season from June to October, and vegetation ranging from grasslands to woodland savannahs. Home to 2.6 million people and significant mechanised agriculture across 4.2 million hectares (OCHA, 2023), the state also supports large pastoral populations who practise long seasonal migrations. However, expanding large-scale farming, illegal land grabs, and emerging artisanal mining have fragmented rangelands, restricted pastoral mobility, and intensified competition over resources, fuelling FHCs. These tensions have blurred traditional lines between farming and herding, impacted livelihoods and food security, and strained once-cooperative relationships. The large-scale LULC change analysis focuses on an area of 6,500 km² (130 km x 50 km) within Gadarif where such dynamics are most acute, building on earlier research by the team. The fine-scale FHC hotspot analysis was conducted in an area of about 100 km² (10 km x 10 km) surrounding the village of Azaza Sogora.

FIGURE 2. MAP OF THE CASE STUDY AREA IN GADARIF STATE, SUDAN



Source: authors' own.

2.2.2 Nigeria case study

The case study in Nasarawa State, North Central Nigeria, focuses on a region with Guinea Savanna vegetation, seasonal rainfall, and temperatures ranging from 25°C to 38°C. Human activities such as extensive farming, overgrazing and mining have transformed the landscape, reduced forests and increased vulnerability to floods. Agriculture and livestock production are the main livelihoods, supported by rivers and fertile floodplains that are valuable for irrigation farming and dry season livestock rearing, while a mix of customary and formal land tenure systems often leads to unequal land distribution especially for the pastoral groups (Adadu et al., 2024; Akanwa et al., 2023). Rapid population growth and farmland expansion have intensified competition over shrinking pastures, fuelling recurrent farmer–herder conflicts, especially in areas like Awe and Doma. These conflicts disrupt livelihoods, heighten food insecurity and disproportionately impact vulnerable groups. The large-scale LULC change analysis was conducted across the whole of Nasarawa state (~27,117 km²) to explore how land use changes, demographic pressures and governance challenges drive these tensions. The fine-scale FHC hotspot analysis was carried out in Awe Local Government (Figure 3).

FIGURE 3. MAP OF NASARAWA STATE IN NIGERIA

Source: authors' own.

2.3 Data sources

2.3.1 Remote sensing

LULC dynamics spanning 15 years were examined using Landsat imagery from 2010, 2015, 2020 and 2025. The dates of image acquisition are within January and February. Technical details of the series of images used in the analysis are provided in Annex 1. A Random Forest classifier was employed for supervised classification, with a 70%:30% split for training and validation, assessed using Kappa and user/producer accuracy metrics. The focus of fine-scale LULC analyses for FHC hotspot areas was on recent land encroachments, confined to the period 2020 to 2025. Changes in LULC classes were determined by using post-classification comparison. To calculate the proportions of change from one thematic class to another and to explain the magnitude and direction of LULC transitions across the four periods, a LULC trajectory matrix was used.

In Sudan, the main types of LULC classes in the study area are natural vegetation, agricultural land, water bodies, and bareland. The natural vegetation was sub-classified into dense and sparse, with dense cover dominated by large evergreen trees. The sparse natural cover is typical of savannah environments and consists of a mix of woody trees/shrubs, mainly deciduous and acacia trees, and grasses. The agricultural land is the area under rainfed cultivation by large-scale and small-scale farming. In January, the month of the satellite image used in the LULC analysis, the agricultural land could be divided into harvested and unharvested.

The dominant LULC categories identified in the Nigerian study area include agricultural land, natural vegetation, built-up areas, water bodies, and bareland. Natural vegetation was classified into dense and sparse categories. Dense vegetation corresponds to thicker forested areas dominated by closed canopy trees, while sparse vegetation, characteristic of the Guinea and Sudan savannah zones, consists of scattered trees, shrubs, and uncultivated lands. Built-up areas include urban and peri-urban settlements, many of which are expanding into traditional grazing zones and corridors.

2.3.2 Field surveys

Fieldwork in both countries was undertaken in June 2025, during which geocoded surveys were conducted to support the remote sensing classifications and improve the mapping of FHC hotspots. During the survey, KIIs and FGDs were conducted. These interviews explored the drivers of land use change, patterns of resource availability, and key factors behind FHCs. The fieldwork also captured community perceptions of land use dynamics and conflict trends, and used a gender-sensitive approach to understand how men and women differently experienced and responded to these challenges.

2.3.3 Focus group discussions and key informant interviews

FGDs were conducted separately for men and women to capture collective views on land use changes, conflict experiences, and community responses. Four FGDs were conducted with the resident farming community and were organised with men of mixed ages, women of mixed ages, and male and female youth (the age of all respondents generally varied from about 20 to 65 years). The same types of sessions were conducted with the transhumant pastoralists in the area. The KIIs were organised with the two community leaders from each group and institutional actors. Annex 2 gives detailed accounts of the FGDs and KIIs conducted in both countries.

2.4 Gender and ethical considerations

The study adopted a gender-sensitive and ethically rigorous approach, deliberately engaging men, women, youth, and elders through FGDs and KIIs to capture diverse experiences. Female researchers led the discussions with women to encourage openness. Ethical safeguards included obtaining informed consent in local languages, guaranteeing confidentiality and anonymity, and securing community approvals through traditional leaders. Leveraging the team's local language skills and cultural familiarity, the research ensured sensitive topics were handled with care, fostering trust and meaningful participation.

2.5 Summary of data analysis methods

The study employed an integrated analytical approach, combining quantitative spatial analysis with qualitative insights to investigate farmer–herder conflicts. It used multi-temporal Landsat imagery to classify LULC changes and map conflict hotspots, alongside trajectory matrices to track land transitions. These spatial patterns were contextualised with narratives from KIIs and FGDs. By examining how LULC changes intersect with local conflict histories and perceptions, the study aimed to uncover actionable strategies to manage LULC dynamics and reduce conflict risks.

Meeting with a group of Fallata (Fulbe) community leaders in southern Gadarif, Sudan. Credit: Hussein M. Sulieman.

3. FINDINGS AND ANALYSIS

3.1 Land use and land cover (LULC) change patterns

Figure 4 illustrates the LULC comparisons in the study area in Sudan between 2010 and 2025, and the spatial distributions of the LULC changes are mapped in Figure 5. The accuracy of the Random Forest classification is shown in Annex 3, while the LULC change trajectories are detailed in Annex 4. Over these 15 years, the study area in Gadarif State experienced significant transformations in LULC, predominantly shaped by the rapid expansion of agriculture and the continued decline of natural vegetation. The analysis of the LULC maps and corresponding area data shows that agricultural land (combined harvested and unharvested fields) expanded from a total of 528,070 hectares (66.7%) in 2010 to 662,268 hectares (83.6%) in 2025. This transformation reflects an increasing shift toward the expansion of agricultural cropfields.

The trend in agricultural expansion was not linear. Between 2010 and 2015, the area under agriculture increased markedly by over 11%, reaching 524,693 ha in 2015. A slight rise continued into 2020 (596,159 ha) and on to 662,268 ha in 2025. This consistent increase indicates conversion of both natural vegetation and bareland into cultivated land, supported by the spatial distribution of land cover in the maps. Central and northern portions of the study area, in particular, show intensified cultivation over time.

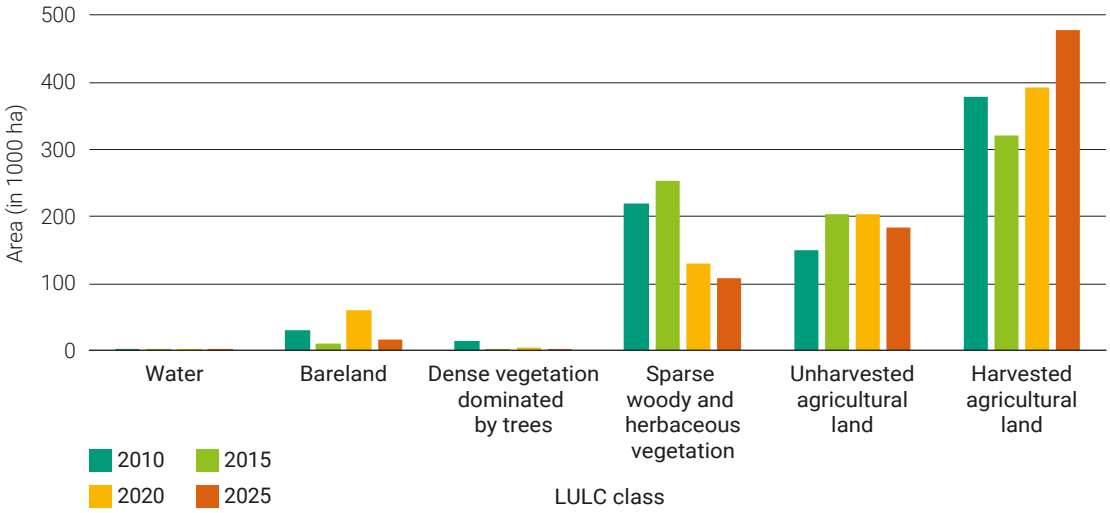
As agriculture expanded, natural vegetation declined considerably. Sparse woody and herbaceous vegetation, which accounted for 218,477 ha (27.6%) in 2010, shrank to 107,928 ha (13.6%) by 2025. Likewise, dense tree-dominated vegetation dropped from 14,567 ha (1.8%) to 3,668 ha (0.5%) over the same period. These reductions reflect widespread land clearing and degradation, likely resulting from fuelwood collection, and the loss of protected forest areas to agriculture. However, although dense vegetation in absolute terms was not significantly altered, the locations of tree clearing are significant.

Bareland exhibited a fluctuating trend, starting at 30,442 ha (3.8%) in 2010, decreasing in 2015, then sharply rising to 61,302 ha (7.7%) in 2020, before declining to 17,404 ha (2.2%) in 2025. The spike in 2020 could be linked to land abandonment, while the reduction in 2025 may indicate re-cultivation. Water bodies, which are mainly the Rahad river and its tributaries in the southern fringe of the study area, remained consistently low in coverage, growing from 289 ha (0.04%) in 2010 to 602 ha (0.08%) in 2020, and then slightly declining to 577 ha in 2025.

Long-term LULC change trajectories reveal dynamic exchanges (Annex 4), especially involving unharvested farmland, harvested cropland, and sparse vegetation. Unharvested fields repeatedly expanded at the expense of sparse vegetation and bareland, cycling back and forth with harvested land, suggesting a pattern of rotational or shifting agriculture. Harvested land consistently gained area from sparse vegetation but also reverted to unharvested or semi-natural states. Sparse vegetation, central to these shifts, persistently lost ground to cropland, yet occasionally reclaimed areas. Bareland showed mixed interactions, pointing to cycles of degradation, abandonment or early cultivation. Dense vegetation remained relatively stable, and water bodies exhibited minimal change.

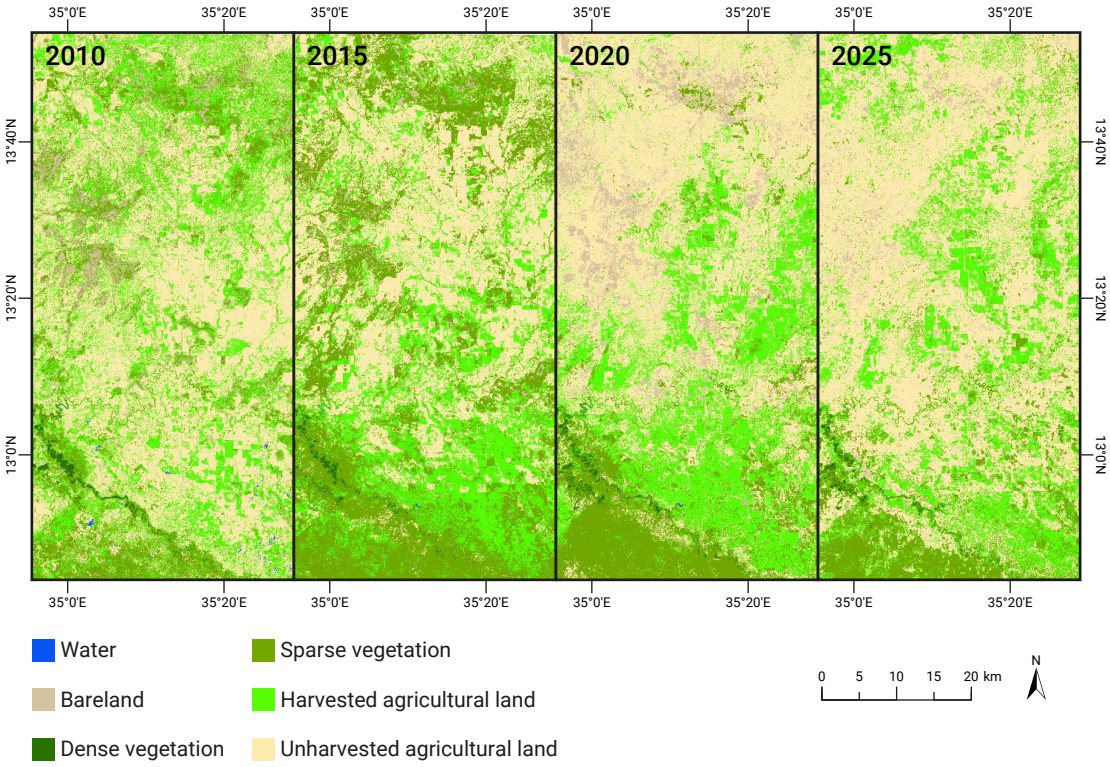
These evolving patterns highlight the expansion of agricultural land use at the direct cost of grazing resources, reducing the reliability and extent of pastures. Such fluid competition over shrinking land resources underscores the increased pressures on both farmers and pastoralists and elevates the risk of conflict as these groups vie for the same contested spaces.

FIGURE 4. COMPARISONS OF LULC CLASSES IN THE INVESTIGATION AREA IN GADARIF STATE, SUDAN



Source: authors' own.

FIGURE 5. LULC MAPS FOR THE INVESTIGATION AREA IN GADARIF STATE, SUDAN



Source: authors' own.

Figure 6 presents the comparison of LULC in the study area in Nigeria between 2010 and 2025, while Figure 7 maps the spatial distribution of these changes. The accuracy of classification is shown in Annex 3. Detailed LULC change trajectories are provided in Annex 5. Between 2010 and 2025, Nasarawa State underwent LULC transformations marked by the expansion of agricultural land, urban growth, and a notable decline in natural vegetation. Agricultural land has undergone the most significant expansion, increasing from 493,634.48 ha (36.6%) in 2010 to 1,411,374.12 ha (57.2%) in 2025. The most substantial jump occurred between 2010 and 2015, where agricultural land nearly doubled, and this trend continued into 2020. The slight reduction by 2025 likely indicates a plateauing of land conversion into other uses, but agricultural use remains dominant across most of the state. This expansion appears to come largely at the expense of vegetation and grasslands.

In the classification, there is some confusion between dense vegetation and grasslands/uncultivated surfaces, with the classifier giving prominence to one or other in different years. This makes it essential to interpret the two vegetation classes together. Dense vegetation cover stood at 734,519.12 ha in 2010, while grassland/uncultivated surfaces only covered only 34,512.12 ha, indicating that part of the grasslands might have been identified as dense forest. In 2015, the area covered by dense vegetation increased to 1,023,844.10 ha while grassland/uncultivated surfaces covered 300,209.44 ha, indicating an increase in total area covered by both dense vegetation and grasslands/uncultivated surfaces. In 2020, the area covered by dense forest was 227,254.3 ha and grasslands/uncultivated surfaces nearly doubled to 670,723.29 ha. In 2025, dense forest was 297,628.01 ha while grasslands/uncultivated surfaces was 569,397.4 ha. Cumulatively, therefore, it can at least be deduced that the vegetation cover (both dense vegetation and grasslands/uncultivated surfaces) declined in 2025 when compared to previous years. The maps illustrate widespread fragmentation and degradation of forested areas, especially in the southern and western zones, where cropping expansion is more intense. This can be explained by the rapid expansion of agricultural land that followed the relative return of peace in some parts of the state in the early part of 2025. This shift supported increased crop cultivation in many areas around the Nasarawa–Benue borderlands that had been in conflict, including areas under many local authorities along the banks of the river Benue such as Awe, Keana, Doma and Toto.

Urban areas more than doubled in size over the period under study, increasing from 14,463.00 ha in 2010 to 36,296.52 ha in 2025. Although still a small fraction of the total area, the trend reflects steady urban expansion driven by population growth, settlement expansion and infrastructure development, particularly around state capitals and major transport corridors.

Bareland increased between 2010 and 2020, from 58,327.12 ha to 96,948.67 ha in 2020, but declined again to 52,080.33 ha in 2025. The temporary spike in 2020 might be associated with environmental degradation (e.g. deforestation or soil erosion) or post-harvest land clearing. The subsequent decline may suggest partial recovery or re-use of these lands as the need for land for both cropping and settlements increased.

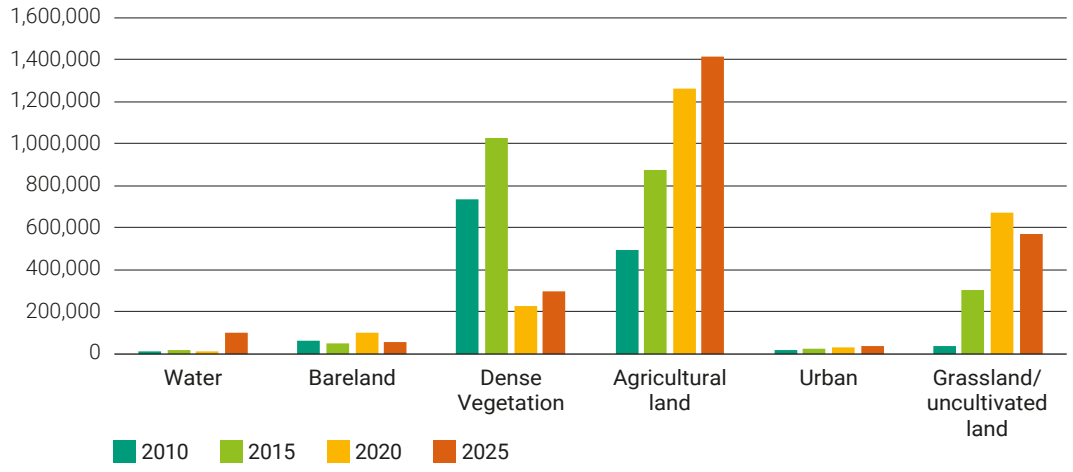
Water bodies also featured in the classification. Water bodies covered 12,694.9 ha in 2010; they increased to 15,422.31 ha in 2015 but declined to 8,124.99 ha in 2020. Due to the heavy rainfall and flooding of the 2024 rainy season, especially along the broad valley of the Benue river, the area covered by water bodies in 2025 had substantially increased to 98,780.62 ha.

Long-term trajectories across the state reveal three dominant processes: extensive agricultural expansion, increased urbanisation (partly linked to the proximity of Nigeria's Federal Capital city of Abuja), and the contraction of grazing areas and natural vegetation. The steady conversion of grazing areas, virgin fields and communal forests into farmland and settlements has undermined traditional pastoral mobility, restricted livestock access to seasonal grazing

and water resources, and intensified land competition. In addition, the expansion of mining activities is further fragmenting landscapes and degraded soils, especially in areas like Wamba, Awe and Nasarawa Local Government Areas.

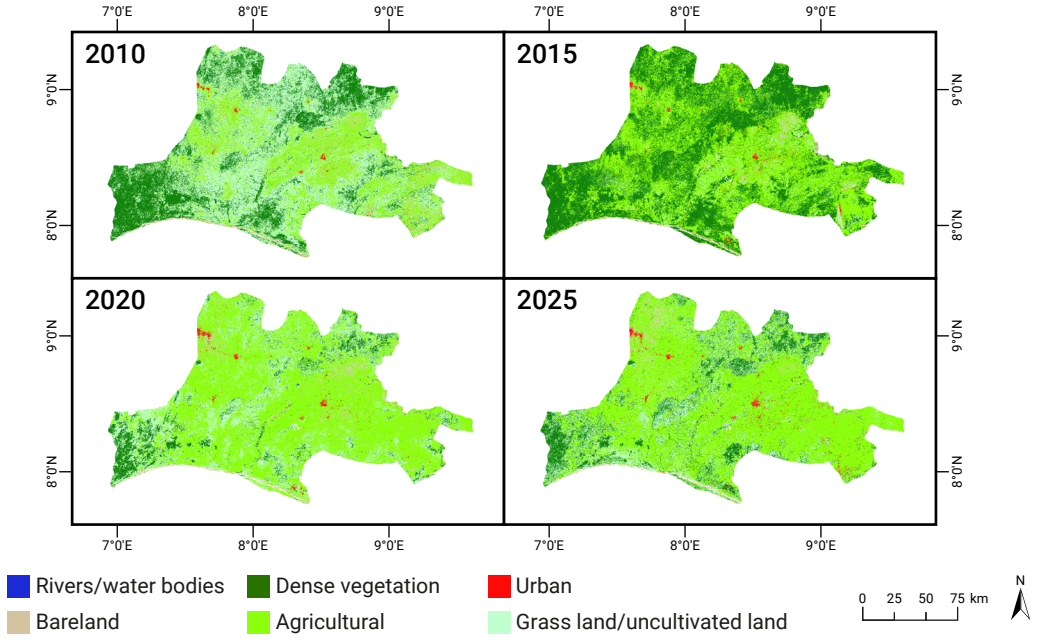
Collectively, these patterns reflect the intersection of demographic growth, livelihood shifts, weak land governance and insufficient planning. The spatial overlap of farmland expansion, settlement growth, mining zones and key livestock corridors underscores how these dynamics drive competition, displacement and farmer–herder conflicts across Nasarawa State. Without integrated land management and targeted conflict-sensitive interventions, these pressures risk deepening land scarcity, disrupting livelihoods, and fuelling further resource-based violence. The findings highlight the urgency of restoring degraded rangelands, safeguarding grazing corridors and adopting participatory governance approaches to support sustainable livelihoods and social stability.

FIGURE 6. COMPARISONS OF LULC CLASSES IN THE INVESTIGATION AREA IN NASARAWA STATE, NIGERIA



Source: authors' own.

FIGURE 7. LULC MAPS FOR THE INVESTIGATION AREA IN NASARAWA STATE, NIGERIA



Source: authors' own.

3.1.1 Comparative synthesis of LULC change patterns in Sudan and Nigeria

The analysis of LULC dynamics in Gadarif State, Sudan, and Nasarawa State, Nigeria, reveals parallel trajectories of landscape transformation driven by expanding agriculture, shrinking natural vegetation, and increasing pressures on pastoral resources. In both regions, agricultural activities have steadily spread into areas historically used for grazing, leading to the progressive loss and fragmentation of key pastoral landscapes. This expansion has been fuelled by a combination of subsistence and commercial cultivation, often targeting virgin fields, grazing areas, floodplains and forests.

In Sudan, farming (and particularly mechanised farming) has encroached on grazing areas and livestock corridors, fragmenting grazing spaces and disrupting traditional seasonal movements. In Nigeria, the conversion of Guinea Savanna grasslands and riparian forests into farmland and settlements has similarly eroded grazing reserves. The proximity of Nasarawa to Nigeria's Federal Capital city of Abuja has accelerated urban growth, further reducing natural vegetation and grazing lands, while mining has degraded soils and expanded bare or abandoned areas.

Both study areas also exhibit dynamic land transitions, where agricultural lands cyclically move between active cultivation, fallow, and semi-natural states. These shifting patterns, which have became more intense, create additional stress and instability in the availability of pasture, making it increasingly difficult for pastoralists to plan seasonal migrations and access consistent grazing resources. As a result, traditional mobility systems have been constrained, forcing livestock into closer proximity with cropland and settlements.

These intertwined processes have profound implications for the availability of grazing resources. As grazing lands diminish and become more fragmented, competition over remaining resources intensifies, heightening the risk of disputes and violent conflict. In both contexts, the overlap of cropping zones, pastoral corridors, water points and expanding urban areas has created highly contested spaces.

Overall, the synthesis underscores how agricultural intensification, urban expansion, mining pressures and inadequate land management are reshaping rural landscapes in Sudan and Nigeria. These trends threaten the sustainability of both farming and pastoral livelihoods and highlight the need for integrated land use planning that protects grazing routes and communal rangelands, alongside inclusive governance approaches to manage competing demands and mitigate conflict.

3.2 Land use change in FHC hotspots

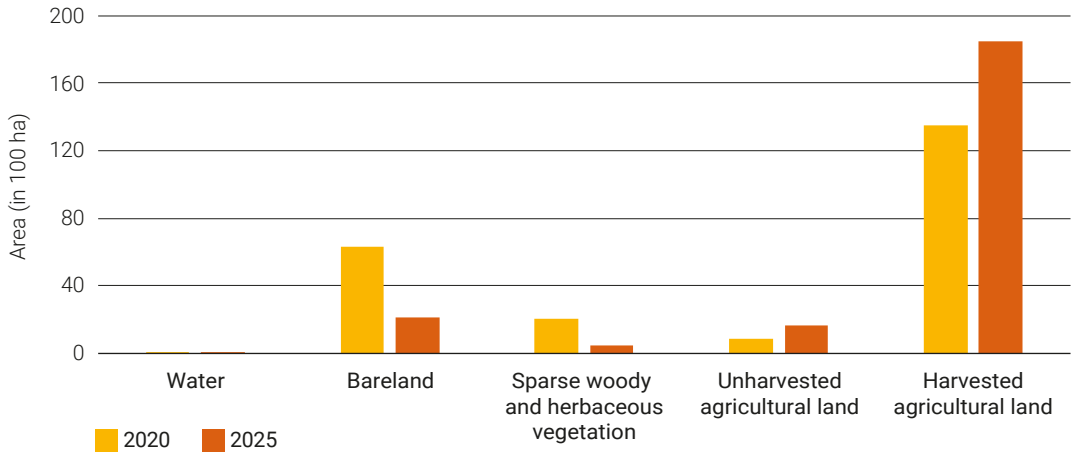
3.2.1 Azaza Sogora village – Gadarif State, Sudan

The area surrounding Azaza Sogora village, identified as a farmer–herder conflict hotspot, experienced notable LULC changes between 2020 and 2025. Figure 8 shows comparisons of LULC changes in this hotspot for the period from 2020 to 2025. The most striking pattern is the substantial expansion of harvested agricultural land, which increased by over 3,000 ha within this period. This expansion occurred largely at the expense of natural grazing resources, especially sparse woody and herbaceous vegetation, which contracted dramatically from over 2,000 ha to less than 500 ha. This indicates widespread clearing of natural vegetation cover for cultivation, thereby reducing the availability of key grazing areas that pastoralists rely upon during the dry season.

Additionally, unharvested agricultural land nearly doubled, suggesting the ongoing conversion of land to agricultural use, including fields that may be left fallow or under preparation. This expansion underscores the intensifying footprint of farming activities in zones traditionally shared or dominated by pastoral land uses. The analysis also reveals a sharp decline in bareland, dropping from about 6,300 ha to just over 2,000 ha. Such a reduction likely reflects the absorption of previously degraded or idle lands into cultivation, indicating a shift toward more intensive land use in areas that may have once served as informal grazing buffers. Meanwhile, water bodies showed a slight increase, which may be linked to seasonal changes, water harvesting efforts, or localised flooding tied to land clearing and runoff dynamics.

Field observations and satellite imagery both show that there is a growing dominance of harvested fields surrounding Azaza Sogora and that farms are encroaching closer to the main livestock route. This spatial convergence of cropping areas with livestock pathways intensifies the potential for direct interactions – and conflicts – between farmers and herders. As the mosaic of sparse vegetation fragments and shrinks, pastoralists face a narrowing of options for manoeuvring herds without trespassing on farmland, elevating the risks of crop damage, retaliation and broader tensions.

FIGURE 8. COMPARISONS OF LULC CHANGES IN THE FHC HOTSPOT IN GADARIF STATE, SUDAN



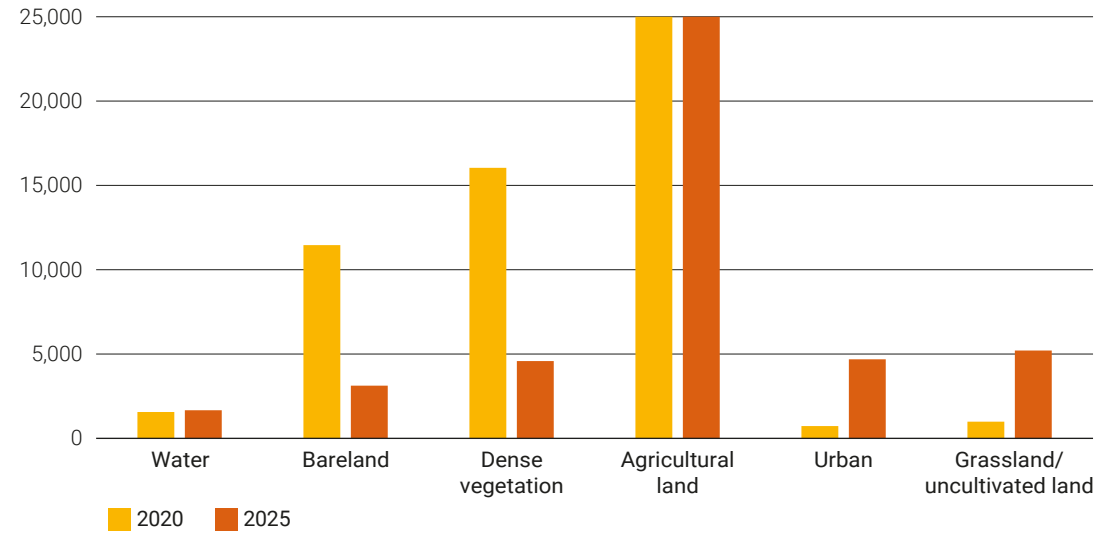
Source: authors' own.

3.2.2 Awe Local Government, Nasarawa State, Nigeria

Figure 9 illustrates the LULC changes in Awe Local Government – the FHC hotspot in Nasarawa State in Nigeria – between 2020 and 2025. The LULC changes showed a clear pattern of encroachment into critical pastoralist spaces. Agricultural land has expanded substantially, particularly into dry season grazing areas and lowland floodplains. Between 2020 and 2025, croplands grew by approximately 3,600 hectares in these zones, often at the direct expense of natural grasslands that previously supported pastoral mobility during the dry season.

Field observations and classified imagery indicate that key livestock corridors and seasonal resting points, especially along the Benue river floodplain, have been blocked or narrowed by new cultivation and peri-urban development. Water points and traditional grazing areas have also been converted into smallholder plots, further restricting mobility. Notably, several pastoral watering sites along the river have diminished in accessibility due to sedimentation and surrounding agricultural activity, aggravating dry-season pressures.

FIGURE 9. COMPARATIVE LULC CHANGES IN NASARAWA STATE, NIGERIA



Source: authors' own.

3.2.3 Overlap of LULC changes and reported conflict cases

In Sudan, the area surrounding Azaza Sogora village has experienced significant LULC changes in recent years that have directly overlapped with and intensified FHCs. Since the eruption of war in Sudan in April 2023, the area has also become a destination for internally displaced people (IDPs) fleeing violence in other parts of the country. Many of these displaced households have settled near the forests, and have few livelihood options beyond exploiting forest resources. Clearing land for small farms or producing charcoal has become one of the only immediate means to secure food and income, adding new layers of pressure on already stressed landscapes.

Local farmers, similarly affected by the national economic deterioration triggered by the war, have increasingly turned to forest exploitation to sustain their families. With traditional gum arabic harvesting proving less profitable or disrupted by instability, many households have resorted to expanding cultivation deeper into forest reserves or intensifying tree cutting for firewood and charcoal production. Field observations in the forests in the area revealed widespread tree felling, burning, and conversion of the forest into new agricultural plots. Even perennial acacia stands, critical for both grazing and community livelihoods, have been felled to make way for cultivation.

As farmers extend their fields into what were once open grazing routes or communal forests, pastoralists now struggle to move their herds without crossing cultivated lands. This overlap has heightened the risk of accidental crop damage, sparking disputes that can escalate quickly. Accounts from FGDs and KIIs described how herders are often forced to drive their animals across farmland to reach remaining grazing grounds or water sources, creating frequent points of friction. In response, farmers have grown more protective, charging fees for access to fallow lands that were once informally shared during the dry season and expressing concern about soil degradation caused by roaming livestock.

The situation is further complicated by changing settlement and livelihood patterns. Many pastoralist groups, including displaced families, have established quasi-permanent camps within forested areas, often clearing land for cultivation themselves as mobility options shrink. Meanwhile, farmers in the area have increasingly invested in livestock, leading to overlapping land use interests that blur traditional boundaries between herders and

cultivators. Women from farming households have taken on greater roles in agricultural labour, charcoal production, and petty trade, as men migrate seasonally in search of gold or other work, which has intensified local pressures on land and resources.

Environmental factors have further compounded tensions. Deforestation, erosion, and reduced rainfall have decreased the productivity of both farmlands and pastures, pushing farmers and herders into more intense competition. As traditional grazing reserves are lost or fragmented, and reliable seasonal migration is disrupted and climatic uncertainty increases, herders are concentrating their livestock in the Azaza Sogora area for longer periods. This more permanent presence raises land use pressures even higher and increases the likelihood of conflict, especially during the critical dry season when both water and forage are scarce.

Taken together, these dynamics – worsened by the recent influx of IDPs and the broader economic fallout of war – reveal how intertwined land use changes, forced migration, and shifting survival strategies have created a landscape where farming and herding physically and economically overlap in ways that drive conflict. However, the conflict is not characterised by large-scale violence but rather by localised clashes and disputes between farmers and pastoralists. These tensions typically arise over access to land and resources, and while they may not escalate into widespread violent confrontation, they nonetheless contribute to insecurity and the disruption of livelihoods.

In Nigeria, overlaying the spatial distribution of FHC incidents between 2020 and 2025 (reported by informants) with the observed LULC changes reveals a high degree of spatial convergence. The most intense conflict clusters correspond directly with areas experiencing cropland encroachment into grazing reserves and livestock corridors, confirming the role of land competition as a primary conflict driver. Notably, conflict hotspots in the border areas of Nasarawa and Benue States coincide with recent patterns of land conversion and fragmentation.

Key features identified by informants within the FHC hotspots include livestock corridors, resting points, watering sources, and riparian wetlands, all of which have been increasingly degraded or obstructed due to land use change. The loss or fragmentation of these resources not only disrupts pastoral mobility and seasonal migration patterns but also undermines traditional conflict prevention mechanisms, such as negotiated access and shared resource management.

The spatial evidence highlights the urgent need for integrated land use planning and conflict-sensitive resource governance in Nasarawa State. Protection and restoration of livestock corridors, grazing reserves and communal watering points are essential to mitigating resource competition and fostering peaceful co-existence between farmers and herders.

3.2.4 Identification of key issues in the hotspot area

Based on insights drawn from FGDs with farmers and pastoralists, KIIs, and detailed field observations, the hotspot area surrounding Azaza Sogora village reveals a complex interplay of land use issues that together generate intense pressures on resources and heighten the risks of FHC. At the centre of this dynamic landscape are extensive forests, which historically served as vital grazing reserves, resting places, sources of gum arabic and firewood, and important wildlife habitats. These forests have come under significant strain due to widespread tree cutting, burning for land clearance and large-scale charcoal production. As forest cover declines, critical pastoral grazing spaces have diminished, pushing herders to move their livestock deeper into cultivated areas or fragmented patches of remaining woodland, increasing the likelihood of livestock trespass and disputes over damaged crops.

Alongside this, there has been aggressive expansion of cultivated farmland across the area, driven by both long-established villagers and newly arrived IDPs who have settled nearby. Fields now stretch across lands that once functioned as seasonal grazing zones, effectively squeezing traditional livestock routes. The growth of both harvested and fallow agricultural plots introduces not just physical barriers to herding but also new sources of tension, as pastoralists face fees to graze on fallow fields, or fines when their animals inadvertently damage standing crops.

This forces pastoralists either to guide their herds directly across cultivated land, risking immediate conflicts, or to use costly cart transport to navigate around farming zones. As these corridors close and the spatial overlap between grazing and cropping intensifies, the chances of conflict multiply. Within the forests themselves, three newly established villages are growing more permanent, with infrastructure such as schools, water pits, and houses shifting from traditional materials to cement construction. Many residents who previously focused on herding now actively farm within the forest, directly competing with pastoral uses and reducing open grazing areas even further.

Additional pressures come from the construction of small dams and rainwater harvesting pits; these support both farming and herding communities, but they also anchor settlements more permanently. Similarly, the widespread presence of farmer camps deep inside the forest underscores how agricultural practices have penetrated what were historically grazing landscapes.

Charcoal production adds another layer of stress: it drives extensive tree felling, including productive acacia trees, which accelerates land degradation, strips away protective cover and makes remaining grazing areas more vulnerable to erosion. Quarrying for road construction has also scarred parts of the landscape, leaving behind bare, eroded soil. While such degraded areas may still be used opportunistically for grazing on crop residues, they are far less productive, adding to the overall scarcity of dependable pasture.

Taken together, these interconnected land uses – documented through FGDs, KIIs, and direct field observation – illustrate how expanding agriculture, shrinking forests, fragmented grazing corridors and mounting environmental degradation have created a crowded, contested landscape. As farmers and pastoralists compete for shrinking and increasingly intertwined resources, the physical closeness of fields, grazing patches, water sources and extraction sites makes daily livelihood activities more likely to clash.

In Nigeria, critical components within the hotspot include blocked livestock corridors – previously used for north–south transhumance – that are now disrupted by permanent cultivation; degraded resting points, many of which have been converted into settlements; encroached water sources, including traditional river access points and seasonal ponds that now serve as both irrigation channels and domestic water for settled communities; shrinking wet-season grazing areas that have been converted into farmlands in many areas (such as parts of Lafia and Obi Local Governments); and dry-season grazing areas near riverbanks which are increasingly fenced off or reserved for private use.

These changes collectively undermine the resilience and adaptability of pastoral systems. As herders face increased difficulty in locating secure routes and access to water, they are often forced into narrow, contested areas, intensifying crop damage and retaliatory violence. Simultaneously, farmers perceive the lingering presence of livestock in proximity to farmland as a growing threat, prompting defensive practices and reinforcing inter-group mistrust.

The spatial findings reinforce the urgent need for conflict-sensitive land use planning. Delineating and restoring livestock corridors, enforcing grazing reserves and mapping seasonal water points should form part of an integrated land governance framework. Geospatial conflict mapping provides an effective tool for local government authorities, planners, and peacebuilding actors to anticipate flashpoints and guide zoning reforms. Without deliberate interventions, the continued fragmentation of pastoral landscapes will deepen livelihood insecurity and perpetuate the cycle of violence in Nasarawa's high-risk zones.

3.3 Governance and institutional gaps exacerbating FHC

3.3.1 Community perceptions on governance failures

Governance failures and institutional gaps are significantly exacerbating FHCs in the Azaza Sogora and Awe hotspots. Across community narratives, there is a pervasive sense that decisions around land allocation and management have often been top-down, poorly coordinated and disconnected from local realities, intensifying competition and disputes.

One major governance challenge arises from how state institutions allocate land within forests and grazing reserves. The responsible government authorities routinely issue permits for cultivation inside forests, sometimes issuing to large agricultural investors or politically connected individuals in the case of Sudan, while largely ignoring forest governance in Nigeria, without consulting local pastoralists who traditionally rely on these areas for grazing. For instance, in several accounts from Sudan, farmers received contracts to cultivate forest lands, only for these to become flashpoints when herders arrived with livestock seeking pasture. The informal settlement of some pastoral groups within forests has also introduced new dynamics: these groups often transition into farming, thereby directly competing with existing farmers over plots they once used for seasonal grazing, creating multi-layered tenure tensions. In areas such as Awe grazing reserve, local authorities indiscriminately allocate land or permit cultivation by farmers without recourse to existing legislation and policies that demarcate the area exclusively for grazing.

The weakening or bypassing of traditional governance systems compounds these pressures. While local conflict resolution is still often effectively handled through customary mechanisms – using respected community leaders to mediate disputes (*ajawid*, *omdas*, and sheikhs in Sudan; *ardos* and village and district heads in Nigeria) – these systems are increasingly undermined by administrative decisions that fail to respect established norms. Informants mentioned that in recent years, several conflicts reported by farmers and pastoralists ultimately ended up in courts or police stations, but outcomes through formal channels frequently left lingering resentment. In contrast, traditional systems typically produced mutually acceptable solutions that restored relationships, but their scope is limited when official land allocations continue to fuel tensions.

Community perceptions consistently highlight how these governance shortcomings intersect with resource scarcity. Farmers, pastoralists and local leaders all noted how political decisions, such as granting cultivation rights deep within forests or failing to maintain adequate livestock corridors and water points, directly squeezed the space available for grazing and exacerbated conflicts. Moreover, local institutional weaknesses mean that even when routes and resting areas are formally demarcated, enforcement is lax, and they are overtaken by agricultural expansion.

In Nigeria, non-governmental organisations (NGOs) and some state initiatives have attempted interventions, such as planting acacia to serve dual roles in pasture and livelihoods, or establishing trails and water ditches to alleviate pressure. In some areas, boreholes have been drilled to provide water to communities so as to allow animals to take water in the narrow streams and ponds that were hitherto used as domestic water sources, thereby minimising disputes over local water contamination by animals. However, these efforts have often been temporary or poorly sustained, with reforested areas again cleared for farming, revealing broader issues of policy inconsistency and enforcement gaps.

3.3.2 Role of local leaders, tenure systems and land management practices

Local leaders, including village heads and sheikhs, *omdas*, *ardos* and clan elders, continue to play an important role in mediating day-to-day disputes over land and resource use. In many of the sessions, both farmers and pastoralists described how these traditional authorities step in to settle conflicts, negotiate compensation for crop damage and establish informal agreements over access to fallow fields or water points. This local mediation process is generally perceived as faster, cheaper and more balanced than turning to courts or the police.

However, these traditional systems face growing challenges under pressure from changing land tenure arrangements and the evolving land economy as well as the influence of political leaders and security agencies. The customary tenure system, which historically relied on communal understandings of land rights managed by lineage or village authorities, is increasingly under strain. Formal allocations by the state – such as contracts or licences issued for farming within forests or creating grazing reserves – have overridden local norms without adequate consultation. Farmers and pastoralists alike pointed to cases where large tracts were allocated for cultivation, often deep inside traditional grazing reserves or migratory corridors, forcing herders to reroute livestock and intensifying disputes. The introduction of formal land documents and boundaries mostly to the benefit of private businesses and large-scale farmers, such as the Dangote sugar and rice plantation in parts of Awe, has begun to replace or contradict the more flexible, negotiated access that previously characterised relations between farming and herding communities.

Land management practices in the areas also fuel these tensions. On one hand, farmers have expanded cultivation into forests and grazing areas, and along livestock corridors, sometimes encouraged by official permits or simply by a lack of enforcement of reserve boundaries. On the other hand, pastoralists have adapted by seeking out any remaining patches of sparse vegetation, or paying to graze on fallow fields – practices that were once informally tolerated but now increasingly attract fees or disputes over timing and intensity of use. This commercialisation of fallow land and seasonal grazing access has eroded the historical shared expectations that land could be rotated between cropping and livestock needs without conflict. Additionally, crop residue that was previously free has to be paid for. Thanks to the entry of pastoralists into crop farming to supplement food needs, the animal dung that used to represent a vital product for farmers – free organic manure – is now less available to the farming communities.

Local leaders find themselves caught in the middle of these shifts. While they continue to play a critical role in resolving disputes, their authority is increasingly undermined by formal institutions and state-led land decisions that do not fully recognise traditional tenure arrangements. Several farmers and pastoralists noted that even after elders broker local agreements, official land allocations or political pressures can override these deals, leading to renewed disputes. Additionally, local leaders often lack the power to enforce community-level management rules, such as regulating tree cutting or protecting key grazing corridors, which further weakens collective stewardship of the land.

In sum, the interplay of traditional authority systems, evolving tenure practices, fragmented land management and increased influence by political leaders and security agencies has left local leaders struggling to maintain the balance between farming and pastoral livelihoods. This erosion of customary governance – combined with inconsistent state oversight – has opened the door to unchecked land encroachment, insecure access for pastoralists, and rising tensions that frequently spill into conflict.

In both Sudan and Nigeria, governance and institutional failures play a pivotal role in the persistence and escalation of FHCs. Across both contexts, weaknesses in land administration, poor coordination among regulatory institutions, and inconsistent support for customary land governance have created structural vulnerabilities. These weaknesses have enabled unchecked land conversion, obstructed pastoral mobility and undermined the capacity of local communities to resolve disputes peacefully.

3.4 Gendered dimensions of land use and conflict

3.4.1 Gender-specific access to land and conflict exposure

The findings from FGDs with both farmers and pastoralists, supported by KII insights and direct field observations, reveal that land use changes and FHCs in the hotspot have deeply gendered dimensions. Women and men experience land access, tenure security and conflict exposure in distinct ways, shaped by both cultural norms and shifting livelihood pressures.

Among farming communities in both countries, men generally control formal land holdings and make primary decisions regarding the allocation and expansion of cultivated fields. However, the economic importance of agriculture has led to an intensification of women's involvement in farming activities especially in Sudan and for some farming groups in Nigeria. Women are heavily engaged in land preparation, weeding and harvesting, and increasingly in managing small plots around homesteads. As farmland pushes deeper into former forests and grazing areas, women spend longer hours working in more distant fields, often walking to isolated plots. This has increased their physical exposure to the risks associated with contested lands, including disputes with pastoralists over crop damage or encroachment. Women from these farming households also reported engaging in charcoal production and collecting firewood in increasingly depleted forests. Moreover, there is an increasing trend among women to work as wage labourers in large-scale mechanised farms, particularly in Sudan. There exists the potential for a similar shift in the Nigeria study area, considering the emergence of large-scale commercial farms in many parts of Nasarawa state.

Among the pastoralist groups in both countries, the gender dynamics reflect a different but equally significant pattern. Men are primarily responsible for moving livestock along traditional corridors and negotiating grazing access, and conflict with farmers can arise during herd movements when livestock stray into cultivated areas: confrontations that often involve men and boys on both sides. Meanwhile, pastoralist women face impacts that are more indirect, yet still significant. They are typically responsible for managing household economies, processing dairy products, and caring for small ruminant livestock that depend on accessible nearby pastures. As grazing areas shrink and mobility becomes restricted, pastoralist women bear the burdens of declining household nutrition and income (according to FGD with the male group in Gidan Julde, Nasarawa, Nigeria). In some cases, they are also drawn into conflicts when fines or compensation payments strain family resources, forcing them to take up additional labour or send daughters to seek wage work, or to engage in hawking milk where such opportunities exist.

The conflict environment itself has reinforced gender-specific vulnerabilities. Farmers' wives reported being left to manage fields and household security when men migrate seasonally for off-farm work or gold mining, such as described in Sudan. This leaves them to navigate disputes with passing herders or negotiate fees when pastoralists seek to graze on crop residues. For pastoralist women, prolonged stays in contested zones due to blocked migration paths increase the risks of harassment and limit their access to distant markets or health services, such as in many parts of Nasarawa state in Nigeria.

Traditional systems for resolving land and resource disputes have also been largely male-dominated, meaning women's concerns are often underrepresented in local conflict management processes. Even when cases are brought before elders or local leaders, discussions typically involve male household heads, sidelining women's perspectives on how land pressures affect their daily survival strategies or workloads.

In summary, the findings highlight that land use change and rising FHCs do not affect all community members equally. Men tend to be directly involved in negotiations, confrontations, and physical disputes over land, while women disproportionately shoulder the hidden burden and costs – increased labour demands, food insecurity, and exposure to environmental degradation.

3.4.2 Women's roles in conflict and peacebuilding

The experiences captured through FGDs and KIIs reveal that while women often bear the hidden costs of land competition and FHC, they also play important and sometimes overlooked roles in both sustaining tensions and facilitating peace.

On the conflict side, women contribute indirectly to land pressures by expanding cultivation in forested areas or maintaining a stock of small ruminants around homesteads that graze in patchy areas around densely cultivated land. As agricultural land becomes scarcer and men pursue seasonal migration or alternative livelihoods such as mining, women often take the lead in opening new fields, producing charcoal, and collecting firewood. These activities, while essential for household survival, also accelerate deforestation and encroach into spaces traditionally used by pastoralists for grazing, thereby fuelling land competition and potential disputes. Women's agricultural labour is critical to the viability of farming on these contested lands, embedding them structurally in the dynamics that heighten local conflict risks.

At the same time, women are deeply involved in managing the day-to-day impacts of conflict and play subtle but critical roles in local peacebuilding. Within both farmer and pastoralist households, women frequently act as informal negotiators. Women also maintain social networks across farming and herding communities through shared market activities, water point use, and family ties, which can serve as quiet but powerful channels for rebuilding trust after disputes. Narratives from key informants suggested that while formal mediation sessions are typically male-dominated, women's behind-the-scenes discussions often lay the groundwork for reconciliation, especially in areas where the disputes are not yet violent. They share information about acceptable settlement amounts (such as compensation), encourage male relatives to accept negotiated outcomes, and help enforce local agreements by maintaining community pressure against retaliatory acts, including exerting influence on their adult children to dissuade them from violence. In some cases, women's mutual dependence on shared water and market spaces has compelled them to maintain cooperative ties even when broader community relations are strained.

These insights point to the dual reality of women's involvement in the FHC context. On one hand, their intensified use of forest resources and quest to expand farms into virgin land – driven by necessity – contributes to land pressures. On the other hand, their everyday interactions, informal diplomacy and economic interdependence make them vital actors in preserving social cohesion and preventing localised disputes from hardening into long-term enmity. This highlights the importance of including women not only as vulnerable stakeholders but also as essential partners in designing conflict-sensitive land management and local peacebuilding initiatives.

The study's evidence from Sudan and Nigeria reveals deeply rooted inequalities that shape access to land, participation in decision-making, and vulnerability to conflict impacts. Across both countries, women play vital roles in agricultural production, resource management and household resilience. However, their rights to land and natural resources are often mediated through male relatives or restricted by customary norms, legal barriers and socio-cultural expectations.

Drone shot of cattle grazing.
Credit: ILRI/ Folusho Onifade

4. MITIGATION OPTIONS AND POLICY IMPLICATIONS

4.1 Land use planning and zoning

The spatial analysis from Sudan and Nigeria underscores the ways in which unchecked agricultural expansion; rapid growth and expansion of settlements; and extractive activities such as charcoal production, artisanal mining and road construction have steadily encroached on traditional pastoral landscapes. This process has fragmented livestock corridors, degraded grazing reserves, reduced forest cover and limited access to critical water sources. As these resources become scarcer and more unevenly distributed, pastoralists are increasingly forced to navigate complex mosaics of farmland and settlements, dramatically raising the likelihood of livestock trespass resulting in crop damage, which serves as a common trigger of violent confrontation.

A priority mitigation option identified by this study is the adoption of conflict-sensitive and participatory land use planning and zoning approaches that explicitly safeguard pastoral mobility needs alongside agricultural and settlement interests. This type of approach was mentioned by pastoral respondents and, in fact, does already exist in many public policy documents, such as the stock routes development strategy introduced by the Nigerian government in the 1990s during the implementation of the World Bank-supported Second Livestock Development Project. It involves legally delineating and demarcating livestock corridors to ensure that well-defined migration routes are recognised in both statutory and customary tenure systems, and are physically marked on the ground to secure pathways for seasonal movements and access to water points. Resting points (overnight camping areas during the migratory period) are needed along these corridors, where key infrastructure such as water and veterinary services can be provided. Effective enforcement mechanisms are essential to prevent encroachment or blockage by farmers or investors, and to stop opportunistic settlement. In practice, implementing and sustaining such initiatives requires strong public institutions, as well as political commitment which is difficult to secure.

Protecting and rehabilitating grazing reserves also emerges as a crucial strategy. This means conserving remaining communal grazing areas and investing in the restoration of degraded rangelands through measures such as reseeding, erosion control, and sustainable grazing practices. In the Nigerian context, for instance, this may require revisiting underutilised or partially encroached grazing reserves and securing them through updated land management plans that balance multiple land use demands. Essential services and key infrastructure can be provided in these areas for common use, thereby stimulating improved productivity; this was part of the strategy of the country's National Livestock Transformation Plan (2019–2028), but its implementation has suffered a consistent lack of government commitment at all levels.

Equally important is the protection of riparian forests and water resources, particularly the surface water resources along streams, rivers, and floodplains (*fadama*). Given their role as critical dry season grazing sites and watering points, riparian zones, seasonal ponds

and forested riverbanks need targeted conservation. This can be achieved by establishing protective buffer zones, regulating cultivation along waterways, promoting reforestation and maintaining communal access rights that allow pastoral groups to rely on these lifelines without triggering disputes.

Mapping and safeguarding seasonal water points, livestock corridors and grazing reserves through participatory GIS offers a practical tool. Engaging herders and farmers in identifying key watersheds and water sources helps protect these sites from privatisation or unsustainable extraction, thereby reducing a major source of resource-driven tensions.

Integrating conflict risk analysis into broader land use planning allows local authorities and planners to anticipate areas where new cultivation, settlement, or infrastructure might exacerbate land competition. By incorporating spatial conflict hotspot data into district and state-level planning, stakeholders can steer development away from critical pastoral zones or design compensatory measures to ensure continued access. This will also help avoid the negative impact of unplanned and destructive activities that degrade natural ecosystems, increase loss of biodiversity, and exacerbate the impact of climate change.

Embedding these strategies into local and regional land use frameworks requires participatory approaches that meaningfully involve both farming and pastoral communities as well as other important stakeholder groups. This helps build consensus, strengthens the legitimacy of zoning decisions, and fosters joint stewardship over shared landscapes. Ultimately, such integrated and inclusive land use planning not only mitigates immediate conflict risks but also enhances the long-term sustainability of rural livelihoods and supports broader peacebuilding efforts.

4.2 Inclusive and equitable land governance reforms

The analysis of evidence from both Sudan and Nigeria clearly reveals that weak, exclusionary, or inconsistently applied land governance systems lie at the heart of many FHCs. In Sudan, the legacy of colonial and post-independence land policies – most notably the 1970 Unregistered Land Act – has effectively nationalised vast tracts of communal rangelands. This has allowed state authorities to allocate these lands for farming (particularly large-scale mechanised farming) without adequate consultation with, or compensation for, the pastoralist communities who have traditionally relied on them. As a result, pastoral groups have faced systematic dispossession, reduced mobility and growing livelihood insecurity. In Nigeria, while the 1978 Land Use Act places land under the trusteeship of state governors, ambiguities around the management of grazing reserves and livestock corridors, coupled with fragmented implementation of land use laws by local governments, have created an environment ripe for overlapping claims, opportunistic land appropriation, and tenure insecurity, especially for pastoralists. Even though the 1965 Grazing Reserve Law in Northern Nigerian states permits and authorises state authorities to establish and develop land areas for livestock grazing by pastoralists, the implementation of the legislation is weak, allowing mass encroachments on grazing reserves such as at Awe in Nasarawa state.

Addressing these deep-seated problems requires a suite of inclusive and enforced land governance reforms that strengthen tenure systems and align statutory laws with local realities. Reform efforts must begin with a recognition of the legitimacy of customary and communal land tenure systems that sustain both pastoralist and smallholder farming communities. In practice, this means revisiting or amending national and state-level legislations to explicitly protect communal grazing lands, seasonal migratory corridors and forest reserves. For Sudan, this could involve reviewing provisions that have historically

favoured mechanised agriculture at the expense of pastoral systems, while ensuring that pastoralist access rights are legally recognised and enforceable. In Nigeria, revitalising the management of communal grazing areas and existing grazing reserves through updated land use plans, clear demarcation of grazing areas and cattle routes, and participatory oversight can help secure these critical spaces for pastoral use.

Transparency and local participation are equally essential. The process of allocating land – whether for agriculture, settlement expansion or investment – should be governed by clear guidelines that involve meaningful consultations with affected communities. Mechanisms such as community land boards or multi-stakeholder committees can serve as platforms to vet land allocations, mediate competing claims, and ensure that decisions reflect local interests and uphold social equity. Providing legal support and public awareness campaigns can empower local populations, including marginalised groups such as pastoralists to understand and advocate for their land rights. It may also require revisiting some legislations, such as the Open Grazing Prohibition and Ranches Establishment Law in Benue state that failed to recognise communal access rights for pastoralists.

Strengthening land administration institutions is another critical pathway. Many conflicts persist or escalate because local authorities don't have the capacity, resources or impartiality to enforce land tenure regulations. Building institutional capacity at the state and district levels, clarifying roles and responsibilities across agencies, and fostering coordination among ministries of agriculture, environment and local government are necessary to uphold equitable land governance. In places like Nasarawa state, improved inter-agency collaboration could ensure that land allocation decisions account for existing pastoral uses and integrate conflict risk assessments, rather than being driven solely by agricultural or urban development priorities.

These reforms must also explicitly incorporate provisions for conflict-sensitive land governance. This involves integrating geospatial conflict hotspot data and local knowledge of tension points into land allocation and tenure regularisation processes. Doing so can help pre-emptively identify areas where granting cultivation licences, settlement plots, or mining concessions might exacerbate land competition and trigger disputes. It will also help in identifying critical pastoral production areas and categorising existing resources, thereby enabling initiatives to protect and revitalise them: for example, through the design and implementation of land reclamation initiatives such as reseeding and control of erosion, and the provision of key production infrastructure.

Ultimately, inclusive and equitable land governance reforms are about more than just technical fixes to land laws or registries. They require a fundamental shift toward participatory, transparent, and locally grounded systems that recognise the diverse ways in which communities – farmers, herders, women and youth – access, manage, and depend on land. By addressing structural tenure insecurities and empowering local actors in land decision-making, these reforms can reduce the drivers of FHCs, foster more sustainable land stewardship, and build trust in institutions.

4.3 Strengthening local dialogue and mediation platforms

The findings from both Sudan and Nigeria suggest that formal land governance structures and policies often falter in managing farmer–herder relations, and that local dialogue and customary mediation platforms remain critical for navigating day-to-day disputes over cropland, water and grazing resources. In many communities, traditional leaders play an indispensable role in negotiating access arrangements, brokering compensation for crop

damage, and de-escalating tensions before they spiral into violence. These customary mechanisms are typically seen by local residents as more accessible, culturally appropriate and responsive formal judicial processes.

However, these local systems are under increasing strain. As land pressures mount and disputes become more frequent and complex, traditional institutions often lack the authority, resources or support to enforce agreements. Additionally, when state decisions around land allocation – such as granting farming contracts within forest reserves or establishing new settlements in grazing areas – override customary agreements without consultation, they undermine local leaders' legitimacy. In Nigeria, for example, local leaders have struggled to mediate disputes where grazing reserves are informally encroached or subdivided without clear higher-level enforcement to back their rulings. In Sudan, the bypassing of customary processes by state allocation of mechanised farming blocks has left pastoralists and smallholders without trusted avenues for addressing grievances.

Strengthening local dialogue and mediation platforms begins with recognising and formalising the role of customary institutions within broader land governance frameworks, so that their decisions and agreements are not easily overturned by external actors or ignored by state agencies. Providing training and resources to traditional leaders on evolving land laws and documentation of local agreements can bolster their capacity to handle increasingly complex land disputes.

Multi-stakeholder land and resource committees that include farmers, pastoralists, local leaders and representatives from relevant government departments can act as inclusive spaces to proactively identify and address emerging conflicts. Such committees can be instrumental in overseeing the maintenance of livestock corridors, resolving disagreements over seasonal access, and planning shared use of critical water points. They also offer an opportunity to link local dialogue more directly with formal administrative processes.

Investing in community-based early warning and response systems is another practical approach. By building networks of peace monitors and facilitators who can track signs of rising tension – such as unusual herd movements, expanding cultivation into contested zones, or deteriorating relations between groups – interventions could be initiated before disputes escalate.

Importantly, strengthening local dialogue also requires addressing barriers that limit who can participate. Women, youth, and marginalised groups often have distinct experiences of land conflict, yet are underrepresented in customary decision-making bodies. Creating spaces where their voices are heard – not just as victims but as active agents in shaping agreements – can deepen local ownership of conflict management and make outcomes more robust.

4.4 Gender-sensitive land management and conflict resolution

The study's fieldwork in Sudan and Nigeria reveals that land use changes and FHCs are deeply gendered in their impacts, yet women's roles, needs and contributions are often overlooked in both land governance and conflict resolution. As landscapes become more fragmented and competition over land intensifies, women experience unique burdens – from increased labour demands in farming and resource collection, to heightened vulnerability when travelling longer distances to gather firewood or water, or to tend more distant fields. At the same time, women play central but under-acknowledged roles in sustaining both farming and pastoral household economies, managing small livestock, producing charcoal, or engaging in petty trade, and maintaining vital social networks that can either mitigate or compound tensions.

Despite their pivotal economic and social roles, women often have few formal or informal land rights, and limited say in decisions around land allocation, zoning, or the resolution of disputes. Customary and statutory systems of land governance in both countries are predominantly male-dominated, with land generally held in the names of male household heads and traditional dispute forums rarely including women as decision-makers. This exclusion not only undermines women's security and agency but also weakens the effectiveness of local conflict resolution.

Integrating gender-sensitive approaches into land management and conflict resolution mechanisms involves, first, ensuring that women have meaningful representation in local land committees, peacebuilding platforms, and participatory land use planning processes. In practice, this means setting quotas or establishing women's caucuses within local decision-making bodies, supporting leadership training, and ensuring meeting times and venues are accessible and culturally appropriate to encourage women's participation.

Second, policies and programmes aimed at formalising land rights need to account for women's formal or informal claims to land. This could include joint titling initiatives that register land in the names of both husbands and wives, or specific provisions that protect women's rights to inherit, use, and control land. These steps help safeguard women's access to critical resources, particularly in the event of widowhood, divorce or male out-migration.

Third, gender-sensitive conflict resolution requires recognising and leveraging the informal roles women already play as negotiators and peacebuilders. As highlighted by FGDs and KIIs, women often maintain essential social ties across farming and pastoral communities through shared markets, water sources and extended networks. Supporting community initiatives that build on these informal mediation practices – such as women-led dialogues or cross-group livelihood cooperatives – can strengthen local peace processes.

Additionally, addressing the practical burdens that contribute to women's exposure to conflict is crucial. For example, investing in closer water points, fuel-efficient stoves to reduce the need for firewood collection, or community woodlots can help reduce the distances women must travel through contested spaces, thereby lowering their risk of confrontation or violence. Strengthening alternative income-generating skills and cooperatives will be valuable.

Ultimately, integrating gender considerations into land management and conflict resolution is not simply about mitigating women's vulnerabilities, but about harnessing their agency and insights to build more inclusive, effective and durable solutions to FHCs. By making women visible and active stakeholders in land governance and peacebuilding, interventions can better reflect the complex realities of rural livelihoods and foster more cohesive, resilient communities.

5. CONCLUSIONS

This study set out to explore how LULC dynamics intersect with FHCs in Sudan and Nigeria, drawing on spatial analysis, participatory field methods and local narratives. Across both contexts, the research reveals strikingly parallel trajectories: agricultural expansion, growth of settlements, and extractive activities have steadily encroached upon traditional pastoral landscapes, fragmenting grazing corridors, diminishing forests and constraining access to vital seasonal water points. These transformations have intensified resource pressures, compelling farmers and pastoralists into closer spatial proximity and heightening the risk of disputes over crop damage, passage and water use.

Simultaneously, weakened customary governance structures and ambiguous or exclusionary tenure regimes have undermined communities' ability to navigate these new pressures. Traditional systems that once balanced farming and herding interests struggle under the weight of demographic change, economic shocks, and state policies that often favour large-scale agriculture or fail to protect communal grazing lands.

Gendered dimensions further complicate this landscape. Women, while heavily involved in both farming and pastoral livelihoods, face unique burdens and often lack a formal voice in land or conflict resolution processes, deepening vulnerabilities and missing opportunities to leverage their roles as peacebuilders.

5.1 Reflections on structural inequalities, policy gaps and tenure systems

The findings from Sudan and Nigeria highlight that the challenges described above are deeply tied to structural inequalities, longstanding policy biases and fragile tenure systems. These are not merely matters of local competition over resources, but reflections of how institutional arrangements shape the opportunities and constraints faced by different groups.

In Sudan, decades of state policies have consistently prioritised privatised crop production, particularly large-scale mechanised agriculture, over communal and customary land use systems. Laws such as the 1970 Unregistered Land Act effectively nationalised vast expanses of land, enabling state authorities to allocate rangelands traditionally used by pastoralists to investors and politically connected elites. This has systematically eroded the land security of pastoral communities, compressed their mobility systems, and narrowed the ecological options that are vital for managing climate variability. Pastoralists are often forced into direct competition with farmers, undermining long-standing adaptive strategies.

In Nigeria, the legal framework provided by the 1978 Land Use Act was intended to clarify and regulate land administration, but its implementation has been inconsistent and often fragmented across state and local levels. This has left many pastoralists and smallholder farmers with insecure or informal claims, exposed to ad hoc land allocations and speculative land grabs. Grazing reserves, livestock corridors and communal water points that once supported seasonal transhumance have become degraded, encroached, or repurposed for cultivation and settlements without adequate consultation or compensation. As a result, farmers and pastoralists alike find themselves navigating an increasingly uncertain and contested landscape.

These gaps in policy and tenure security have not only intensified direct competition over land and water but have also weakened the very social institutions that once helped to mitigate conflict. Customary authorities, such as village heads and clan elders, historically played pivotal roles in negotiating seasonal grazing arrangements, resolving disputes over crop damage, and maintaining flexible, trust-based systems of shared access. Presently, however, these local mechanisms often lack the authority or institutional support needed to enforce communal practices, especially when formal state decisions or commercial pressures override local understandings.

This erosion of customary governance has profound implications. As formal land allocations proceed without sufficient coordination with local institutions, and as new investments or settlements transform landscapes once governed by negotiated norms, communities are left with few trusted channels to manage emerging tensions. Disputes that might once have been settled through dialogue and compensation are increasingly likely to escalate, feeding cycles of mistrust and violence.

Addressing these deeply rooted challenges will require more than technical fixes to land registries or isolated conflict resolution projects. It demands a fundamental rebalancing of land governance systems to ensure they are inclusive, transparent, and responsive to the needs of both farming and pastoral populations. Tenure security needs to be strengthened through reforms that recognise customary rights and protect critical mobility corridors. The role of local institutions needs to be revitalised and, potentially, integrated into formal governance processes. Considering the current erosion of pastoral resources and gross inadequacy of natural grasslands, investment in rangelands restoration is important, while the introduction of innovative practices for the production of pasture and other alternative feed resources for animals should also be considered.

5.2 Closing thoughts on potential cross-regional learning

While this study focuses on Sudan and Nigeria, its insights have broader relevance across the Sahelian and Sudano-Sahelian belt, the sub-humid zone and other dryland regions grappling with similar challenges. The findings highlight the shared pressures of expanding agriculture, settlement growth, environmental degradation, and weak land governance systems that disrupt pastoral mobility and strain farmer–herder relations. These are not isolated dynamics but part of a wider pattern affecting dryland communities across Africa and beyond.

There are, therefore, significant opportunities for cross-regional learning and exchange of practical experiences. Countries across sub-Saharan Africa are experimenting with diverse approaches to balancing agricultural expansion and pastoral mobility. Lessons from this initiative can inform future interventions in Sudan and reinforce adaptive practices in Nigeria. Similarly, Sudan's long history of taking traditional grazing land and giving it to large-scale mechanised farming investors offers cautionary lessons on the risks of state-led land allocation that overlooks local tenure systems. Such lessons are relevant to countries considering large-scale agricultural investments, such as Nigeria, where commercial agriculture is presently taking root in many states including Nasarawa.

There is also growing experience in the region with integrated early warning systems that combine spatial monitoring of land use and vegetation changes with local conflict reporting. These systems can help anticipate hotspots where resource pressures and social tensions are likely to converge, allowing for proactive measures before disputes escalate into violence. In addition, the broader Sahelian context provides innovative examples of community peace

committees and cross-border pastoral agreements that facilitate seasonal movements, which could be adapted to emerging realities in Sudan's post-conflict landscape or inform policy harmonisation across states in Nigeria.

Moreover, there is a strong case for sharing experiences on gender-sensitive land governance and conflict mediation. Initiatives that promote women's participation in land and natural resource management – for example, through dedicated women's committees or quotas in local decision-making bodies – have begun to show promise in enhancing social cohesion and expanding the range of actors committed to conflict prevention.

Ultimately, fostering cross-regional learning requires more deliberate investment in platforms for dialogue and technical exchange, supporting policymakers, traditional authorities, civil society, and researchers to share evidence and adapt strategies to local realities. By learning from each other's successes and missteps, countries like Sudan and Nigeria can craft more flexible, inclusive and sustainable approaches to managing land use dynamics and mitigating farmer–herder conflicts.

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ANNEXES

Annex 1. Landsat data type and date of acquisition

Landsat data type and date of acquisition for the LULC change analysis in Sudan

Year	Data type	Date of acquisition
2010	Landsat 5	12 Jan 2010
2015	Landsat 8	10 Jan 2015
2020	Landsat 8	1–24 Jan 2020
2025	Landsat 9	13 Jan 2025

Landsat data type and date of acquisition for the LULC change analysis in Nigeria

Year	Data type	Date of acquisition
2010	Landsat 7	1 Dec 2010 – 20 Feb 2010
2015	Landsat 8	1 Dec 2014 – 20 Feb 2015
2020	Landsat 8	1 Dec 2019 – 20 Feb 2020
2025	Landsat 9	2 Jan 2025 – 20 Feb 2025

Annex 2. Summary of FGDs and KIIs undertaken in Sudan and Nigeria

FGDs undertaken in Gadarif State, Sudan

Group	Community	Gender and age	No. of participants
1	Farmers	Male; mix of ages	8
2	Farmers	Female; mix of ages	15
3	Farmers	Male youth	9
4	Farmers	Female youth	7
5	Pastoralists	Male; mix of ages	15
6	Pastoralists	Female; mix of ages	18
7	Pastoralists	Male youth	10
8	Pastoralists	Female youth	20

FGDs undertaken in Nasarawa State, Nigeria

Group	Community	Gender and age	No. of participants
1	Farmers	Male; mix of ages	12
2	Farmers	Female; mix of ages	19
3	Farmers	Male youth	13
4	Farmers	Female youth	9
5	Pastoralists	Male; mix of ages	6

Group	Community	Gender and age	No. of participants
6	Pastoralists	Female; mix of ages	16
7	Pastoralists	Male youth	13
8	Pastoralists	Female youth	12

KIIs undertaken in Gadarif State, Sudan

No.	Stakeholder/institution	Position	Gender
1	Farming community in Azaza Sogora	Local leader	Male
2	Farmer	Local leader	Male
3	Internally Displaced Person (IDP)	IDP representative	Female
4	Fallata pastoralist traditional leader (*omda*)	Tribal leader	Male
5	Crop Damage Assessment Committee	Head of the committee	Male

KIIs undertaken in Nasarawa State, Nigeria

No.	Stakeholder/institution	Position	Gender
1	Village Head of Tunga, Awe LGA	Community leader	Male
2	Child Education and Community Development Initiatives (CECDI), Lafia	Programmes manager	Male
3	Ministry of Environment, Lafia	Director of Mining	Female
4	Ardo Baure, Awe LGA	Community leader	Male
5	Community-based care and support programme	Programmes manager	Male
6	Ministry of Agriculture, Lafia, Nasarawa state	Director of Livestock Services	Male

Annex 3. Accuracy assessment of the Random Forest classification

Accuracy assessment of Random Forest classification for the LULC classes in Sudan

Year	Overall accuracy	Kappa coefficient
2010	84%	0.80
2015	89.76%	0.87
2020	85.52%	0.82
2025	84.14%	0.80

Source: authors' own.

Accuracy assessment of Random Forest classification for the LULC classes in Nigeria

Year	Overall accuracy	Kappa coefficient
2010	79.67%	0.79
2015	84.37%	0.79
2020	85.26%	0.81
2025	78.14%	0.74

Source: authors' own.

Annex 4. LULC change matrices during the period 2010–2025 in Sudan (area in ha)

	Change matrix 2010–2015						
	Water	Bareland	Dense vegetation	Sparse vegetation	Harvested agricultural land	Unharvested agricultural land	Total
Water	80.6	3.8	0.5	72.3	55.1	69.5	281.8
Bareland	12.4	3,778.1	7.5	15,162.4	3,796.7	2,479.4	25236.5
Dense vegetation	10.5	46.4	2,298.2	2,018.8	325.9	152.8	4852.6
Sparse vegetation	163.2	4,331.1	1,026.2	117,191.1	37,328.3	62,170.5	222210.4
Harvested agricultural land	59.6	1,071.8	95.8	65,630.9	52,580.8	56,356.9	175795.8
Unharvested agricultural land	77.3	1,701.6	10.4	61,240.3	115,806.3	211,411.6	390247.5

	Change matrix 2015–2020						
	Water	Bareland	Dense vegetation	Sparse vegetation	Harvested agricultural land	Unharvested agricultural land	Total
Water	185.3	6.7	12.4	144.4	26.7	28.2	403.7
Bareland	9.1	5,836.3	30.5	469.6	376.9	4,210.3	10932.7
Dense vegetation	1.1	19.4	2,197.1	1,074.4	134.7	11.9	3438.6
Sparse vegetation	78.4	26,738.3	2,067.2	90,460.1	42,112.2	99,859.6	261315.8
Harvested agricultural land	134.7	12,574.1	319.8	29,530.9	81,011.1	86,322.6	209893.2
Unharvested agricultural land	212.7	18,258.6	11.3	11,802.2	86,765.1	215,590.8	332640.7

	Change matrix 2020–2025						
	Water	Bareland	Dense vegetation	Sparse vegetation	Harvested agricultural land	Unharvested agricultural land	Total
Water	144.2	14.9	32.4	127.6	120.8	181.7	621.6
Bareland	55.3	8,009.5	2.0	1,587.8	3,701.8	50,076.9	63433.3
Dense vegetation	1.2	54.1	2,291.0	2,034.2	203.5	54.3	4638.3
Sparse vegetation	98.7	1,522.0	1,217.1	56,787.7	33,849.2	40,008.8	133483.5
Harvested agricultural land	100.5	1,036.3	172.5	22,528.6	72,197.2	114,391.8	210426.9
Unharvested agricultural land	195.8	7,370.8	71.7	28,383.6	79,896.3	290,105.3	406023.5

Source: authors' own.

Annex 5. LULC change matrices during the period 2010–2025 in Nigeria (area in ha)

	Change matrix 2010–2015						
	Water	Bareland	Dense vegetation	Agricultural land	Urban	Grassland/ Uncultivated land	Total
Water	8,779.8	3,608.1	1,894.2	1,153.7	622.9	1,147.5	17,206.2
Bareland	2,407.2	12,584.9	375.9	25,130.0	685.8	3,502.3	44,686.1
Dense vegetation	1,231.0	9,289.6	575,347.8	102,898.6	1,305.1	482,520.2	1,172,592.4
Agricultural land	488.4	77,947.0	92,431.5	518,624.2	5,967.8	547,743.1	1,243,202.1
Urban	599.3	1,754.2	895.3	6,855.9	4,256.7	6,751.7	21,113.2
Grassland/Uncultivated land	237.1	7,031.8	21,443.4	48,716.8	832.3	47,126.5	125,387.9

	Change matrix 2015–2020						
	Water	Bareland	Dense vegetation	Agricultural land	Urban	Grassland/ Uncultivated land	Total
Water	13,240.8	2,937.3	4,238.7	1,964.7	1,302.9	403.5	24,088.0
Bareland	2,157.0	15,305.2	8,311.7	54,485.9	1,189.7	5,296.9	86,746.4
Dense vegetation	364.1	6.0	211,863.9	5,463.9	171.5	6,677.5	224,546.9
Agricultural land	457.8	25,356.2	458,979.5	1,069,453.3	11,766.2	88,838.0	1,654,851.0
Urban	863.1	828.3	1,508.6	8,476.9	6,101.9	1,073.7	18,852.5
Grassland/Uncultivated land	123.5	252.1	487,690.1	103,357.4	581.0	23,098.3	615,102.3

	Change matrix 2020–2025						
	Water	Bareland	Dense vegetation	Agricultural land	Urban	Grassland/ Uncultivated land	Total
Water	15,061.1	1,832.9	514.9	3,332.2	1,032.4	2,717.5	24,491.0
Bareland	4,258.6	13,847.2	144.0	27,335.3	1,705.3	2,028.4	49,318.9
Agricultural land	1,992.1	667.7	147,134.8	80,426.4	781.8	150,361.1	381,363.9
Urban	764.5	66,932.3	34,888.9	1,299,266.7	4,072.1	239,211.8	1,645,136.2
Grassland/Uncultivated land	1,457.6	1,153.7	298.0	15,010.3	10,266.3	2,194.7	30,380.7
Unharvested agricultural land	556.3	2,318.4	41,480.3	229,462.5	1,003.0	218,568.8	493,389.3

Source: authors' own.

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Cover: Sudanese pastoralist and camel, Darfur State, Sudan.
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