CGIAR SUSTAINABLE FARMING

Farmer-Managed Natural Regeneration contribution to soil health in the southern part of Niger: A remote sensing Perspective

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Technical report

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Executive summary

Farmer-Managed Natural Regeneration (FMNR) is more than a greening initiative—it is a critical intervention for soil health and climate resilience. Comparing Magaria's landscape between 2019 and 2024 reveals a dramatic recovery. In 2019, half the department faced severe soil exposure due to low vegetation cover; by 2024, FMNR practices helped move 60% of the land into a healthy, productive state.

The data shows that FMNR provides a "biological floor" that protects the land even during drought. By fostering indigenous tree growth, FMNR prevents erosion, manages floodwaters through better soil infiltration, and ensures a steady supply of nutrients. This restoration follows a non-linear path: as cover increases toward the 80% mark, the ecosystem reaches a tipping point where soil health becomes permanent and self-replenishing.

> *Farmer-Managed Natural Regeneration (FMNR) has proven to be a cost-effective, scalable policy instrument for restoring degraded Sahelian landscapes. Remote sensing evidence from southern Niger shows a clear transition from widespread bare soils to productive land cover within five years, confirming FMNR's strategic role in achieving national soil health, climate resilience, and land degradation neutrality targets.".*

1. Introduction

The West African Sahel, particularly Niger, faces chronic challenges from land degradation, desertification, and the harsh impacts of climate variability (Reij et al., 2009; Tougiani et al., 2009). For decades, agricultural productivity has been threatened by the loss of soil fertility, soil organic matter, and severe wind and water erosion, jeopardizing the livelihoods and food security of predominantly rural populations (Larwanou et al., 2006). Conventional large-scale tree-planting efforts often failed due to low survival rates in the arid environment.

Farmer-Managed Natural Regeneration (FMNR) emerged as a low-cost, highly scalable, and farmer-led agroforestry practice that has resulted in one of Africa's largest positive environmental transformations. FMNR began in the 1980s as a locally-led initiative to protecting and managing the regrowth of indigenous trees and shrubs from existing rootstocks, stumps, and seeds on their farmlands (Weston et al., 2015; Rinaudo et al., 2019), further promoted by extension workers with support of development partners. By 2007 FMNR has led to the "re-greening" of an estimated five million hectares of farmland in Niger, integrating valuable woody species back into the agroecosystem (Tougiani et al., 2009).

Niger is actively committed to achieving several soil health initiatives and programs, and FMNR is very significant in delivering soil health outcomes. Regenerated and protected trees contribute leaf litter and root biomass, which are vital for sequestering carbon and improving soil structure, especially crucial for the Sahel's sandy soils (Bayala et al., 2018). Certain indigenous species, particularly leguminous trees like Faidherbia albida, fix atmospheric nitrogen, naturally enriching the soil (Tougiani et al., 2009). The increased tree cover, leaf litter, and root systems stabilize the soil surface, acting as windbreaks and reducing the impact of high-intensity rainfall (Rinaudo et al., 2019). The increased soil organic matter and shade from the tree canopy reduce water runoff and evaporation, enhancing water infiltration and availability for crops (Larwanou et al., 2006).

Over 5-year implementation (2019–2024) in Zinder region with the support of USAID funds through GIRMA project. The goal of enhancing ecosystem resilience and agricultural productivity through FMNR aligns closely with the critical need to improve soil health – a foundational element for biodiversity, carbon sequestration, and sustainable livelihoods. Soil health, characterized by organic matter content, nutrient cycling, erosion resistance, and microbial activity, is challenging to measure directly at scale due to costs and logistical constraints. However, proxy indicators such as vegetation recovery, reduced bare soil exposure, and improved land cover strongly correlate with soil health improvements, offering viable alternatives for evaluation.

Remote sensing provides a powerful, scalable tool to quantify these proxies across large spatial and temporal scales. By analysing satellite-derived metrics like vegetation vigour, biomass accumulation, and land-use changes, we can infer FMNR's contributions to soil stabilization, organic matter buildup, and reduced erosion. This approach bridges the gap between ground-data limitations and the need for evidence-based assessment, enabling stakeholders to validate restoration outcomes and inform adaptive management strategies. In this paper we are presenting a replicable cost-effective approach to assess the impact of Farmer-Managed Natural Regeneration (FMNR) on soil health and climate mitigation in Niger and beyond.

2. Methodological approach

2.1. Study area

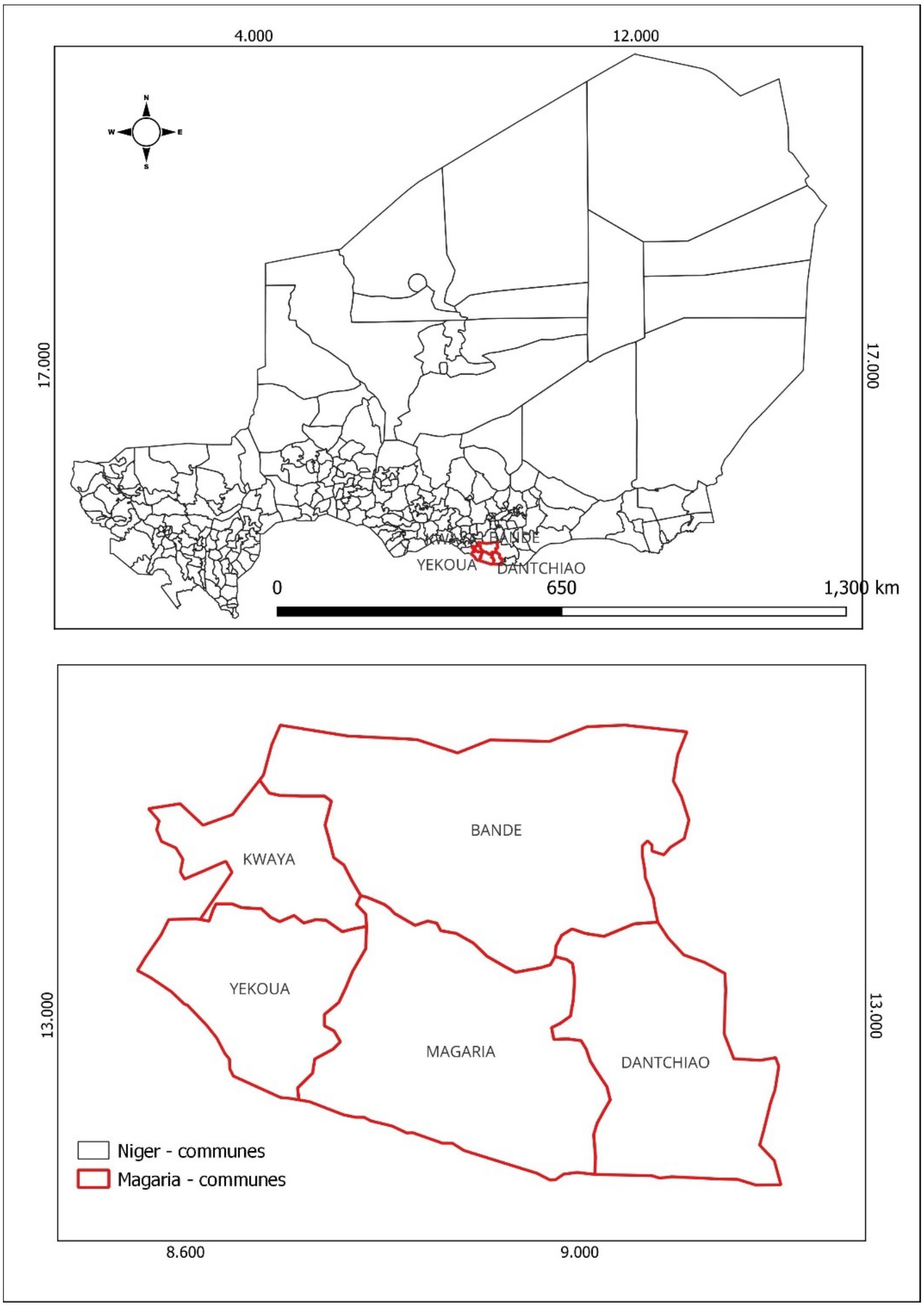


Figure 1: Study area

2.2. Satellite image collection: Sentinel 2

This initial phase prepares the satellite data needed for analysis. Sentinel-2 Level-2A (Bottom-of-Atmosphere reflectance) data were chosen for the study area. The imaging time frame is critical, and it is usually set to coincide with the ground-truth data collection (or peak growing season). The collected photographs are filtered to provide the greatest scenes. Images depicting the area of interest (AOI) are chosen. Images are chosen between 01/01/2023 and 31/12/2024. Images with a significant cloud cover are eliminated, and advanced cloud/cloud-shadow masking methods are used to keep only clear-sky pixels.

2.3. Fractional Vegetation Cover estimation

Fractional Vegetation Cover (FVC) is an important and sensitive ecological parameter for explaining the variation in vegetation and biomes (Gitelson et al., 2002; Haynes, 2014). The estimation of FVC has tremendous importance for ecological and social structures (Zhang et al., 2013; Shobairi et al., 2018). FVC measures the percentage of a land surface covered by live vegetation. In the context of soil restoration, FVC acts as both a **driver** and an **indicator** of recovery (Niu et al., 2025).

The FVC is computed directly by using NDVI images (Zhang et al., 2013; Shobairi et al., 2018). NDVI is a measure of vegetation greenness calculated from the Sentinel-2 sensor's Near-Infrared (NIR) and Red bands. The NDVI was determined by Eq (1).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \qquad (1)$$

FVC was determined by Eq (2). Where NDVI_soil is the lowest and NDVI_veg is the highest value.

$$FVC = \frac{NDVI - NDVI\_soil}{NDVI\_veg - NDVI\_soil} \qquad (2)$$

2.4. FVC time series analysis

Analysis of time series was determined using data of annual FVC from 2019 to 2024 with Google Earth Engine API through Google-Colab. The choice from 2019 is based on FMNR implementation throughout the project in the study area. Practically, 2019 stands for the baseline for ICRISAT's intervention while 2024 represents the endline. The FVC of both years were calculated and reclassified into three categories:

- Category 1 = Low FVC (FVC value < 20^{th} percentile)
- Category 2 = Medium FVC (20% ≤ FVC value < 70^{th} percentile)
- Category 3 = High FVC (FVC value ≥ 70^{th} percentile)

The reclassified FVC images were then compared using change detection approaches. This consisted in subtracting the baseline FVC (2019) from the recent year FVC (2024). The classes areas were calculated and compared as well.

3. Results

3.1. Fractional Vegetation Cover for 2019

The 2019 FVC map for Magaria typically depicts a landscape under significant climatic stress and unsustainable management practice, reflecting the severe drought and degraded conditions of that year. The map is dominated by low FVC values, often ranging between 0.0 and 0.2 (0%–20% coverage). The

Northern/Central Magaria displays large, contiguous blocks of “extremely low” to “low” vegetation cover. These areas appear as broad swaths of bare soil or sparse grasslands. In the south, narrower bands of light green (FVC 0.3 – 0.4) appear near the border with Nigeria, indicating slightly higher moisture retention or denser shrublands. The small, isolated green dots (higher FVC) are separated by vast areas of low-reflectance land, indicating patchy growth or significant deforestation activities. Sparse green lines may follow the Korama River tributaries, though these are significantly thinner and less intense than in wet years.

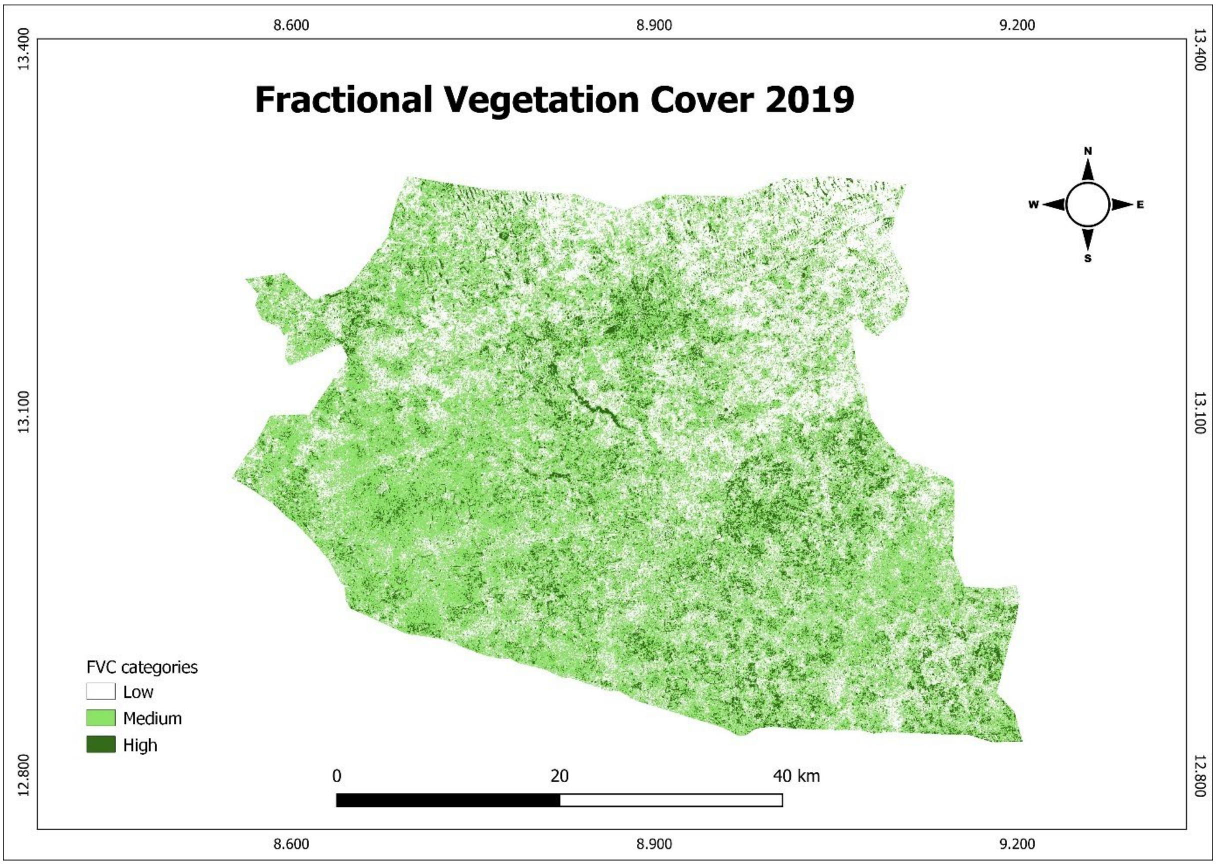
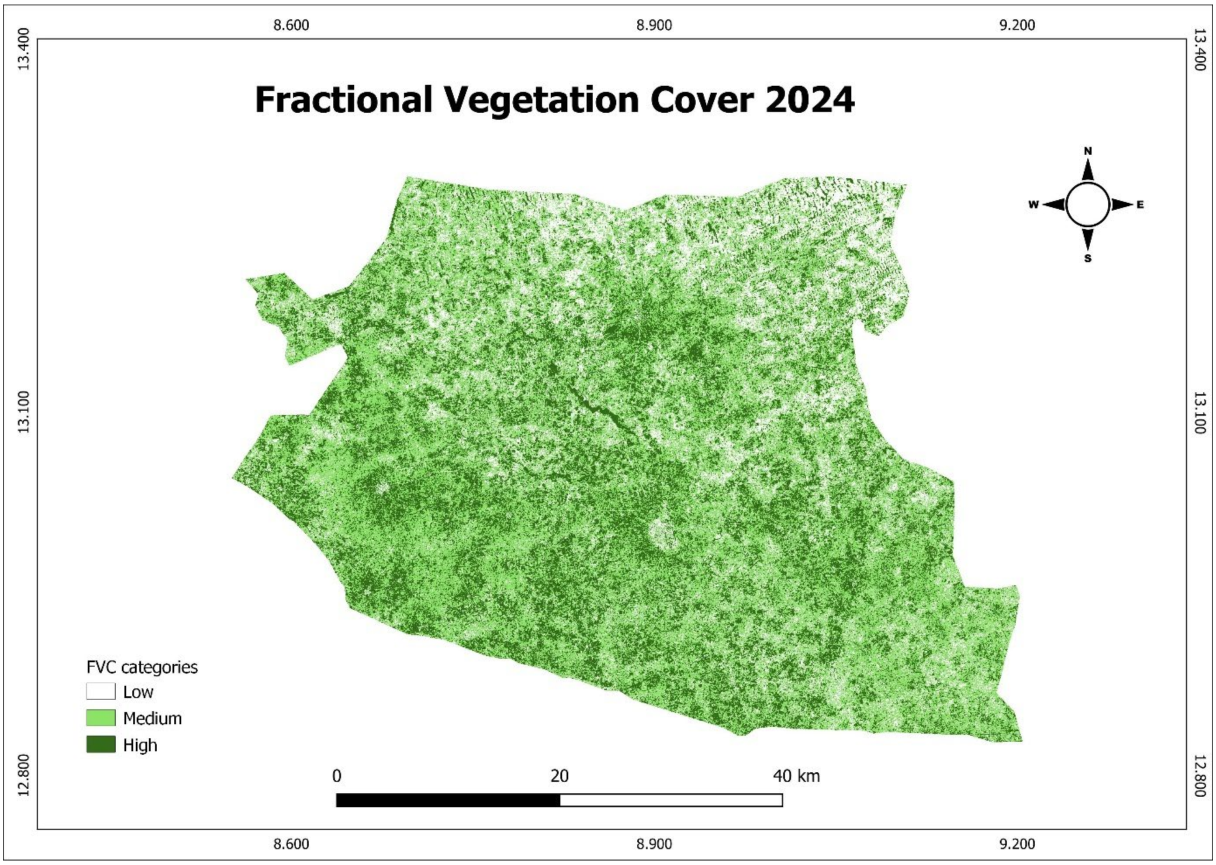


Figure 2:

3.2. Fractional Vegetation Cover for 2024

The 2024 FVC map reflects a year of record-breaking rainfall and expanded FMNR practice areas, resulting in a significantly different visual signature. The map shifts toward a cool/vibrant palette (greens and deep greens). Large portions of the commune show FVC values in the 0.5 to 0.8 range (50%–80% coverage). The previously bare northern and central regions are now overlaid with broad "carpets" of light and medium green. Areas surrounding the Korama watershed and low-lying valleys (bas-fonds) show the highest intensity of dark green, marking important shrubby and woody growth. The map appears more homogenous and “smooth” than the 2019 version. The previous fragmentation is replaced by large, interconnected blocks of vegetation.



3.3. FVC changes between 2019 and 2024: Physical attributes

The following table provides a comparison of the spatial distribution of Fractional Vegetation Cover (FVC) in Magaria, Zinder, for the years 2019 and 2024.

Table 1:

Feature	2019 Map Characteristics	2024 Map Characteristics
Dominant Color	White (Low FVC)	Green (High FVC)
Texture	Speckled, fragmented	Broad, continuous blocks
Coverage Range	Mostly 0.1 – 0.3	Mostly 0.4 – 0.7
Visible Hydrography	Faded or invisible	Highly pronounced green corridors

3.4. Comparative distribution of FVC (2019 vs. 2024)

The following table provides a comparison of the spatial distribution of Fractional Vegetation Cover (FVC) in Magaria, Zinder, based on the pixel-count characteristics of the year 2019 and the year 2024.

Table 2:

FVC Class (%)	Description	2019 Area Share (Km^2)	2024 Area Share (Km^2)	Visual Change
1	Bare Soil / Extremely Sparse	875.04	471.08	Drastic reduction in bare soil (white colour).
2	Moderate Coverage	1412.92	1352.40	Shift of land from “sparse” to “moderate” density. Dominant class in 2024; vast “green carpet.” Significant FMNR adoption
3	Dense Vegetation	241.03	705.51	Expansion of riparian and FMNR zones.

4. Conclusion and Recommendations

The results indicate that Magaria’s “greening” in 2024 is a direct result of the persistent efforts by local communities, who have been trained and sensitized to expand Farmer-Managed Natural Regeneration (FMNR). While the sparse vegetation of 2019 reflected an unsustainably managed landscape – where much of the map appeared “white” due to low cover – the resilient patches of green that survived that year were almost exclusively FMNR sites. These trees, supported by an "underground forest" of deep, mature root systems, were able to tap into groundwater reserves inaccessible to annual crops and grasses. In contrast, the expansive green cover seen in 2024 is largely composed of “opportunistic” annual vegetation. Without the structural anchoring provided by FMNR trees, this cover will rapidly disappear during the next dry cycle, leaving the soil exposed to the intense wind erosion that typically follows heavy flooding. Currently, Magaria is in a “Rapid Recovery Phase.” The transition from the fragmented patches of 2019 to the continuous cover of 2024 proves that the biological potential for restoration is alive in the soil; however, this potential requires systematic, long-term management to transform temporary seasonal flushes into permanent landscape features.

Recommendations

- **Protect Gains:** Use the current moisture surplus to accelerate the pruning and protection of new FMNR sprouts. These “opportunistic” trees must be managed now to ensure they survive the next inevitable drought cycle.
- **Incentivize Persistence:** Shift policy focus from “reforestation” (planting) to “protection” (management) by strengthening tree tenure rights for local farmers. Promote the implementation of FMNR 2020 Presidential Decree and its harmonization at the local level.
- **Integrated Infrastructure:** Combine biological FMNR with physical water-harvesting structures (half-moons/stone bunds) to maximize the “Islands of Fertility” effect identified in the FVC maps.
- **Conduct ground measurements:** support remote sensing data with soil properties analysis to generate and strengthen ground truth evidence.

Citation:

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About CGIAR Sustainable Science Program Report

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© Photo FMNR field in Niger (Bouba Traore)

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FMNR, Soil health, Fractional Vegetation Cover, Magaria

Partners

CRS, DGDT, IRC

About CGIAR Sustainable Farming Science Program

The CGIAR Sustainable Farming Science Program will address key challenges in agrifood systems by fostering efficient production of nutritious foods and safeguarding the environment to create fair employment opportunities, as we simultaneously tackle climate change, soil degradation, pests, diseases, and desertification.

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