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Endogenous practices for soil fertility management in the Niakhar observatory, south of the Senegalese Groundnut Basin

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Abstract

Soil degradation is a major threat to agriculture in sub-Saharan Africa. In the Senegalese Groundnut Basin, this phenomenon particularly compromises the food security of rural populations. This study aims to evaluate endogenous soil fertility management practices in the Niakhar observatory, a representative area of the southern Senegalese Groundnut Basin. The methodology is based on an in-depth survey conducted in September 2024 among 300 farmers selected at random from the 30 villages of the study area (10 farmers per village). The results reveal six main fertility management practices, often combined by farmers: spreading organic manure (25%), millet-groundnut crop rotation (23%), mineral fertilisation (23%), Assisted Natural Regeneration (ANR) of Faidherbia albida (8%), fallow land (5%) and animal grazing (13%). Comparative analysis shows that combined organo-mineral fertilisation is perceived by 52% of farmers as the most effective method for maintaining soil fertility and improving productivity, compared with 34% and 14% for organic and mineral fertilisation respectively. Crop rotation between millet and groundnuts, combined with ANR of Faidherbia albida, helps maintain fertility by providing nitrogen from legumes and increasing the organic matter content of the soil through improved vegetation cover. This study demonstrates the effectiveness of traditional agroecological practices and suggests their integration into sustainable agricultural development programmes. It also recommends strengthening synergies between endogenous knowledge and technical innovations for greater resilience of Sahelian agricultural systems.

Keywords : *endogenous practices, soil management, soil fertility, agroecology, groundnut basin, niakhar observatory, faidherbia albida, soil degradation.*

Résumé

Évaluation des pratiques endogènes de gestion de la fertilité des sols dans l'observatoire de Niakhar, au sud du bassin arachidier sénégalais

La dégradation des sols constitue une menace majeure pour l'agriculture en Afrique subsaharienne. Dans le Bassin arachidier du Sénégal, ce phénomène compromet particulièrement la sécurité alimentaire des populations rurales. Cette étude vise à évaluer les pratiques endogènes de gestion de la fertilité des sols dans l'observatoire de Niakhar, une zone représentative du Sud du bassin arachidier sénégalais. La méthodologie s'appuie sur une enquête approfondie menée auprès de 300 paysans, sélectionnés aléatoirement dans les 30 villages de la zone d'étude (10 exploitants par village), en septembre 2024. Les résultats révèlent six pratiques principales de gestion de la fertilité, souvent combinées par les paysans : l'épandage de fumure organique (25%), la rotation culturale mil-arachide (23%), la fertilisation minérale (23%), la Régénération Naturelle Assistée (RNA) de Faidherbia albida (8%), la jachère (5%) et le parcage des animaux (13%). L'analyse comparative montre que la fertilisation organo-minérale combinée est perçue par 52% des paysans comme la méthode la plus efficace, contre respectivement 34% et 14% pour la fertilisation organique et minérale. La rotation culturale mil-arachide, associée à la RNA (Faidherbia albida), permet de maintenir la fertilité par l'apport d'azote des légumineuses et l'augmentation de la teneur en matière organique du sol. Cette étude démontre l'efficacité des pratiques agroécologiques traditionnelles et suggère leur intégration dans les programmes de développement agricole durable. Elle recommande également le renforcement des synergies entre savoirs endogènes et innovations techniques pour une meilleure résilience des systèmes agricoles sahéliens.

Mots-clés : *pratiques endogènes, gestion des sols, fertilité des sols, agroécologie, bassin arachidier, observatoire de niakhar, faidherbia albida, dégradation des sols.*

1. Introduction

Soil degradation is a major challenge for countries in the Global South, where socio-economic development relies heavily on the agricultural sector [1]. This phenomenon, which manifests itself through a decline in soil fertility, compromises the performance of family farming and leads to poverty and food insecurity. As highlighted by CCR/PFBC [2], land degradation in Central Africa has led to a decline in soil fertility and exacerbated rural poverty. This decline is often linked to agricultural production models favouring intensive use of synthetic fertilisers and heavy exploitation of crop residues, hindering the natural restoration of cultivated soils [3]. Senegal's groundnut basin, characterised by predominantly family-based agriculture, is no exception to this problem [4]. The area is experiencing 'soil fatigue' (the depletion of soil under intensive and prolonged agricultural exploitation). Population growth puts increasing pressure on natural resources, confirming Malthus' theory of resource degradation [5]. This has led to the scarcity of fallow land and livestock grazing, practices that traditionally supported soil fertility [6]. Faced with insufficient state subsidies for chemical fertilisers, farmers also experience a 'human fatigue', forced to invest their meagre resources in the purchase of inputs. In this context, farmers are turning to more accessible and sustainable practices to manage their soil fertility. The evaluation of these endogenous practices is therefore essential to measure their impact on agricultural yields and soil fertility improvement. It is in this perspective that the present study aims to evaluate endogenous soil management practices in the southern part of the groundnut basin, particularly in the Niakhar observatory area.

2. Material and methods

2-1. Presentation of the study site

The groundnut basin, located in central Senegal, is a major ecogeographical region known for its significant agricultural contribution, mainly through groundnut production [7]. Spanning several administrative areas (Fatick, Diourbel, Kaolack, Kaffrine, Thiès and part of Louga), it is characterised by a Sudano-Sahelian climate with annual rainfall between 500 and 800 mm distributed over June to October, and a long dry season from October to May [8, 9]. The southern part of the Groundnut Basin includes the administrative regions of Fatick, Kaolack and Kaffrine. These regions present a relatively flat terrain with typical wooded savannah landscape and vegetation composed of shrubs and scattered trees providing partial cover that protects soils against wind and water erosion [10]. Temporary watercourses play an essential role in recharging groundwater and regenerating soils. The soils of this area are mainly sandy-clay and clay in texture predominantly tropical ferruginous soils, leached or slightly leached [11]. Although well-suited to crops such as peanuts and millet, they present constraints including low water retention, low fertility and acidity. Hydromorphic soils subject to flooding and halomorphic soils with high salt content further limit agricultural use [12]. The Niakhar Observatory, founded in 1962 in a rural area 150 km from Dakar in the Serer region, is the oldest population observatory in Africa still in operation [15 - 17]. It comprises 30 villages spread across the communes of Ngayokhème and Diarrere. See ***Figure 1*** for the location of the study area.

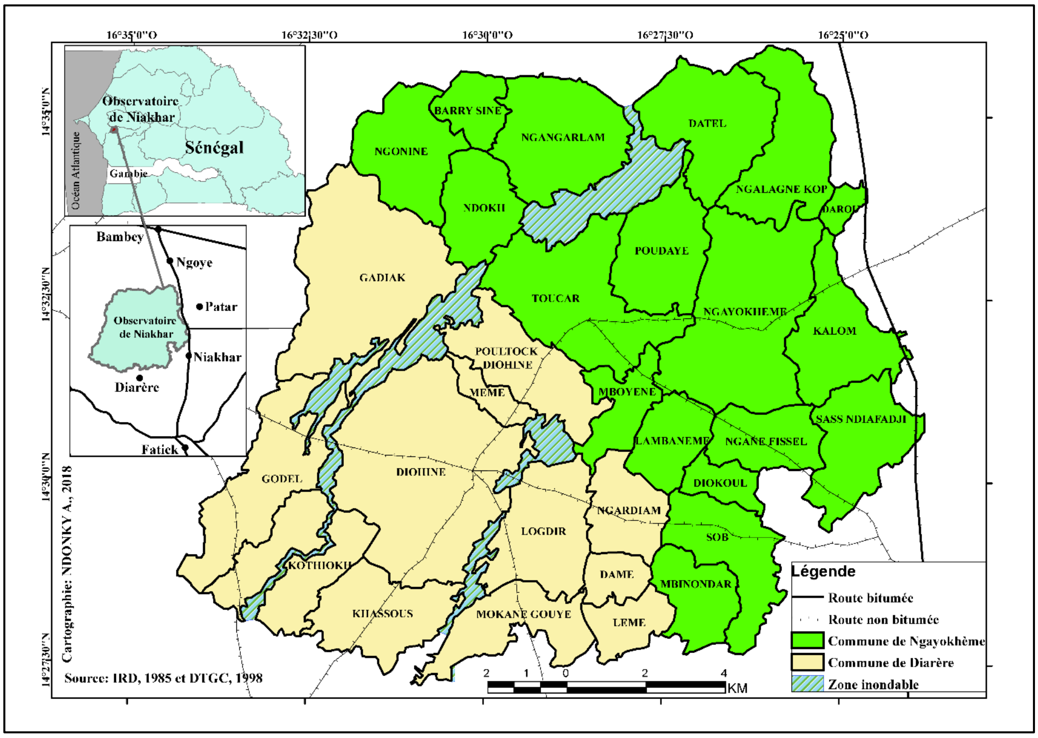

Figure 1 : *Location of the study area* [17]

2-2. Data collection

The survey was conducted in September 2024 among 300 farmers in 30 villages of the communes of Ngayokhème (18 villages) and Diarère (12 villages). In each village, 10 farmers were interviewed to ensure uniform and balanced distribution of information. A 10% sampling rate was considered sufficient to reflect the diversity of agricultural practices while remaining economically and logistically feasible. Farmers were selected taking into account sociodemographic factors such as age, agricultural experience, types of soils cultivated and crops practised, ensuring representative perceptions of agricultural practices. A 76-question semi-structured questionnaire was used to collect data on: soil management practices, types of soil amendment or fertilisation, types of crop rotation, fallow periods, species favoured in Assisted Natural Regeneration (ANR) practices, and associated yields. In addition to questionnaire surveys, interviews were conducted with village chiefs, the Niakhar rural agricultural advisory officer, and heads of the water, forestry, hunting and soil protection departments. Direct field observations and photographic documentation complemented the primary data.

2-3. Data processing

Data were entered and analysed using Excel software. The relative frequency of each practice was calculated using the following ***Formula*** :

$$Fi\ (\%) = (\frac{ni}{N}) \times 100 \tag{1}$$

Where Fi is the relative frequency of practice i; ni is the number of farmers practising technique i; and N = 300 is the total number of farmers surveyed. This approach is standard in ethno-pedological surveys [41]. Automatic tabulation classified responses and calculated relative frequencies. Graphs were generated to visually represent results. The declarative nature of survey data introduces subjectivity limitations.

3. Results

3-1. Endogenous soil management practices

The adoption of endogenous soil management practices is widespread: 99% of farmers adopt at least one soil fertility management practice ***(Figure 2)***. This near-universal adoption demonstrates that farmers are primary actors in soil management initiatives. Among the practices identified, organic manure application is practised by 25% of farmers, crop rotation by 23%, mineral fertilisation by 23%, animal grazing by 13%, ANR by 8%, fallow land by 5% and phosphating by 3% ***(Figure 3)***. These three dominant practices account for 71 % of strategies deployed, reflecting a pragmatic rationality in the face of resource availability constraints. Organic manure application is the most prevalent practice due to the local availability of organic matter sources: household organic waste, domestic animal manure and fodder residues. It improves soil organic matter content ***(Figure 4)***. Crop rotation (23%) is mainly practised in bush fields with annual alternation of millet, groundnuts and sometimes fallow land. Mineral fertilisation (23%) is used primarily through NPK fertilisers and urea during the growing season. The low adoption of fallow land and animal grazing is linked to the lack of agricultural space due to demographic pressure and the decline in livestock numbers. ANR is limited by difficulties in protecting regenerated species from stray livestock and firewood exploitation.

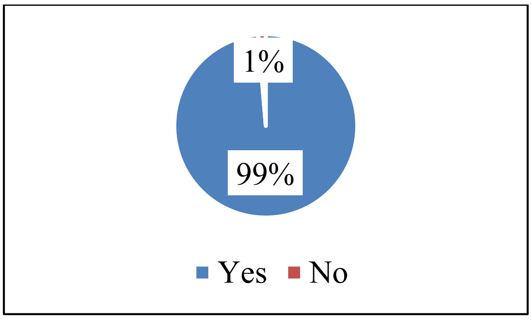

Figure 2 : *Level of adoption of soil fertility management practices by farmers*

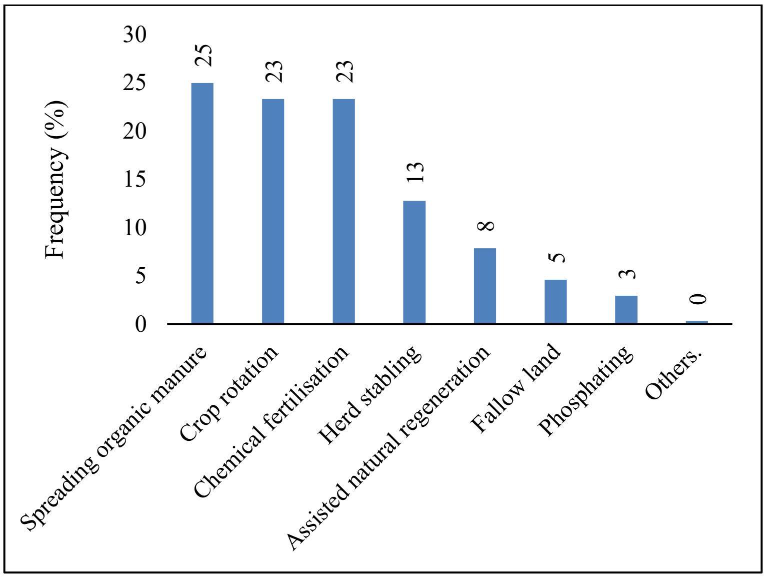

Figure 3 : *Farmers' perceptions of soil fertility management practices*

Figure 4 : *Organic manure heap in a field (Source : Sene, September 2024)*

3-2. Assessment of soil management practices

3-2-1. Fertilisation and soil amendment

Soil amendment and fertilisation are two key practices in fertility management. Soil amendment involves adding organic or mineral matter to improve the physical, chemical and biological properties of the soil [18]. Fertilisation aims to provide nutrients to improve crop growth and yield [19]. Results in ***Figure 5*** shows three types of amendments and fertilisers : organic amendments (37%), mineral amendments (33%) and organo-mineral amendments (30%). Organic amendments dominate due to the availability of household waste, animal manure and crop residues. Mineral inputs remain limited and expensive for smallholder farmers.

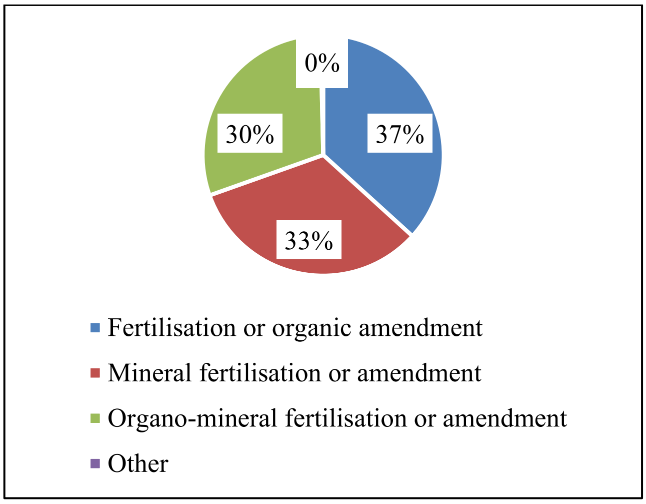

Figure 5 : *Farmers' perceptions of types of soil amendments and fertilisers*

3-2-2. Sources of fertilisers and soil improvers

Analysis of ***Figure 6*** reveals greater availability of organic fertiliser sources than mineral ones. Organic fertilisation relies mainly on household waste (26.47%), animal manure (26.20%), crop residues (15.58%), animal grazing (13.93%), cattle feed (5.90%) and composting (2.21%), representing 91.41% of total sources ***(Figure 7)***. Mineral soil improvers, mainly commercial agricultural inputs (9.32%), are used less frequently. This predominance of organic sources reflects both the economic constraints of farmers and the cultural heritage of Serer farming systems, which have traditionally relied on crop-livestock integration for soil fertility management.

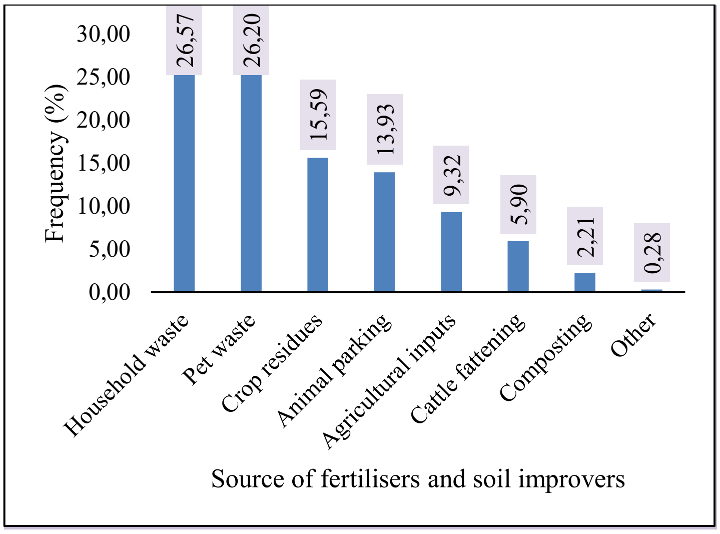

Figure 6 : *Farmers' perceptions of different sources of fertilisers and soil amendments*

Figure 7 : *Sources of organic manure : A: night grazing ; B : household waste and manure ; C : crop residues (Source : Sene, September 2024)*

3-2-3. Effectiveness of soil amendments and fertilisers

According to producers, organo-mineral amendments (52%) are perceived as the most effective method, compared to organic (34%) and mineral (14%) amendments alone ***(Figure 8)***. The integration of organic matter into chemical fertilisers improves soil structural stability, water and nutrient retention capacity, and helps regulate soil pH, optimising the effectiveness of mineral fertilisers [20]. Organic fertilisation alone (34%) is valued for its long-term restorative effects on soil organic and biological properties. In contrast, mineral fertilisation alone (14%), although providing rapid nutrient supply, is widely perceived by farmers as contributing to long-term soil fertility degradation; consistent with observations of accelerated acidification under exclusive mineral fertilisation in comparable Sahelian environments. Organo-mineral amendments, combining the advantages of both organic and mineral inputs, emerge as the preferred practice. This combination, associated with crop rotation, represents the most promising integrated approach for sustainable soil management in the study area.

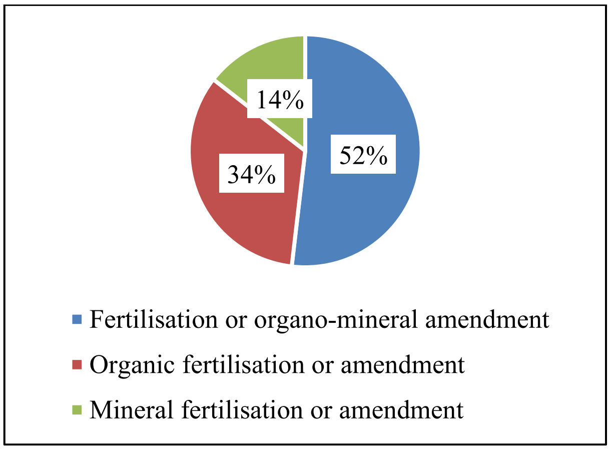

Figure 8 : *Farmers' perceptions of the effectiveness of different types of soil amendments and fertilisers*

3-2-4. Crop rotation

Crop rotation involves alternating crops on a plot from one year to the next [21]. In the study area, biennial rotation (millet-groundnut) is the most common, followed by triennial rotation incorporating fallow periods ***(Figure 9)***. Results in ***Figure 10*** show that yields vary by succession type. In millet-groundnut succession: groundnut yield after millet is rated good by 56.11%, very good by 35.29% and average by 8.6% of farmers. Millet yield is rated good by 57.47%, very good by 26.44%, average by 14.94% and poor by 1.5%. In fallow-millet succession, millet yield is rated good by 48%, very good by 30% and average by 22%. In fallow-groundnut succession, groundnut yield is rated good by 50.73%, very good by 44.88% and average by 4.39%. The higher proportion of very good ratings for fallow-groundnut (44.88%) versus fallow-millet (30%) confirms the synergistic effect of combining restorative fallow with the nitrogen fixation capacity of groundnuts. The fallow-groundnut-millet rotation is therefore the most optimal sequence for sustainably increasing agricultural yields in the area.

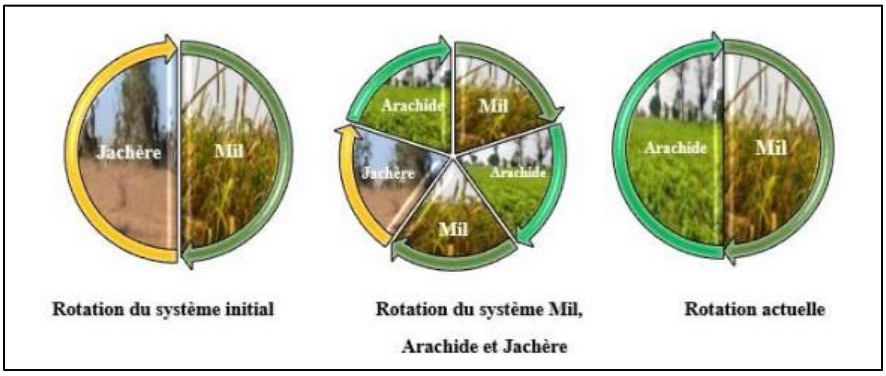

Figure 9 : *Evolution of crop rotation over time* [12]

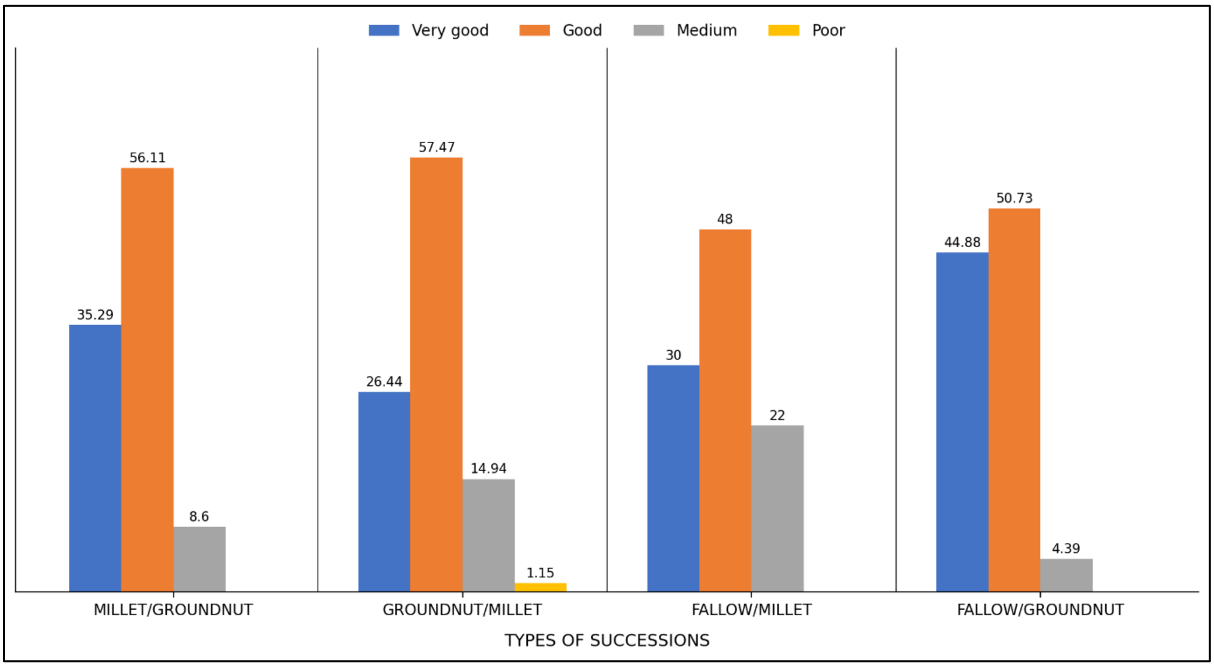

Figure 10 : *Farmers' perceptions of the impact of crop succession types on agricultural yields*

3-2-5. Fallow land

Fallow land involves leaving soil to rest for a period to restore its fertility. In the study area, fallow periods have shortened dramatically: from long-term fallow (10 to 15 years) to 1-3 years, and even complete abandonment by some farmers ***(Figure 11)***. The results ***(Figure 12)*** reveal that one-year fallow periods are overwhelmingly the most common (91%), seriously questioning their effectiveness in restoring soil fertility. Two-year fallows (7%) and five-year or longer fallows (2%) are rare, highlighting the need to introduce improved fallow techniques combined with ANR and regulated herd grazing.

Figure 11 : *Vast expanse of fallow land in the Diohine terroir (Source: Sene, June 2025)*

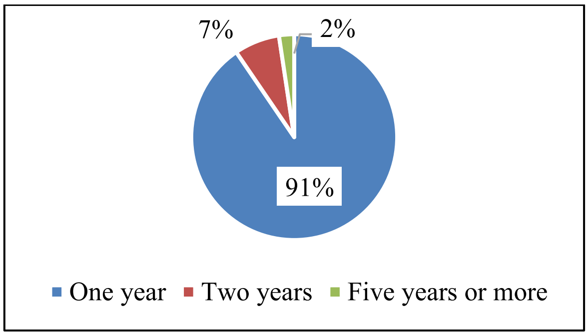

Figure 12 : *Farmers' perceptions of the duration of the fallow period*

3-2-6. Assisted Natural Regeneration (ANR)

Assisted Natural Regeneration (ANR) involves protecting and managing small trees and natural regrowth to improve vegetation cover. This practice is based on the selection of trees beneficial to the environment, that improve soil fertility and coexist harmoniously with crops. Farmers actively promote species including Faidherbia albida (kadd or sass), Guiera senegalensis (ngoond), and Combretum micranthum (Ndaague), among others. ***Figure 13*** shows that Faidherbia albida (73%) is the dominant species chosen by farmers. Faidherbia albida plays a key role in maintaining soil fertility through its inverted vegetative cycle: it releases nitrogen-rich leaves during the rainy season, increasing soil nitrogen content and allowing maximum sunlight to reach crops. During the dry season, its foliage provides shade for livestock and its pods attract animals, generating organic matter through their droppings ***(Figure 14)***. Farmers therefore state that 'a field with seven Faidherbia albida trees is capable of producing a granary of millet'. Guiera senegalensis (7.67%) and Combretum micranthum (5.67%) are also targeted in ANR practices ***(Figure 13)***. These shrubs play an important role in protecting soils against erosion and also possess recognised medicinal properties. According to farmers, ANR plays an important role in soil management because it is a source of organic matter (38.22%), improves vegetation cover (32.23%), stabilises the soil (19.21%) and serves as a windbreak (7.02%) ***(Figure 15)***. The contribution of organic matter is made possible by improved vegetation cover, which provides the soil with litter through dead leaves and branches. This litter decomposes into humus, which binds to mineral clays and forms the clay-humus complex. By maintaining the C/N ratio balance in the soil, ANR enables farmers to combat both water and wind erosion sustainably.

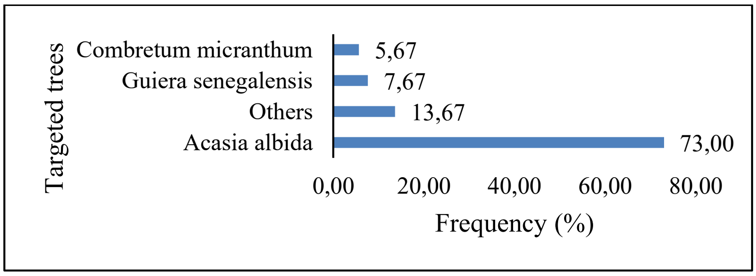

Figure 13 : *Farmers' perceptions of the main regenerated tree species*

Figure 14 : *Reverse cycle of Faidherbia albida : (A) dry season and (B) rainy season (Source : Sene, September 2024)*

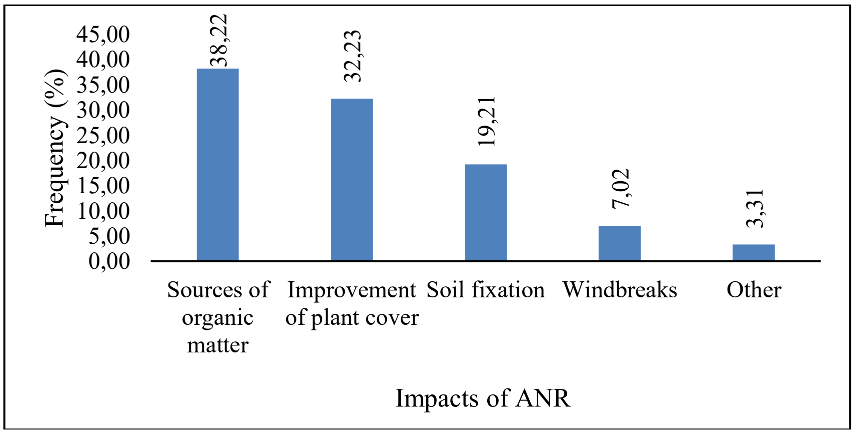

Figure 15 : *Farmers' perceptions of the impacts of ANR on soil fertility*

4. Discussion

4-1. Organic and organo-mineral fertilisation

The results demonstrate significant adoption of endogenous soil fertility management practices (99 % of farmers). These practices are fundamental for maintaining agricultural productivity in a context of soil degradation and limited resources. Organic fertilisation is the most widely used method (25%). This trend is consistent with observations from other arid and semi-arid regions of West Africa [22, 23]. Ganry and Laurent [24] confirm that organic matter governs the cation exchange capacity of soils, strengthening their resilience. The local availability of organic matter makes it a preferred input for smallholder farmers due to its low cost compared to chemical fertilisers [25]. Furthermore, 52% of farmers consider organo-mineral fertilisation the most effective method for improving soil fertility. This preference is corroborated by Ndiaye [26] in Casamance, and by Ngoun et al. [27], who demonstrate that organic amendments produce better results when combined with mineral fertilisers. Koumbem et al. [28] further establish that soil cultivation combined with organo-mineral fertilisation optimises agricultural productivity. The low perceived effectiveness of mineral fertilisation alone (14%), despite its wide adoption (23%), reveals a critical gap: farmers adopt mineral fertilisation for its short-term yield response while recognising its long-term detrimental effects on soil structure. This has important implications for fertilisation subsidy programmes focused exclusively on mineral inputs.

4-2. Crop rotation and fallow land

Crop rotation (23%) remains a widespread practice. Research in Niger, Benin and Senegal confirms that succession of cereals and legumes promotes soil nitrogen regeneration while improving yields [29, 30]. The high proportion of very good yield ratings for fallow-groundnut succession (44.88%) confirms the synergistic combination of restorative fallow and biological nitrogen fixation by groundnuts. However, demographic pressure leads to a worrying reduction in fallow periods. With 91% of farmers limiting fallow to one year, the restorative capacity of this practice is severely compromised. Duponnois [31] confirms that this reduction hinders the natural recovery of soils. Hien et al. [32] demonstrate that even a three-year fallow period does not systematically result in significant fertility improvements in ferruginous tropical soils, suggesting effectiveness depends not only on duration but also on vegetation management during the resting period. This progressive marginalisation of fallow calls for the urgent promotion of improved fallow techniques, combining ANR, targeted seeding of nitrogen-fixing species and regulated grazing management, to restore soil biological and chemical functions without requiring land area no longer available in densely populated landscapes [35].

4-3. Assisted Natural Regeneration

The adoption of ANR, particularly with Faidherbia albida (73%), constitutes a key finding consistent with observations from other Sahelian regions. Reij et al. [33] highlight the essential role of ANR in combating deforestation and restoring vegetation cover. Zounon et al. [34] demonstrate that species in fields under ANR contribute significantly to soil fertility improvement through their biomass. In the study area, the impact of ANR is amplified by indigenous species with differentiated contributions to soil enrichment, aligned with the Great Green Wall initiative [35]. The recognition of Faidherbia albida's agronomic properties by farmers long before their scientific confirmation illustrates the depth of endogenous ecological knowledge [41]. ANR enables sustainable combat against both water and wind erosion; a crucial issue in a context of climate variability [38].

4-4. Structural constraints and policy implications

While near-universal adoption (99%) signals strong farmer motivation, it conceals significant disparities in implementation intensity. The structural constraints of family farming (plot fragmentation, limited financial capital and erosion of social cohesion structures) limit the scaling of individual practices to a level generating measurable soil fertility improvements [4]. Endogenous practices in sub-Saharan Africa reduce dependence on chemical inputs while preserving long-term soil fertility, thereby contributing to poverty reduction and food security [36, 37]. The absence of effective agricultural extension systems hinders the adoption of improved or integrated practices [45]. Without ongoing support to combine local knowledge with modern agronomic approaches, endogenous practices remain unable to respond adequately to climate change and demographic pressure [46]. Agricultural training structures that value farmers' knowledge rather than standardising technical prescriptions are better positioned to catalyse the transition to resilient production systems [47]. Diouf [39] and the FAO [40] argue that incentives for the adoption of agroecological techniques are crucial for environmentally friendly agriculture that simultaneously improves soil resilience and supports increased agricultural yields. Integrating endogenous practices into inclusive agricultural policies combining local knowledge with scientific innovations is an essential pathway for sustainable soil management and food security [49].

5. Conclusion

Soil fertility degradation constitutes a major challenge in Senegal's peanut-growing region. In response, farmers of the Niakhar observatory have developed a diverse portfolio of endogenous practices: organic manure application, crop rotation, mineral fertilisation, fallow land, animal grazing and Assisted Natural Regeneration. The results highlight several key findings: organic fertilisation, favoured by local resource availability, is the main soil improvement method; the organo-mineral approach is perceived as the most effective (52%); biennial millet-groundnut rotation plays a crucial role in soil nitrogen enrichment; and ANR through Faidherbia albida contributes significantly to improving vegetation cover and restoring soil fertility. This study opens several important perspectives: further quantitative analysis of long-term impacts on soil properties; development of extension programmes specifically integrating endogenous practices; and integration of these practices into national agroecology promotion strategies. Strengthening synergies between endogenous knowledge and scientific innovations remains an essential lever for improving the resilience of Sahelian agricultural systems. These results underscore the importance of participatory approaches in agricultural development policy, enabling the valorisation of local knowledge while addressing the challenges of sustainability and food security in the groundnut basin.

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