

From Structural Vulnerability to Sustainable Intensification: Diagnosis of Perimeter Security Systems and Technological Arbitration of Cassava (*Manihot esculenta* Crantz) Producers in Burkina Faso

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Abstract

Crop protection is a crucial yet underexplored aspect of agricultural systems in Sub-Saharan Africa. This research examines protection methods in *Manihot esculenta* Crantz cropping systems in Burkina Faso. Producers from three regions provided data, which were subsequently examined using descriptive statistics. The analysis reveals a high percentage of unprotected farms (57.7%), indicating a structural reliance on open perimeter systems rather than direct measurements of animal damage or quantitative loss rates. Traditional methods based on local resources, such as cereal and cassava stalks, largely predominate, whereas the integration of contemporary technologies remains restricted. Even though certain regions are beginning to evolve toward more advanced solutions, adoption is heavily hindered by financial constraints, insufficient access to dissemination services, and limited spread of innovations. These findings reveal that the integration of crop protection is still low within production systems. This study helps to better understand the mechanisms of technological adoption and risk management within agricultural systems. The optimization of protection systems stands out as an essential tool to increase productivity, reduce vulnerability, and support the transition to more resilient and sustainable agricultural systems in Sub-Saharan Africa.

Keywords

Crop Protection, *Manihot esculenta*, Technological Adoption, Burkina Faso

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a perennial dicotyledonous plant belonging to the Euphorbiaceae family, native to South America and naturalized in tropical regions for its starchy tuberous roots and high-protein foliage [1]. In the agrosylvopastoral landscape of Burkina Faso, this crop has undergone a structural transformation, establishing itself as a strategic component of resilience in the face of seasonal shifts [2]. Its phenological plasticity, coupled with an intrinsic tolerance to water stress, allows it to express potential yields ranging between 30 and 40 t/ha depending on genotypic performance [3] [4]. However, the optimization of this productivity under real-world conditions is limited by complex biotic and anthropogenic constraints that are often underestimated.

The agronomic paradox of cassava lies in its strategy of maintaining foliage cover during the critical phase of the dry season. While the senescence of cereals (millet, sorghum) and wild grasses drastically reduces fodder availability, cassava persists as one of the few sources of green biomass in village territories [5]. Although the plant synthesizes cyanogenic glucosides as a chemical defense mechanism [6], this protection proves insufficient against livestock pressure. This chlorophyll persistence transforms plots into attractive resource islands, exposing the crop to open-access grazing (*vaine pâture*), a post-harvest free-space management practice in the Sudanian-Sahelian zone [7] [8]. The impact of this animal intrusion directly affects plant physiology. Repeated browsing induces severe defoliation that disrupts the interception of photosynthetically active radiation and alters carbon remobilization toward storage organs. This imbalance compromises starch accumulation and drastically reduces the harvest index [9]. Beyond the agronomic impact, this phenomenon generates major social externalities. The degradation of social cohesion between farmers and herders is often linked to the scarcity of common resources and inadequate land access rules [10]. The expansion of off-season crops such as cassava mechanically reduces transit corridors and traditional grazing areas, exacerbating the risks of land-use conflicts [11] [12]. Despite the importance of these issues for food security, research in Burkina Faso has primarily focused on varietal selection [13] or post-harvest processing procedures [14]. There is a deficit of scientific knowledge regarding the efficiency of rudimentary physical barriers generally erected by producers to protect their farms. Indeed, securing plots imposes transaction and investment costs that weigh heavily on the gross margin of farming operations. The lack of technical and financial data regarding these protection systems, in the face of widespread standing capital losses linked to open-access grazing, constitutes a major barrier to investment in the value chain.

This study aims to fill this gap by analyzing the dynamics of interactions between cassava cultivation and pastoral pressure in the production zones of Burkina Faso. The objective is to evaluate the adaptation strategies and organizational innovation levers necessary for the sustainable intensification of this sector.

2. Material and Methods

2.1. Study Framework and Agroecological Characterization

The study was conducted along a Sudanian-Sahelian gradient in Burkina Faso, covering three major geographical zones distinguished by their tuber production potential and agropastoral dynamics:

- **South-Sudanian Zone (Djôrô Region):** Provinces of Poni and Ioba. Characterized by an average annual rainfall of $P > 900$ mm, this zone offers a long cropping cycle favorable to tuberization (analytic sample $n = 31$ producers).
- **Sudanian Zone (Guiriko Region):** Provinces of Houet and Kénédougou. A true diversification hub, it integrates orchard systems and cash crops (analytic sample $n = 39$ producers).
- **Transition Zone (Tannouyan Region):** Province of Comoé. This zone is distinguished by a high density of artisanal processing units (*attiéké, gari*), inducing constant pressure on the fresh root supply (analytic sample $n = 41$ producers).

2.2. Sampling Design and Inclusion Criteria

This study evaluates a purposively selected scope comprising cooperative-affiliated cassava producers exposed to agropastoral conflict across the study zones. Conclusions are strictly scoped to these surveyed cooperative-affiliated cassava producers rather than generalized to all independent national farmers. To structure this selection, a two-stage procedure was applied:

- **First stage:** Purposive selection of 11 cooperative societies (distributed as 3 in Djôrô, 4 in Guiriko, and 4 in Tannouyan), chosen on the basis of their legal recognition, primary activity related to cassava production, functional structuring, and active experience in the value chain.
- **Second stage:** Simple random sampling from cooperative lists initially yielding 100 participants, which, alongside field adjustments and complete responses during the survey period conducted from January to March 2026, resulted in a final analyzed analytic sample of 111 farm plots (31, 39, and 41 respectively per region) with a 100% response rate.

Inclusion criteria required:

- Effective practice of cassava cultivation over at least two consecutive cropping cycles;
- Proven exposure to the risk of agropastoral conflicts linked to animal roaming during the dry season;
- Active demographic profile (17 to 75 years old), allowing for consideration of both the innovation of young farmers and the endogenous knowledge of el-

ders.

Grawitz's approach was applied to minimize selection bias and guarantee the validity of the setup [15].

2.3. Agronomic Diagnosis and Direct Observation

Field surveys were conducted to perform a visual diagnosis of the plots. Observations focused strictly on:

- Architecture of protection systems: Typology and presence/absence of fences and physical barriers.
- Qualitative characterization: Identification of fence materials and recording of perimeter security status across the sampled plots.
- Definition of protected farm and absence of protection
 - **Protected farm:** An agricultural plot subject to active physical investment or anthropogenic management (whether of plant, mineral, or industrial origin) explicitly aimed at preventing the intrusion of free-roaming livestock or predators.
 - **Absence of protection:** A plot lacking any physical fencing device or perimeter barrier, leaving the crop entirely vulnerable to external biotic pressures.
- Typology of protection categories and multi-barrier classification rule: The recorded devices were classified according to a rigorous typology distinguishing industrial materials (wire mesh, black nylon netting, barbed wire), living or dead plant elements (thorny live hedges, sisal, dry cereal or cassava stalks), and earthen structures (pisé walls or earth brick walls).
- Classification rule in case of combination: To avoid double counting and ensure the uniqueness of the dependent variable per surveyed cultural unit, when a single plot combined multiple types of barriers (e.g., a combination of cassava stalks and plant weaving), the classification retained the predominant barrier system (determined by the covered area or the structural resistance level visually assessed during the agronomic diagnosis).

2.4. Ethical Considerations and Informed Consent

The conduct of this study strictly adhered to research ethics principles. Prior to each interview or plot diagnosis, an informed consent protocol was administered orally in the local Dioula language, as well as in French. Producers were informed of the strictly academic purpose of the study and the total anonymization of collected data. No financial incentives were offered to ensure the sincerity of statements.

3. Data Processing and Statistical Analysis

The SPHINX V.5 software was used to create the questionnaire. Collected data were analyzed using SPSS Statistics 20.0 software. Data processing relied on descriptive statistical analysis applied to quantitative data to characterize regional

trends in agricultural resilience.

4. Results

Field survey results showed high heterogeneity in cassava farm protection practices across the three regions: Djôrô, Guiriko, and Tannouyan, within the scope of the surveyed cooperatives. **Table 1** shows the distribution of different cassava crop protection practices. A wide disparity in protection methods exists across the three regions of Burkina Faso, along with a very uneven organization of technical options. The survey reveals that among the 111 surveyed farms, 64 have no protection measures in place, representing 57.7% of the sample. This predominance demonstrates a structural vulnerability in the analyzed cassava agricultural protection systems, in a context where safeguard mechanisms are crucial to minimize damage caused by pests, stray animals, or various rural invasions. Protected farms (42.3%) rely essentially on simple and accessible methods, mainly based on live hedges. Results by region highlight distinctly different protection profiles.

In the Djôrô zone, protection conditions are markedly better as no farm is unprotected (0%). Data analysis reveals a predominance of cereal stalk fences (41.9%) (**Figure 1**), followed by cassava stalk fences (22.6%) (**Figure 2**). Other methods remain uncommon but varied: earth wall (12.9%) (**Figure 3**), sisal (9.7%) (**Figure 4**), wire mesh (6.5%) (**Figure 5**), and thorny plants and barbed wire (3.2% each). In this region, the use of accessible local resources is widely adopted by producers.

In the Guiriko region, 87.2% of farms (34 out of 39) benefit from no protection. Uncommon devices observed include wire mesh (7.7%), barbed wire (2.6%), and thorny plants (2.6%), while all other methods are entirely nonexistent. In this region, these results denote limited investment capacity, restricted access to protection means, or the absence of a perceived need to protect crop fields in the face of varying animal roaming episodes. The near-total absence of plant or traditional solutions, unlike Djôrô, also highlights a lack of integration of endogenous security practices.

The Tannouyan region is at an intermediate level, with 73.2% of farms benefiting from no protection (30 out of 41 farms). However, this region is characterized by a higher use of black nylon netting (17.1%) (**Figure 6**), as well as wire mesh (7.3%) and barbed wire (2.4%). A gradual use of more contemporary materials is observed, even though their integration remains restricted in volume and model. A total absence of plant-based practices (such as the use of cereal or cassava stalks) also indicates increased dependence on purchased materials.

Comparative analysis of the different methods indicates that plant-based solutions (cereal and cassava stalks) are extensively practiced in the Djôrô region, constituting over 60% of methods used there. Conversely, modern approaches (mesh and nylon) are scarce and more frequently observed in the Tannouyan region, with a marginal presence in Guiriko.

These findings show a marked disparity in the adoption of agricultural protection technologies for cassava fields among the evaluated sample.



Figure 1. Dry millet stalk fencing in Ouatinaow, Djôrô region.



Figure 2. Dry cassava stalk fencing in Ouatinaow, Djôrô region.



Figure 3. Earthen wall associated with a trench in Gourpwô, Djôrô region.



Figure 4. Sisal fence in Ouatinaow, Djôrô region.



Figure 5. Wire mesh fencing in Ouatinaow, Djôrô region.



Figure 6. Black nylon mesh fencing in Takalé-kôkô, Tannouyan region.

Table 1. Distribution of different cassava crop protection practices.

Regions	Metal wire mesh	Black nylon netting	Barbed wire	Thorny plants	Sisal	Cereal stalk fence	Cassava stalk fence	Earth wall	No protection	TOTAL
Djôrô (n = 31)	2 (6.5%)	0 (0%)	1 (3.2%)	1 (3.2%)	3 (9.7%)	13 (41.9%)	7 (22.6%)	4 (12.9%)	0 (0%)	31 (100%)
Guiriko (n = 39)	3 (7.7%)	0 (0%)	1 (2.6%)	1 (2.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	34 (87.2%)	39 (100%)
Tannouyan (n = 41)	3 (7.3%)	7 (17.1%)	1 (2.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	30 (73.2%)	41 (100%)
TOTAL (N = 111)	8 (7.2%)	7 (6.3%)	3 (2.7%)	2 (1.8%)	3 (2.7%)	13 (11.7%)	7 (6.3%)	4 (3.6%)	64 (57.7%)	111 (100%)

5. Discussion

The study highlighted heterogeneity in protection methods for *Manihot esculenta* Crantz farms, characterized by a predominance of unprotected farms (57.7%) across the three regions of Burkina Faso. This reflects vulnerability in cassava production against pressures such as animal roaming. This situation confirms recent trends observed in Sub-Saharan Africa, where agricultural systems remain dominated by low-investment strategies heavily dependent on economic and institutional constraints [16].

The importance of traditional methods, such as barriers made of cereal and cassava stalks, demonstrated the prominent place of internal approaches in risk management. These methods align with a constrained optimization approach, where

producers prioritize locally available resources. Akanmu indicates that local resources remain a dominant trait of agricultural systems in Africa, in connection with constraints on access to financing, technologies, and information [17]. However, even when available, the impact of these solutions is often restricted and ephemeral, raising questions about their viability amid growing tension over natural resources. According to research conducted in Burkina Faso, the adoption of agricultural methods is strongly linked to socio-economic factors such as education level, access to information, farm size, and membership in farmer groups [18]. Furthermore, Sana *et al.* proved that access to technologies and information is a crucial factor in agricultural innovation processes [19]. These results help understand the differences noted between the analyzed regions. Moreover, studies carried out in West Africa highlight that agricultural innovation adoption processes exhibit high heterogeneity and are influenced by local adaptation dynamics [20]. This variability indicates that agricultural systems do not progress linearly, but rather through complex processes frequently constrained by structural factors.

Compared to more intensive agricultural systems, the results underline a persistent lag in adopting protection technologies. Despite their demonstrated potential to increase productivity and resilience, the use of sustainable agricultural practices and protection technologies remains globally limited in Sub-Saharan Africa, as revealed by Sithole and Olorunfemi [16]. In addition, pest and constraint management studies demonstrate that current methods remain frequently scattered and ineffective for smallholders [21]. However, recent advances such as wire mesh fencing have shown significant potential to optimize crop defense [22]. Nevertheless, their deployment remains restricted in the analyzed situations, highlighting the importance of financial and technology access restrictions.

The baseline assessment drawn in this study underscores the urgent need to rethink support for smallholders facing worsening climatic conditions. Since the high cost of protection and irrigation equipment constitutes a substantial financial barrier for the majority of farmers, new partnership opportunities must be explored to break the low-productivity cycle.

In this regard, contract farming could emerge as a promising strategic solution to lift these financial and technical bottlenecks. Drawing on the vertical coordination theory developed by Key and Runsten [23], integrating perimeter security into partnership agreements between producers and processing units would transform an individual constraint into a shared responsibility. As suggested by Eaton and Shepherd [24], this model offers the possibility of pooling systemic risks and pre-financing essential protection infrastructure (live hedges, fences), which are often beyond individual financial reach.

This approach, which will be the subject of subsequent studies to evaluate its impact on yield and income stability, offers a concrete perspective for transforming cassava from a subsistence crop into a secure, competitive, and resilient industrial sector in Burkina Faso. Such a transition would help overcome the inaccessibility of warrantage mechanisms for this root crop by using contracts as an

effective substitute for traditional material collateral.

6. Conclusion

The study highlights a wide disparity in crop protection methods within *Manihot esculenta* Crantz production systems among surveyed cooperative-affiliated producers in Burkina Faso, with a majority of unprotected farms reflecting structural vulnerability. The exclusive use of traditional methods, while aligned with local realities, is insufficient to ensure effective and sustainable protection. The observed differences attest that adoption trends are largely determined by agroecological, socio-economic, and institutional factors. The emergence of intermediate solutions in various regions indicates gradual technological progression, albeit hindered by financial restrictions and limited access to extension services. These results emphasize the need to strengthen agricultural policies by facilitating access to adapted protection technologies, improving producer support, and sustaining local innovation. Accounting for methodological limitations regarding sample scoping, this research highlights the crucial role of crop defense as a tool to improve productivity and resilience in Sub-Saharan agricultural systems.

Author Contributions

Conceptualization, A.K.H. and U.S.; methodology, I.Z.; software, P.B.; validation, A.K.H., I.Z., W.M.B., and U.S.; formal analysis, U.S.; investigation, A.K.H.; resources, A.K.H.; data curation, P.B.; writing original draft preparation, I.Z.; writing review and editing, W.M.B.; visualization, A.K.H., I.Z., and W.M.B.; supervision, U.S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Nassar, N.M.A. (2000) Wild Cassava, *Manihot* spp.: Biology and Potentialities for Genetic Improvement. *Genetics and Molecular Biology*, **23**, 201-212. <https://doi.org/10.1590/s1415-47572000000100035>
- [2] Dabiré, C. (2015) Le manioc au Burkina Faso: Enjeux et perspectives pour une filière émergente. Technical Report. INERA.
- [3] Djindiere, O., Rayangnéwendé Ouedraogo, A. and Coulibaly, K. (2025) Premiers résultats sur l'amélioration des performances agro-morphologiques du manioc (*Manihot esculenta* Crantz) par la fertilisation organo-minérale dans la zone ouest du Burkina Faso. *International Journal of Advanced Research*, **13**, 99-110. <https://doi.org/10.21474/ijar01/20881>
- [4] El-Sharkawy, M.A. (2012) Stress-Tolerant Cassava: The Role of Integrative Ecophysiology-Breeding Research in Crop Improvement. *Open Journal of Soil Science*, **2**, 162-186. <https://doi.org/10.4236/ojss.2012.22022>
- [5] UNDP (2023) Rapport sur le développement humain et la résilience agricole au Sahel.

Report. UNDP.

- [6] Ceballos, H. and Fenstermaker, S. (2026) Cassava Breeding: Past, Present and Future. *Tropical Agricultural Sciences*, **1**, Article 100002. <https://doi.org/10.1016/j.tas.2025.100002>
- [7] Lhoste, P. (2004) La traction animale en Afrique subsaharienne: Histoire et nouveaux enjeux. *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, **57**, 125. <https://doi.org/10.19182/remvt.9883>
- [8] Dugué, P., Vall, E., Lecomte, P., Klein, H. and Rollin, D. (2004) Evolution des relations entre l'agriculture et l'élevage dans les savanes d'Afrique de l'Ouest et du Centre: Un nouveau cadre d'analyse pour améliorer les modes d'intervention et favoriser les processus d'innovation. *Oléagineux, Corps Gras, Lipides*, **11**, 268-276. <https://doi.org/10.1051/ocl.2004.0268>
- [9] Adjebeng-Danqua, J. and Safo-Kantanka, O. (2015) Effect of Genotype and Periodic Pruning on Storage Root Yield and Yield Components of Some Cassava Genotypes under Rain-Fed Conditions in Ghana. *Journal of Plant Studies*, **4**, 1-11. <https://doi.org/10.5539/jps.v4n2p1>
- [10] Benjaminsen, T.A., Alinon, K., Buhaug, H. and Buseth, J.T. (2012) Does Climate Change Drive Land-Use Conflicts in the Sahel? *Journal of Peace Research*, **49**, 97-111. <https://doi.org/10.1177/0022343311427343>
- [11] Moritz, M. (2010) Crop-Livestock Interactions in Agricultural and Pastoral Systems in West Africa. *Agriculture and Human Values*, **27**, 119-128. <https://doi.org/10.1007/s10460-009-9203-z>
- [12] Tonah, S. (2006) Managing Farmer-Herder Conflicts in Ghana's Volta Basin. *Ibadan Journal of the Social Sciences*, **4**, 35-45. <https://doi.org/10.36108/ijss/6002.40.0130>
- [13] Djinadou, A.K.A., Olodo, N.I. and Adjanohoun, A. (2018) Evaluation du comportement de variétés améliorées de manioc riches en bêta-carotène au Sud du Bénin. *International Journal of Biological and Chemical Sciences*, **12**, 703-715. <https://doi.org/10.4314/ijbcs.v12i2.8>
- [14] Nadjiam, D., Ayessou, N.C. and Guissé, A. (2020) Physicochemical Characterization of Nine Cassava (*Manihot esculenta* Crantz) Cultivars from Chad. *Food and Nutrition Sciences*, **11**, 741-756. <https://doi.org/10.4236/fns.2020.117053>
- [15] Grawitz, M. (2001) Méthodes des sciences sociales. 11th Edition, Dalloz.
- [16] Sithole, A. and Olorunfemi, O.D. (2024) Sustainable Agricultural Practices in Sub-Saharan Africa: A Review of Adoption Trends, Impacts, and Challenges among Smallholder Farmers. *Sustainability*, **16**, Article 9766. <https://doi.org/10.3390/su16229766>
- [17] Akanmu, A.O., Akol, A.M., Ndolo, D.O., Kutu, F.R. and Babalola, O.O. (2023) Agroecological Techniques: Adoption of Safe and Sustainable Agricultural Practices among the Smallholder Farmers in Africa. *Frontiers in Sustainable Food Systems*, **7**, Article 1143061. <https://doi.org/10.3389/fsufs.2023.1143061>
- [18] Kone, S. and Uzmay, A. (2025) Impact Assessment of Sustainable Agricultural Practices on Smallholder Households Food Security: Evidence from Burkina Faso. *Climate and Development*, **17**, 255-269. <https://doi.org/10.1080/17565529.2024.2357183>
- [19] Sana, I., Diendere, A.A. and Yabi, A.J. (2024) Déterminants de l'adoption des TIC agricoles au Burkina Faso. *European Scientific Journal*, **20**, 121-135.
- [20] Fané, S., Agbotui, D.K., Graefe, S., Sanou, L., Sanogo, S. and Buerkert, A. (2024) Adoption of Agroforestry Systems by Smallholders' Farmers in the Sudano-Sahelian Zones of Mali and Burkina Faso, West Africa. *Agroforestry Systems*, **98**, 2385-2396.

- <https://doi.org/10.1007/s10457-024-01020-8>
- [21] Deguine, J., Aubertot, J., Flor, R.J., Lescourret, F., Wyckhuys, K.A.G. and Ratnadass, A. (2021) Integrated Pest Management: Good Intentions, Hard Realities. A Review. *Agronomy for Sustainable Development*, **41**, Article No. 38.
<https://doi.org/10.1007/s13593-021-00689-w>
- [22] Feuerbacher, A., Lippert, C., Kuenzang, J. and Subedi, K. (2021) Low-Cost Electric Fencing for Peaceful Coexistence: An Analysis of Human-Wildlife Conflict Mitigation Strategies in Smallholder Agriculture. *Biological Conservation*, **255**, 108919.
<https://doi.org/10.1016/j.biocon.2020.108919>
- [23] Key, N. and Runsten, D. (1999) Contract Farming, Smallholders, and Rural Development in Latin America: The Organization of Agroprocessing Firms and the Scale of Outgrower Production. *World Development*, **27**, 381-401.
[https://doi.org/10.1016/s0305-750x\(98\)00144-2](https://doi.org/10.1016/s0305-750x(98)00144-2)
- [24] Charles, E. and Shepherd, A. (2001) Contract Farming: Partnerships for Growth. Food and Agriculture Organization of the United Nations.