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Arable Crop Production in Transition: Constraints, Adaptation, and Sustainable Resilience in Bali Nyonga, 1994–2017

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Abstract

Purpose: This study investigates innovative approaches to sustainable arable crop production in the Bali Nyonga Sub-Division between 1994 and 2017, focusing on how local farmers and agricultural actors adapted their practices to sustain productivity amid environmental, socio-economic, and institutional challenges. It aims to demonstrate how arable farming, central to food security and rural livelihoods, evolved under the combined pressures of colonial legacies, post-independence reforms, and neoliberal economic restructuring.

Methodology: The analysis employs a mixed-method approach, integrating qualitative and quantitative techniques. It draws on primary data, including field interviews and oral testimonies, as well as secondary documentary sources. Descriptive statistics and historical interpretation complemented these to capture long-term transformations in farming systems.

Findings: The study reveals that arable farming in Bali Nyonga underwent significant transitions, constrained by soil infertility, erratic rainfall, land pressure, and limited access to improved inputs. In response, farmers adopted a range of innovative practices such as mixed cropping, organic and compost fertilization, crop rotation, improved seed varieties, and emerging precision and conservation farming techniques supported by extension services. These innovations enhanced yields, improved soil health, reduced production costs, strengthened household incomes, and increased resilience to climate shocks. However, persistent challenges, including weak institutional support, inadequate infrastructure, and limited financing, continue to hinder broader agricultural transformation.

Contribution to Theory, Practice, and Policy: This study contributes to agrarian and environmental history by illustrating how indigenous knowledge systems and scientific interventions intersect to produce locally grounded pathways of sustainable agricultural innovation. Practically, it underscores the value of farmer-led experimentation in building resilient production systems. For policy, the study recommends strengthening farmer training programs, improving access to credit and agricultural inputs, revitalizing extension services, and fostering collaborations between research institutions and local communities. These measures are essential for consolidating existing gains and promoting a resilient, inclusive, and ecologically sustainable agrarian future for Bali Nyonga.

Keywords: *Sustainable Agriculture, Innovation, Arable Crop Production, Bali Nyonga, Food Security.*

Background

The agrarian history of Bali Nyonga, located in the North West Region of Cameroon, reflects a localized expression of the broader national agricultural transformations that unfolded between the 1990s and the 2010s. Historically endowed with fertile soils and a relatively mild climate, Bali Nyonga sustained intensive arable farming systems that anchored local livelihoods and food security (Neba, 1999). Crops such as maize, beans, cocoyams, cassava, and groundnuts have long constituted the backbone of the local economy, while agriculture itself has been embedded in social norms, cultural values, and moral obligations that extend beyond mere subsistence (Nkwi, 1997). The year 1994 marked a critical turning point in this agrarian trajectory. It coincided with the aftermath of Cameroon's economic crisis and the implementation of Structural Adjustment Programs (SAPs), which significantly weakened state support for agriculture through the withdrawal of subsidies and the dismantling of cooperative unions, including the Bali Cooperative Society (Konings, 1993). These changes eroded farmers' institutional safety nets and compelled them to rely more heavily on indigenous systems of soil fertility management and seed preservation. At the same time, the liberalization of agricultural input markets created new opportunities through the introduction of improved seed varieties, while simultaneously exposing farmers to price volatility and unreliable supply chains (Ndenecho, 2005). By the early 2000s, renewed state intervention through the National Agricultural Extension and Research Programme (PNVRA) sought to revive extension services and promote improved farming practices. However, as Konings (2004) observes, these reforms were constrained by weak follow-up mechanisms and inadequate rural infrastructure. Consequently, farmers in Bali Nyonga continued to practice mixed cropping and communal labor arrangements, blending inherited agronomic knowledge with selective technological innovations. During this period, environmental pressures intensified as continuous cultivation, deforestation along the Bali escarpment, and increasingly unpredictable rainfall patterns contributed to declining soil fertility and crop yields (Fokwang, 2003).

From the mid-2000s onward, agrarian change in Bali Nyonga was further shaped by socio-economic and gendered transformations. Male out-migration to urban centers accelerated the feminization of agriculture, placing women at the center of arable crop production across the Grassfields region (Eyoh, 2006). Women's cooperatives, notably the Bali Women Agro Group, established around 2006, became critical actors in sustaining household food systems and community resilience. Concurrently, growing awareness of climate variability encouraged the involvement of non-governmental organizations and church-based initiatives, which promoted composting, mulching, and organic fertilizer use. Nevertheless, innovation adoption remained selective and culturally mediated, guided by local ecological knowledge and deeply rooted ethics of land stewardship (Nfor & Mbuh, 2011). Between 2010 and 2017, Bali Nyonga's agrarian landscape increasingly reflected a complex interplay of constraint and adaptation. Erratic rainfall, rising input costs, and declining youth participation reshaped agricultural practices, yet smallholder farmers continued to experiment with sustainable techniques such as crop rotation,

composting, and organic pest control (Gwan, 2016). This persistence underscores a long-standing tradition of agricultural innovation in Bali Nyonga, revealing a rural society negotiating between tradition and modernization, memory and market, in its pursuit of sustainable arable crop production.

Introduction

Bali Nyonga, a historic Fondom and contemporary Sub-Division in the Bamenda Grassfields of Cameroon, has long been an agrarian society in which social organization, economic life, and collective identity revolve around arable crop cultivation. Situated within Mezam Division in the North West Region, the area's fertile plains and undulating highlands have supported smallholder farming since precolonial times. The community's political and spatial organization emerged through successive waves of migration and conflict that shaped the wider Grassfields region before European colonization. Under German and later British rule, Bali Nyonga was incorporated into colonial economic structures through taxation and cash-crop promotion, yet its subsistence base, dominated by maize, beans, cocoyams, plantains, and groundnuts, remained largely intact. In the post-independence period, particularly between 1994 and 2017, demographic pressure, climatic variability, and economic uncertainty heightened the need for sustainable agricultural innovation to secure food production and rural livelihoods. This study examines these transformations and argues that innovative approaches to arable farming in Bali Nyonga, anchored in indigenous knowledge systems but informed by scientific and institutional interventions, constitute adaptive responses to both historical and contemporary pressures. Grounded in African agrarian historiography, the analysis emphasizes the interconnections between environmental change, technological adaptation, and social institutions.

Scholarly works underscore the importance of historical continuity in understanding agricultural systems. Vansina (1985) highlights the role of oral memory in preserving agrarian knowledge, while Nugent (1996) and Neumann (2005) demonstrate how governance structures and long-term ecological adaptation shape enduring patterns of agricultural innovation. Their findings reveal that socio-political hierarchies historically structured land access and labor organization—dynamics that remain visible in contemporary Bali Nyonga. Similarly, Neba's (1999) synthesis emphasizes the persistence of smallholder farming alongside its vulnerability to environmental degradation. In the postcolonial context, Fonjong (2002) documents how shifting gender roles transformed labor allocation and influenced the diffusion of agricultural technologies. Complementary insights emerge from Page's (2002) analysis of smallholder adaptability amid resource scarcity and policy neglect. In addition, Sop (2015), Lipton (1993), and Uphoff (2002) stress the centrality of cooperative institutions, equitable land access, and locally driven innovation in achieving sustainable agricultural transformation.

Geographically, Bali Nyonga lies approximately 18 kilometers southwest of Bamenda on a volcanic highland plateau ranging between 1,200 and 1,800 meters above sea level. Its fertile soils,

extended rainy season from March to October, and cool dry season have historically supported both subsistence and cash-crop farming. Settlement patterns developed around cultivable valleys and watercourses, producing dispersed farmlands and clustered compounds characteristic of Grassfields agrarian traditions. These environmental conditions have long-shaped agricultural innovation and social cohesion, positioning Bali Nyonga as a microcosm of wider agrarian processes in the Grassfields. Taken together, the historical context and literature reviewed demonstrate that Bali Nyonga's agrarian systems are dynamic constructs shaped by ecology, technology, and governance. Sustainable agricultural innovation, therefore, cannot be understood in isolation from its historical and institutional settings. However, despite this rich scholarship, existing studies on agrarian change in Cameroon and the Grassfields have tended to privilege macro-level policy analysis, cash-crop economies, or generalized accounts of environmental degradation. What remains comparatively underexplored is how local farming communities such as Bali Nyonga have actively generated, adapted, and sustained innovative arable crop production practices over time, particularly in response to post-liberalization constraints and climatic uncertainty. More specifically, insufficient attention has been paid to how indigenous knowledge systems, farmer-led experimentation, gendered labor dynamics, and selective scientific interventions converged to produce locally grounded forms of agricultural sustainability.

It is this analytical gap that the present study seeks to address. By adopting a historical and interdisciplinary lens, the article examines how farmers in Bali Nyonga between 1994 and 2017 navigated ecological, institutional, and socio-economic constraints to develop adaptive and sustainable arable farming practices. The study moves beyond narratives of decline to foreground local agency, innovation, and resilience, demonstrating how mixed cropping, organic soil management, improved seed adoption, and cooperative action contributed to the gradual reconfiguration of farming systems. In doing so, the article contributes to agricultural and environmental history by showing that sustainability in Bali Nyonga was not externally imposed but emerged through a dynamic process of local adaptation rooted in both cultural continuity and selective engagement with modern agronomic knowledge.

Ecological and Institutional Constraints in Arable Crop Production, 1994–2017

From the mid-1990s onward, arable crop production in Bali Nyonga, as in much of the Grassfields region of Cameroon, confronted a convergence of structural, ecological, and institutional challenges that significantly constrained agricultural development. By 1994, the lingering effects of the 1986 economic crisis had become pronounced. Farmers across Mezam Division, including those in Bali Nyonga, experienced declining yields, limited access to credit, and the erosion of institutional support mechanisms. The dissolution of state-supported cooperatives such as the West Development Agencies and the National Produce Marketing Board, institutions that had provided relative stability during the 1960s and 1970s, deprived farmers of collective marketing channels and technical assistance. As state involvement receded, farmers increasingly relied on indigenous systems of mutual aid, locally known as *njangi*. While these arrangements reinforced social

solidarity, they lacked the capital base and organizational capacity necessary for large-scale innovation (Lipton, 1993). This historical reliance on indigenous institutions thus reveals both the resilience of rural society and its vulnerability in the absence of sustained state support.

Ecologically, Bali Nyonga's soils, derived from ancient volcanic formations and historically rich in nutrients, began to show signs of overexploitation by the mid-1990s. Continuous cultivation, combined with shortened or absent fallow periods, accelerated soil exhaustion. Neba (1999) observes that this pattern was widespread across the North West Region, where population density increasingly exceeded the land's regenerative capacity. Local farmers reported declining soil structure and fertility, noting that traditional composting practices and ash application were no longer sufficient to sustain yields. These observations marked an early recognition of ecological limits within the local agrarian system. Simultaneously, the late 1990s ushered in increasing climatic unpredictability that disrupted established agricultural rhythms. Oral accounts from Bali Nyonga farmers describe how ancestral planting calendars, once closely aligned with lunar cycles and the onset of rains, lost reliability as rainfall patterns became erratic. This instability mirrored broader regional trends documented by scholars such as Richards (1985), who identified shifts in rainfall intensity and duration across West and Central Africa during this period. Consequently, farmers in Bali Nyonga faced not only economic and institutional uncertainty but also an altered ecological regime that threatened both subsistence and market-oriented production. These pressures intensified between 2001 and 2003, when prolonged dry spells alternated with torrential rains that accelerated topsoil erosion. Water courses such as the Mbelu and Njenka streams, once perennial, increasingly dried up during mid-season. This transformation imposed additional burdens on households, particularly women, who were compelled to travel longer distances to secure water for domestic use and small-scale irrigation. Mortimore and Tiffen's (1994) argument that environmental stress in African smallholder systems often catalyzes innovation rather than collapse finds partial support here. In Bali Nyonga, women's farming groups responded by experimenting with cassava and sweet potato cultivation on higher grounds formerly reserved for pasture, effectively redistributing land use to accommodate changing hydrological conditions.

The cumulative impact of these challenges is best understood through a combined political-economic and environmental lens. Agrarian historians such as Berry (2001) and Peters (1994) caution that land and labor crises in rural Africa rarely occur in isolation; rather, they are historically layered and socially embedded. This framework helps explain why Bali Nyonga did not experience outright agrarian collapse during the late 1990s. Instead, agricultural production was reorganized around smaller household units. Men, traditionally responsible for land clearing and cash-crop ventures, increasingly sought off-farm employment in urban centers such as Bamenda and Douala. Women and the elderly consequently assumed greater responsibility for subsistence farming. This gendered reallocation of labor altered decision-making structures and constrained the adoption of labor-intensive innovations such as contour ridging and compost mulching, both of which require collective labor mobilization.

Technically, access to improved seed varieties remained limited throughout this period. Although IRAD research trials conducted in the 1980s generated promising results, weak extension services prevented their diffusion to smallholder farmers. Following the withdrawal of national extension services in 1992, guidance on soil conservation and pest management became sporadic and largely dependent on NGOs. As noted by Akeampong (2001) and Richards (1985), farmers increasingly relied on social learning rather than formal institutional channels. In Bali Nyonga, innovations such as maize–beans intercropping and residue mulching spread through neighborhood interaction and observation rather than through structured extension programs. Despite these constraints, the cultural resilience of the Bali Nyonga farming community remained striking. Land stewardship norms enforced by lineage heads and the Fon's council continued to regulate land use and access. However, these customary arrangements also discouraged long-term investments such as terracing and irrigation infrastructure, as farmers lacked secure tenure guarantees (Yeluma, 2025). The resulting tenure insecurity reduced incentives for sustainable land improvements, even where farmers recognized their long-term benefits.

An additional challenge that emerged in the late 1990s was the proliferation of pests and diseases associated with climatic variability. Oral testimonies document rising infestations of maize stem borer (*Busseola fusca*) and fungal diseases affecting cocoyams. In the absence of modern agrochemicals or resistant varieties, farmers relied on indigenous treatments such as wood ash (Nubidga, 2025). While partially effective, these responses highlighted a broader technological disconnect between local knowledge systems and formal agronomic research. Nevertheless, they also underscore farmers' agency in developing adaptive strategies under constrained conditions.

By the year 2000, Bali Nyonga's arable sector exhibited a marked paradox. On one hand, it demonstrated adaptive stability grounded in indigenous knowledge, environmental intuition, and social cohesion. On the other hand, it faced escalating ecological degradation, technological stagnation, and institutional neglect. This tension framed the central dilemma of sustainable agriculture in the locality: reconciling cultural continuity with the necessity of scientific innovation. Uphoff's (2002) reflections on participatory agricultural development are particularly instructive here, emphasizing that sustainability emerges most effectively when local knowledge and scientific insights co-produce context-appropriate practices. Between 1994 and 2000, Bali Nyonga embodied this tension in embryonic form. That is, a community firmly rooted in ancestral practices yet increasingly aware of the need for change.

The early 2000s introduced renewed uncertainty. Agrarian decline did not reverse but deepened into a phase of institutional erosion and ecological anxiety. Although national programs such as the *Programme National de Développement Participatif* (PNDP) and the *Programme National de Sécurité Alimentaire* (PNSA) were introduced, their tangible impact on smallholder farmers remained limited. Most Bali Nyonga farmers operated family plots averaging less than two hectares and faced bureaucratic barriers to accessing microcredit and technical support. Meanwhile, the rural elite who once mediated between the state and local communities

increasingly disengaged, drawn instead to urban employment in Bamenda, Yaoundé, and Douala (Andin, 2025). Compounding these challenges was a pronounced generational shift within the agrarian workforce. From the early 2000s, youth migration intensified as younger men and women pursued education and employment opportunities elsewhere. By 2005, farming was dominated largely by older adults, disrupting the intergenerational transmission of agricultural knowledge traditionally conveyed through apprenticeship, ritual, and oral instruction (Kahmia, 2025). This demographic rupture weakened the moral and intellectual foundations of agrarian heritage in Bali Nyonga.

Between 2008 and 2012, however, signs of cautious reawakening emerged. Triggered partly by the 2008 global food crisis, which exposed vulnerabilities in food supply systems, renewed attention was directed toward local production and self-reliance. In Bali Nyonga, this moment catalyzed reflection on the viability of subsistence farming as a cornerstone of resilience. Farmers began experimenting with ridge realignment and disease-resistant maize and bean varieties. Although these innovations were initially met with skepticism, particularly among elders attached to *njangi*-based hoe cultivation, younger farmers, influenced by formal education and urban exposure, increasingly interpreted them as markers of progress (Evaristus, 2025). This generational dialogue aligns with Richards's (1985) conception of "agriculture as performance," where innovation emerges through local improvisation rather than external prescription.

Institutionally, agricultural extension regained modest relevance through *Programme de Développement du Secteur Rural* (PDSR) workshops, which sought to integrate indigenous knowledge with modern techniques. In Bali Nyonga, these initiatives helped repair weakened farmer–state relations and fostered a renewed sense of collective progress. Concurrently, environmental concerns intensified as deforestation around areas such as Bossa and Mantum threatened soil and water systems. In response, the Bali Nyonga traditional council, in collaboration with the Presbyterian Church, launched tree-planting campaigns grounded in both ecological awareness and spiritual values (Sobila, 2024). These initiatives symbolically reconnected traditional authority with environmental ethics, though agrarian transformation remained constrained by land tenure insecurity, urban expansion, and persistent kin-based disputes (Njichom, 2025).

By 2012, unresolved structural challenges, including limited credit, poor infrastructure, and unstable markets, continued to undermine productivity. Yet community resilience increasingly rested on adaptive creativity rather than material prosperity, reflecting an ongoing negotiation between tradition and modernity. From 2013 to 2017, agriculture entered a phase marked by cautious optimism. Climate change manifested through increasingly erratic rainfall, forcing farmers to revise sowing schedules and rethink long-standing agricultural rhythms. In response, climate-smart agriculture concepts gained traction through extension services and NGOs. Practices such as contour farming, mulching, intercropping, and small-scale drip irrigation were gradually

adopted (Titalanga, 2025), positioning farmers as proactive agents of renewal rather than passive recipients of policy interventions.

Culturally, farming began to be reimagined as a dignified and innovative profession. Women's initiatives, including the Mun Mbo Mun Women Farming Initiative and Bali Women in Action for Development, redefined rural women as agricultural innovators. Through workshops on seed selection, crop preservation, and organic pest control, these groups disseminated success stories in churches and community forums, inspiring wider participation (Nahnyonga, 2024; Bali Women in Action for Development, 2015). Nonetheless, persistent challenges, soil depletion, lack of testing facilities, limited fertilizer access, land fragmentation, and political instability continued to constrain productivity and market access (Dinga, 2025). These realities underscore that agricultural sustainability is as deeply political as it is technical.

In sum, the period witnessed renewed scholarly engagement with agrarian research in Cameroon. Scholars such as Nyamnjoh (2006), Nkwi (2015), and Chem-Langhëe (2014) emphasized the necessity of integrating indigenous knowledge with scientific innovation—an approach that resonated strongly with Bali Nyonga's lived experience. By 2017, agriculture in Bali Nyonga had evolved into a hybrid system blending traditional and modern practices across local and global scales. The central challenge was no longer innovation itself, but its uneven diffusion and weak institutional support, leaving farmers exposed to external shocks. Whether local ingenuity can ultimately compensate for state neglect and global market volatility remains an open historical question, one that situates Bali Nyonga squarely within the broader African agrarian struggle to modernize sustainably without forfeiting cultural autonomy.

Innovation and Sustainability in Arable Crop Production

The early decades of innovation in Bali Nyonga marked a gradual yet significant transformation of local agrarian systems, shaped by mounting economic constraints and environmental pressures. As declining soil fertility, rising input costs, and climatic uncertainty intensified from the early 2000s, farmers increasingly adopted sustainable practices that blended new technologies with long-standing adaptive traditions. This period witnessed a transition toward more precise, knowledge-driven farm management, supported by institutional interventions and smallholder creativity. Key innovations included the use of improved seed varieties, organic fertilization, agro-ecological diversification, and limited small-scale mechanization, all of which reflected a deliberate shift away from earlier extractive farming practices.

Evidence from farmers and extension officers indicates that this transformation gained momentum in the early 2000s, coinciding with rising fertilizer prices and heightened awareness of soil degradation. Farmers began to rethink conventional input use, particularly the indiscriminate application of chemical fertilizers. As Aloysius Njichom recalled, "We used to throw fertilizer anyhow across the field, thinking more fertilizer meant more maize, but with new training from the extension personnel, we learned to measure and apply small quantities at the right time, and

our yields became more even" (Njichom, 2025). This experiential learning illustrates how fertilizer optimization and split application techniques improved both agronomic efficiency and soil health awareness, marking a clear break from earlier practices that had accelerated land degradation.

Alongside improved nutrient management, the introduction of improved seed varieties played a pivotal role in strengthening arable crop productivity in Bali Nyonga. Farmers in Njenka and Nakah confirmed that hybrid maize and bean seeds were distributed between 2012 and 2014 by agricultural authorities and non-governmental organizations, resulting in significantly higher yields under low-input conditions. According to Nahlela Marie, a cooperative farmer, "The new maize we received was stronger against insects and matured faster; before, we lost many crops to maize streak, but now it is less" (Nahlela, 2025). These outcomes demonstrate how scientific seed improvement, when combined with indigenous planting knowledge, enhanced resilience to both climatic variability and pest pressure.

In parallel with these developments, organic fertilization and composting were revived as central soil management strategies. Rooted in pre-chemical farming traditions of the 1970s and 1980s, these practices were reintroduced and systematized through training programs facilitated by organizations such as the Strategic Humanitarian Services (SHUMAS) Cameroon and the Association for the Conservation of the Environment and Food Security (ACEFA). Farmers emphasized the tangible benefits of these methods. As Ngum Grace explained, "When we mix compost and manure, our soil stays soft, and crops look green even when the rain stops early" (Ngum, 2024). This revival highlights the continuity between indigenous ecological wisdom and modern sustainability initiatives, underscoring how past knowledge provided a foundation for contemporary innovation.

More broadly, the evolution of sustainable arable crop production in Bali Nyonga reflects the dynamic interplay between state-led modernization efforts and local willingness to adapt within Cameroon's wider agrarian transformation. Following the neoliberal reforms of the early 1990s, the reduction of state subsidies and the privatization of agricultural support institutions compelled farmers to rely increasingly on indigenous systems and community-based innovations (Geschiere, 1993; Konings, 1996). Within this context, the period from 1994 to 2017 represents a transition from dependency on centralized programs toward a locally driven culture of adaptation and sustainability. NGO interventions, most notably those of SHUMAS Cameroon and the Inland Valley Development Program (IVDP), coincided with government efforts to decentralize agricultural extension services (Andin, 2025). This institutional reconfiguration enabled farmers in Bali Nyonga to become active agents, selectively blending external technologies with traditional ecological knowledge. Such processes align with what scholars describe as "vernacular modernization," whereby communities appropriate innovations in ways that correspond to their socio-cultural values and environmental realities (Bayart, 2000; Konings & Nyamnjoh, 2000). In Bali Nyonga, innovation was not imposed but reinterpreted, filtered through local experience, and reshaped to suit specific ecological conditions. This locally grounded modernization became more

visible after 2010, when women's cooperatives, youth groups, and credit unions expanded access to innovation and market participation.

Women's associations, including the Bali Cooperative, emerged as critical intermediaries between local producers and international NGOs, reshaping gender roles within the agricultural economy (Fisiy, 1992; Nkwi, 2006). Through collective action, women acquired skills in farm record-keeping, compost production, and group marketing, thereby strengthening the sustainability of household and community farming systems. These developments also contributed to a broader redefinition of innovation, emphasizing cooperation, inclusivity, and social learning.

Between 2010 and 2017, environmental awareness and climate-smart agricultural practices gained prominence. Farmers increasingly understood sustainability not merely as a technical objective but as a coping strategy in the face of ecological uncertainty. Through experimentation and peer learning, practices such as crop diversification, organic soil management, and adjusted planting schedules became more widespread (Molua, 2011). The experiences of men, women, and youth collectively demonstrate that sustainable innovation in Bali Nyonga was as much a social and cultural process as it was a technological one. Ultimately, these innovations reflect a historically grounded response to constraint, illustrating how sustainability emerged through adaptation, creativity, and the strategic blending of tradition and modernity.

Impact of Sustainable Arable Farming Innovation on Development in Bali Nyonga

The innovations in arable crop production in the Bali Nyonga sub-division over the period of 1994 to 2017 contributed to the sustainable development agenda in Bali Nyonga through improved food security, economic resilience, and environmental preservation. The adoption of improved seeds, optimal planting densities, and better fertilizer management helped stabilize and increase yields. For example, the trial with maize variety CHC202 showed that applying 12 g of NPK (20:10:10) per plant in two applications produced the highest yields of about 2.4 kg per plant, indicating strong links between plant vigour and output (Achiri et al., 2018). This evidence highlights the benefits of sustainable intensification by increasing productivity on existing land. As a result, pressure on forest and marginal land was reduced, supporting sustainable land use and more reliable food production.

Improved agricultural production enhanced farmers' ability to sell surplus, leading to higher household incomes and stronger livelihoods in Bali Nyonga, where farming dominated the economy. Evidence from neighboring parts of the North West region suggested that improved agronomic practices led to better returns despite limited local data (Tassah et al., 2022). Higher incomes increased household resilience by supporting investments in education, health, and productive inputs. In Bali Nyonga, innovation shifted farming from subsistence to market-oriented production, driving wider rural transformation.

What is more, the adoption of modern and more efficient agronomic practices in Bali Nyonga contributed to sustainable land management by increasing productivity through efficient land use rather than land expansion. For instance, optimal planting densities as tested in Bali Nyonga indicated that 20-25 cm intra-row spacing allows farmers to maximize yields while reducing pressure on forests (Achiri et al., 2019). Precise NKP fertilizer application, with trials showing strong results at 12g per plant, improved plant growth while limiting nutrient losses and environmental damage. These practices represent sustainable intensification by raising yields without increasing land or resource degradation.

Another key dimension is resilience to climate change and climatic variability. The North-West Region of Cameroon, including Bali Nyonga, is subject to erratic rainfall patterns, soil degradation, and other risks associated with climate change (for example, shorter rainy seasons, dryness spells, and heavier rainfall events). While direct studies for Bali Nyonga are limited, broader research on peasant resilience in the region shows that farmers engaged in adaptive practices such as improved crop varieties, adjusted planting densities, and soil fertility management are better able to cope with bio-physical stress (Nyanchi et al., 2021). In Bali Nyonga, adopting improved seed varieties and better farm management practices increases yield stability, reduces vulnerability, and strengthens food and livelihood security despite climate change.

From 1994 to 2017, innovations in arable crop production in Bali Nyonga went beyond productivity gains to drive meaningful social change. By integrating indigenous farming practices with scientific research through participatory approaches, adaptive hybrid crop management emerged. Local farmers, especially in Mantum and Koppin areas of Bali Nyonga, have historically applied techniques such as intercropping, fallowing, and organic composting. These systems strengthened traditional knowledge while improving resilience and yields. As a result, innovation became culturally grounded, boosting farmer adaptation and long-term sustainability (Tangwa, 2014).

Moreover, the local use of low-input technologies such as bio-fertilizers, mulching, and compost pits has expanded the use of environmentally friendly practices. Although the penetration of these techniques was modest in the 1990s, by the early 2010s, many farmers in Bali Nyonga, like those organized under the umbrella of BANDECA agricultural cooperatives, had begun applying cow dung and poultry droppings in maize and vegetable plots to reduce their dependence on costly synthetic inputs (MINADER, 2025). This localized organic nutrient cycle not only helps maintain long-term soil fertility but also reduces environmental degradation, such as nutrient runoff and groundwater contamination

The cumulative ecological effects of this shift were substantial. A survey conducted by local agricultural extension officers in 2016 indicated that over 48 percent of sampled farms in the Bali Nyonga Sub-Division reported improved topsoil structure and enhanced moisture retention as a direct result of increased use of organic inputs (Bali Nyonga Agricultural Officer, 2016). These

improvements in soil quality, in turn, strengthened crop resilience to prolonged dry spells amid increasingly erratic rainfall patterns. Beyond ecological gains, the adoption of sustainable practices also produced significant institutional outcomes by reinforcing local governance mechanisms through farmer cooperatives and community-based seed schemes. By 2015, more than 60 percent of improved maize seeds used in Beisen and Mbufung were sourced through farmer-managed networks rather than through non-governmental or state channels (BANDECA Cooperative, 2015). This transition reduced external dependency, improved the reliability of agricultural inputs, and fostered a stronger sense of ownership among farming communities. In terms of education and capacity building, agricultural innovations did inspire a rise in rural literacy related to farm management, environmental protection, and market systems. Training sessions organized by the Ministry of Agriculture and Rural Development (MINADER), in collaboration with Cameroon Development Corporation (CDC) and international NGOs, led to an increase in record-keeping and farm planning skills among farmers in Bali Nyonga (Cameroon Development Corporation, 2015). More farmers now document planting schedules, rainfall patterns, input applications, and harvest data than before, as a result, improving their ability to make informed decisions and adjust practices over time. These skills are vital for achieving sustainable development, as they encourage a shift from reactive to proactive farming. Additionally, the evolving agricultural landscape has triggered the growth of informal innovation systems. An egregious example includes the use of traditional farm ridging methods to accommodate higher planting concentration for is a clear indication of how farmers are not merely recipients of technology but active experimenters (Nformi, 2016). In other areas, farmers have started modifying ridge spacing and orientation to improve water retention and seeding emergence. These new approaches, though often undocumented in academic literature, are central to the resilience of rural agricultural systems and reflect the agency of local communities in driving sustainable innovation.

Market dynamics in Bali Nyonga have also changed due to the rise in consistent crop surpluses. With increased production, especially in maize, beans, and groundnuts, rural farmers have increased their participation in local markets such as the Bali Central Market and those in the neighboring towns like Mbengwi and Balibo (Neba, 2017). The availability of higher and more reliable production has enabled farmers' access to contractual relationships with local traders and agro-processors, especially in the flour milling and animal feed sectors. This strengthened household incomes and long-term economic stability, a key pillar of sustainable development.

A more indirect but also important fallout is in nutrition and dietary variety. Households that generate consistent food surpluses are better positioned to allocate part of their harvest to a more varied and nutritious diet instead of just selling all produce or relying solely on carbohydrate staples. Reports from the health centers in Bali Nyonga between 2012 and 2016 indicated a reduction in moderate malnutrition cases among children under five years, a trend partly accounted for by improved food access at the household level due to better farming outputs (Bali Nyonga District Hospital, 2016).

In a synopsis, the impact of agricultural innovation in Bali Nyonga between 1994 and 2017 transcends the technical domain of crop yields to encompass a wide array of economic, social, environmental, and institutional dimensions. The Bali Nyonga experience offers a small-scale view of how rural communities can conveniently transition towards sustainable development using localized, adaptive, and community-driven agricultural change.

Conclusion and Recommendations

Conclusion

The agricultural history of Bali Nyonga from 1994 to 2017 reveals a dynamic process of adaptation in which farmers blended indigenous knowledge with scientific innovations to sustain arable crop production amid economic liberalization, institutional decline, and climatic uncertainty. Through practices such as mixed cropping, composting, organic fertilizer use, improved seed varieties, and climate-smart techniques, farmers strengthened soil fertility, enhanced resilience, and rebuilt productive farming systems grounded in ecological awareness. This period highlights the emergence of a hybrid knowledge system in which research-based methods were integrated into traditional communal labor structures and cultural practices. Despite these strides, persistent challenges, including inadequate infrastructure, limited credit access, weak extension services, and labor shortages, continued to undermine sustainable progress. Climate variability and soil degradation further intensified pressures on local livelihoods. These constraints underscore the need for integrated strategies that combine grassroots innovation with stronger institutional support, scientific collaboration, and coherent agricultural policies. Overall, the Bali Nyonga experience demonstrates that sustainable agriculture is both a continuation of ancestral ecological wisdom and an evolving transition toward modern, climate-resilient farming systems.

Recommendations

To further consolidate the gains achieved in Bali Nyonga between 1994 and 2017, several strategic actions are recommended. First, government agencies and NGOs should strengthen institutional support and rural extension services by providing timely technical advice, access to improved seeds, and guidance on soil fertility management, particularly for smallholder farmers with limited resources. Complementing this, farmers should be encouraged and supported to adopt climate-smart and eco-friendly practices, including intercropping, mulching, contour ridging, organic fertilization, and small-scale irrigation, which can enhance productivity while mitigating environmental degradation. Access to credit and agricultural inputs must also be facilitated through microfinance initiatives and cooperative-based input distribution networks, thereby reducing dependency on external actors and strengthening local ownership. In addition, collaborative research programs that integrate scientific innovation with indigenous knowledge systems should be promoted to develop locally relevant solutions for soil fertility, pest management, and crop diversification. Education and capacity building are equally essential; investments in farmer training, record-keeping, and market literacy will improve adaptive capacity, enabling farmers to

make informed decisions and respond proactively to climatic and economic challenges. Finally, gender-inclusive agricultural practices should be prioritized, recognizing the pivotal role of women in Bali Nyonga agriculture. Policies that strengthen women's cooperatives, support leadership in innovation, and provide targeted resources for female farmers will enhance both productivity and sustainability. By implementing these recommendations, Bali Nyonga can consolidate the gains achieved between 1994 and 2017, advancing adaptive local innovations into a resilient agrarian model that harmonizes productivity, environmental stewardship, and social well-being.

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