

Transforming Bambara Groundnut Breeding through Participatory Action Research: A Technical Brief to Inform Policy on Climate-Resilient Seed Systems in Malawi

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1. Executive Summary

Neglected and Underutilised Species (NUS) like Bambara groundnut are critical for climate resilience and food security in Malawi and across sub-Saharan Africa (Chivenge et al., 2015; Hunter et al., 2019). These crops have the potential to produce when weather is less conducive to support crops such as soya and maize. However, research of improved NUS varieties remains low. Our research in Malawi, conducted from 2021-2023 across five Extension Planning Areas (EPAs); Mombezi, Chipala, Kandeu, Eswazini, and Manjawila, over three consecutive cropping seasons through a Participatory Action Research (PAR) approach collaborating with 150 farmers, highlights that each farmer has unique criteria for their preferred crop variety.

Key findings indicate as follows:

- Spatial variability in preferences: Farmer trait preferences varied significantly across locations. At vegetative stage (Season 2), Chipala EPA farmers showed 3.92-fold higher preference for self-mounding of peduncles over early flowering compared to Mombezi EPA ($p < 0.01$), with no such effect elsewhere. At harvest (Season 2), location solely drove preferences for brown seed colour (coefficient: 3.531, $p < 0.01$) and large seed size (coefficient: 2.033, $p < 0.01$); gender and age had no influence.
- Intention-action gap: Across all EPAs, stated preferences consistently diverged from field selections. Intention to plant local Bambara groundnut varieties progressively declined, disappearing entirely by Season 3 as farmers shifted to improved varieties. This confirms one-time consultations are insufficient for breeding decisions (Levin and Milgrom, 2004).
- Dynamic preferences across growth stages: At germination, location influenced preference for waterlogging tolerance over early germination ($p < 0.01$). At vegetative stage, self-mounding preference was location-dependent (Chipala EPA: coefficient = 3.930, $p < 0.01$, Season 2). At harvest, market value drove seed trait preferences, including brown colour (coefficient = 1.851, $p < 0.01$) and early maturity (coefficient = 0.697, $p < 0.05$).
- Demographic influences: Gender and age influenced preferences at certain stages only. At harvest (Season 1), males preferred brown (coefficient = 2.294, $p < 0.01$) and cream seeds (coefficient = 1.922, $p < 0.05$); youth preferred brown seeds (coefficient = 1.647, $p < 0.05$). By Season 2, these effects disappeared, with location alone driving preferences.

This variability presents challenges for researchers and agriculture development organizations to address, yet it reflects farmers' realities, especially given unexpected extreme climate events. Farmers seek the best return of their crops but they attempt to hedge their bets as they take on recent weather events into account (Fadda *et al.*, 2020; Mkwambisi *et al.*, 2021). Weather impacts all aspects of crop production and management thus must be embraced with all PRA agricultural related programs but with less predictability, identification of best systems is difficult (Misiko, 2013). This policy brief argues that a fundamental shift from top-down, standardized seed dissemination to a decentralized, context-specific, and iterative engagement model is required to embrace the relevant challenges faced by the participating farmers across agro-ecological zones. We propose three key policy actions with clear implementation roadmaps:

1. Mainstream long-term PAR Research in national agricultural policy and research that capture farmers' reality of current climate conditions
2. Decentralize and contextualize all seed production and regulation to include NUS, and
3. Integrate PAR principles that actually embrace co-learning and co-development of practices and approaches into the Agricultural Extension Education.

These actions will enhance climate adaptation, improve food security, and empower local farmer-managed seed systems of all crop-types including NUS (Vernooy *et al.*, 2022; Ndlovu *et al.*, 2024).

2. Background and policy context

Malawi's agricultural sector faces the dual challenges of ensuring food security and building resilience to climate change. Neglected and Underutilised Species (NUS)

such as Bambara groundnut offer inherent drought tolerance and nutritional benefits, making them vital for climate adaptation (Chivenge *et al.*, 2015). Despite this, formal efforts to improve and disseminate seeds for these crops have been limited by National programs (Waldman *et al.*, 2016).

The core problem lies in the need for a universal solution or approach. Traditional "quick and dirty" participatory methods, where farmers consultation is limited to a single session, fail to capture the complexity of farmer decision-making (Chambers, 1994a). Our research demonstrates that preferences change from their initial choices as they shift across seasons, growth stages, and different agro-ecological zones as unexpected agricultural related events occur such as floods that cause heavy erosion and high winds causing crop lodging. Relying on previous weather history and interest only in commercial variety leads to the development and promotion of varieties that farmers cannot afford or that are not accessible to remote farmers. Lack of promotion of local varieties wastes scarce resources and misses a critical opportunity to strengthen food systems against climate shocks.

The evidence and recommendations presented in this policy brief are contributing to national policies that aim to strengthen seed and food systems in Malawi. These policies include

- Malawi 2063: The national vision prioritizing agricultural transformation and climate resilience (Government of Malawi, 2021).
- National Agriculture Policy (NAP): Emphasizes agricultural diversification and sustainable production systems (NAP, 2016).
- National Seed Policy: Currently focused on formal seed systems, with limited attention to NUS and farmer-managed seed systems (Government of Malawi, 2018).

- National Climate Change Management Policy: Recognizes the need for adaptation strategies in agriculture (Government of Malawi, 2016).
- National Resilience Strategy: Aims to build community resilience to climate shocks (Government of Malawi, 2018).

3. Key Evidence from Research

We applied a Participatory Action Research approach to understand farmer variety preferences in five different agro-ecological zones and at different crop growth stages over 3 seasons (2021-2023). Our season-long study provides evidence suggesting the need for a new approach to engaging farmers.

Table 1. Evidence Base Summary

Aspect	Detail
Sample Size	150 farmers
Study Duration	3 cropping seasons (2021-2023)
Locations	5 Extension Planning Areas (EPAs) across different agro-ecological zones
Crops Studied	Bambara groundnut
Analytical Methods	Descriptive analysis and Multinomial regression
Key Innovation	Longitudinal design tracking preference changes over time and across growth stages

Elevation map of Malawi

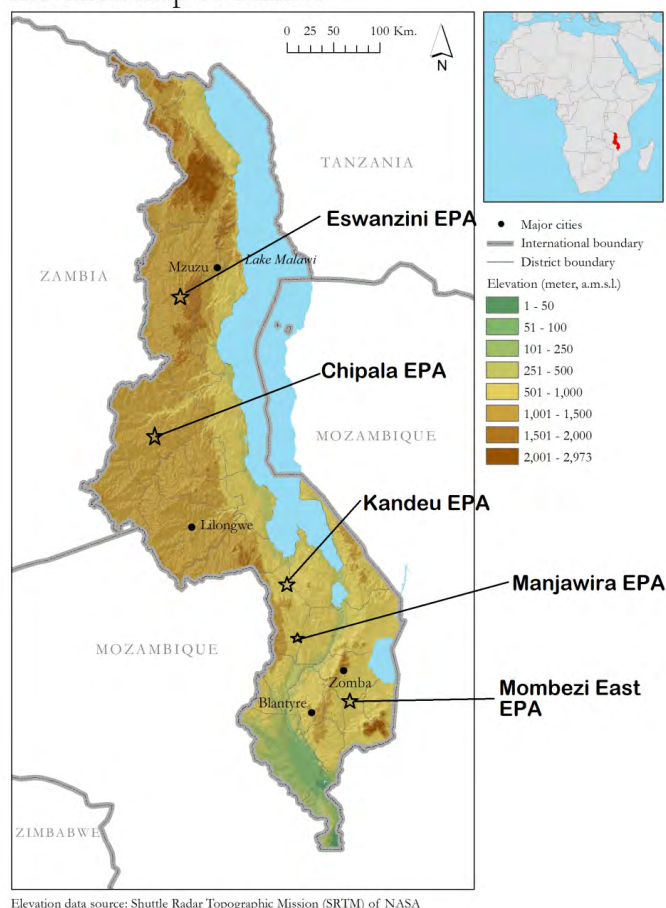


Figure 1. Map of Malawi showing the five research sites

3.1 Spatial Variability

Farmer preferences for traits in Bambara groundnut were not uniform. They varied significantly across different geographic locations, influenced by local socio-economic conditions (e.g., market access, gender roles) and biophysical factors (e.g., soil type, rainfall patterns) (Martey *et al.*, 2021).

Despite no demographic differences in trait preferences for Bambara groundnut crop during germination stage, farmers in Kandeu EPA significantly preferred early-germinating over waterlogging-tolerant Bambara groundnut varieties compared to those in Mombezi EPA.

Table 2. Summary of Trait Preference Variation

Growth Stage	Key Finding	Influencing Factors
Germination	Significant location-based variation in preference for early germination vs. waterlogging tolerance	Geographic location (EPA)
Vegetative Stage	Preference for self-mounding peduncle over early flowering varied significantly	Location only (Chipala EPA) – no gender or age influence
Vegetative Stage (Season 2)	Self-mounding trait preference was strongly significant in only one location	Location only
Harvest Stage (Season 1)	Seed trait preferences (colour, size) varied significantly	Gender, age, and location
Harvest Stage (Season 2)	Seed trait preferences (brown colour, large size) were driven solely by location	Geographic location only – no gender or age influence

Policy Implication: One-size-fits-all breeding and seed dissemination strategies are ineffective. Agro-ecological zone-specific approaches are essential.

Table 3. Farmer Preferences at Germination Stage (Bambara Groundnut), Odds of preferring each trait over early germination

Factor	Vigorous Shoots	Waterlogging Tolerant	Dry Spell Tolerant	Pest/Disease Resistant
Location (compared to Mombezi EPA)				
Chipala EPA	0.82	0.07*	3.58	4.75
Kandeu EPA	0.22	0.07*	1.36	1.16
Gender (Male vs Female)	1.52	3.36	2.61	0.77
Age (Youth vs Elderly)	0.47	1.23	1.37	0.34

Key Message: Farmers in Kandeu EPA are nearly 80% less likely to prefer vigorous shoots over early germination compared to Mombezi EPA. Waterlogging tolerance is 93% less preferred in Chipala and Kandeu compared to Mombezi, suggesting these areas face different constraints.

Table 4. Farmer Preferences at Vegetative Stage – Season 1 & 2, Odds of preferring each trait over early flowering

Factor	Preferences at Vegetative Stage – Season 1			Preferences at Vegetative Stage – Season 2		
	Self-Mounding	Large Canopy	Pest/Disease Resistant	Self-Mounding	Large Canopy	Pest/Disease Resistant
EPAs compared to Mombezi EPA						
Eswazini EPA	12.19	8.15	0.65	4.65	1.58	0.91
Chipala EPA	20.39	16.80	5.70	0.94	0.71	0.45
Kandeu EPA	1.08	11.12	4.39	3.92	1.32	1.25
Manjawila EPA	4.68	16.00	4.57	0.87	0.69	0.35
Gender (Male vs Female)	2.53	1.47	1.45	2.26	1.63	1.70
Age (Youth vs Elderly)	0.47	0.38	0.43	50.85	1.88	1.40

Key Message: In the first season farmers in Chipala EPA are 20 times more likely to prefer self-mounding varieties over early flowering compared to Mombezi EPA. This highlights location-specific priorities that demand decentralized breeding strategies. In the second season Self-mounding preference in Chipala EPA increased dramatically from Season 1 (OR=20.39) to Season 2 (OR=50.85)—demonstrating how preferences evolve across seasons. This supports long-term engagement over single-season consultations.

Table 5. Table 4: Farmer Preferences at Harvest Stage – Season 1 & 2, Odds of preferring each trait over at least 2 seeds per pod in season 1 and Odds of preferring each trait over early maturity in season 2

Factor	Preferences at Harvest Stage – Season 1			Preferences at Harvest Stage – Season 2		
	Appealing Brown	Cream Colour	Early Maturity	Appealing Brown	Cream Colour	Large Seeded
EPAs compared to Mombezi EPA						
Eswazini EPA	7.30	0.38	2.64	34.15	4.72	7.63
Chipala EPA	3.47	0.06	3.15	2.93	0.84	0.84
Kandeu EPA	2.59	0.40	1.19	8.25	0.88	1.51
Manjawila EPA	0.37	0.27	1.60	0.49	0.57	0.88
Gender (Male vs Female)	9.91	6.83	2.32	1.66	0.66	1.06
Age (Youth vs Elderly)	5.19	2.42	1.21	0.94	0.51	0.97
Market Value	6.37	1.26	2.01	0.16	0.29	3.09

Key Message: Men are nearly 10 times more likely than women to prefer appealing brown seeds, suggesting gender-differentiated trait preferences that must be considered in breeding programs where as in second season location effects dominate at harvest—farmers in Eswazini are 34 times more likely to prefer appealing brown seeds than those in Mombezi. Gender and age effects disappear in Season 2, suggesting seasonal dynamics shift preference drivers

3.2 Intention-Action Gap

There was a consistent discrepancy between farmers' stated preferences during interviews and their actual seed selections in the field (supported by Levin and Milgrom, 2004). This highlights the limitations of relying on survey data alone for breeding decisions. This research showed intention to plant local Bambara groundnut varieties progressively declined, disappearing entirely by Season 3 as farmers shifted to improved varieties following field experience. This evidence, supported by literature and this research, clearly shows that one-time consultations are insufficient to guide effective, farmer-centred breeding programs and seed systems for NUS (Begna, 2022).

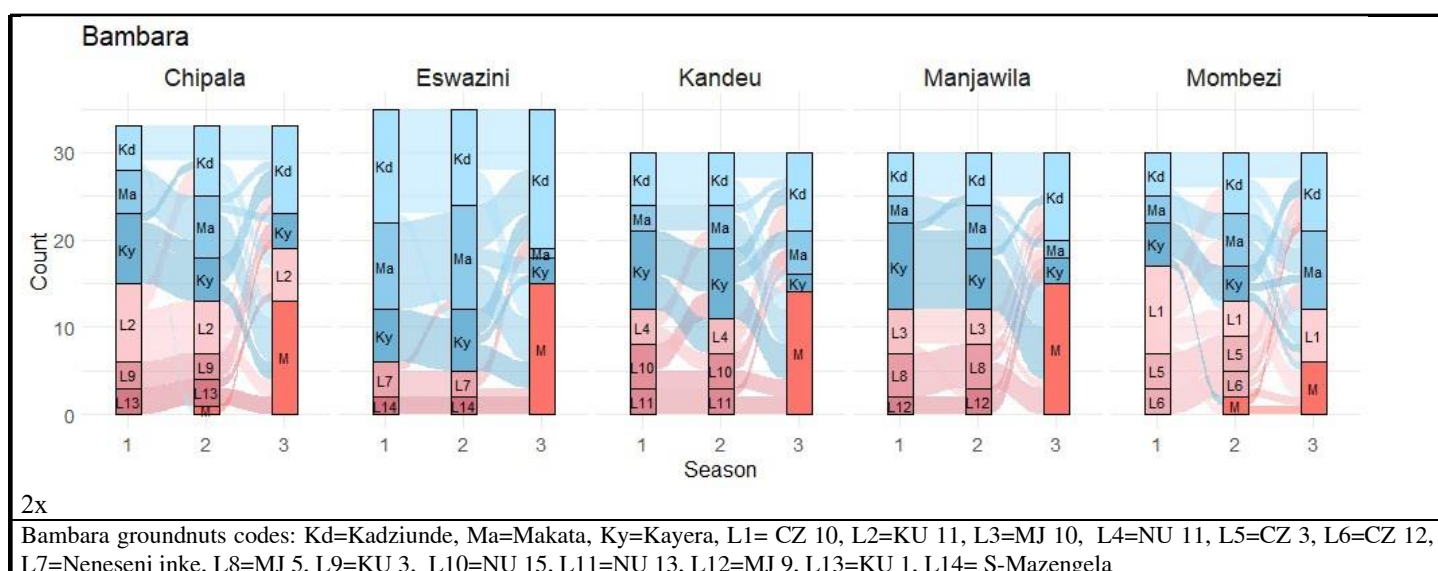
3.3 Dynamic Preferences

Preferences were not static. They evolved throughout the cropping season, from germination through vegetative growth to maturity, and across different growing seasons. A variety preferred at planting might be rejected at harvest based on its performance, a finding consistent with experiential learning theory (Kolb, 2013).

Figure 2 (x, y, z) illustrates the shifts in farmer preferences for Bambara groundnut

varieties and their associated traits across three consecutive pre-planting seasons. Figure 2x depicts the dynamics of individual farmers' variety preferences through connecting wavy lines between Season 1 and Season 3. The colour coding indicates initial preferences in Season 1, with blue representing improved varieties and red denoting local varieties. The patterns of these pre-planting decisions vary by location: in Chipala and Manjawila, minimal shifts in planned variety use occurred between Seasons 1 and 2, followed by substantial switching between Seasons 2 and 3. Conversely, in Kandeu and Mombezi, notable changes in pre-planting preference were observed primarily between Seasons 1 and 2.

Figure 2y presents a consolidated summary across all EPAs, with local varieties grouped together (shown in red). This visualization reveals a progressive decline in the intention to plant local varieties, culminating in their complete absence from pre-planting choices by Season 3, as farmers increasingly opted for improved varieties following Season 2. Figure 2z displays the frequency and proportion of traits preferred by farmers within each EPA, providing insight into the trait-based drivers of these pre-planting selections.



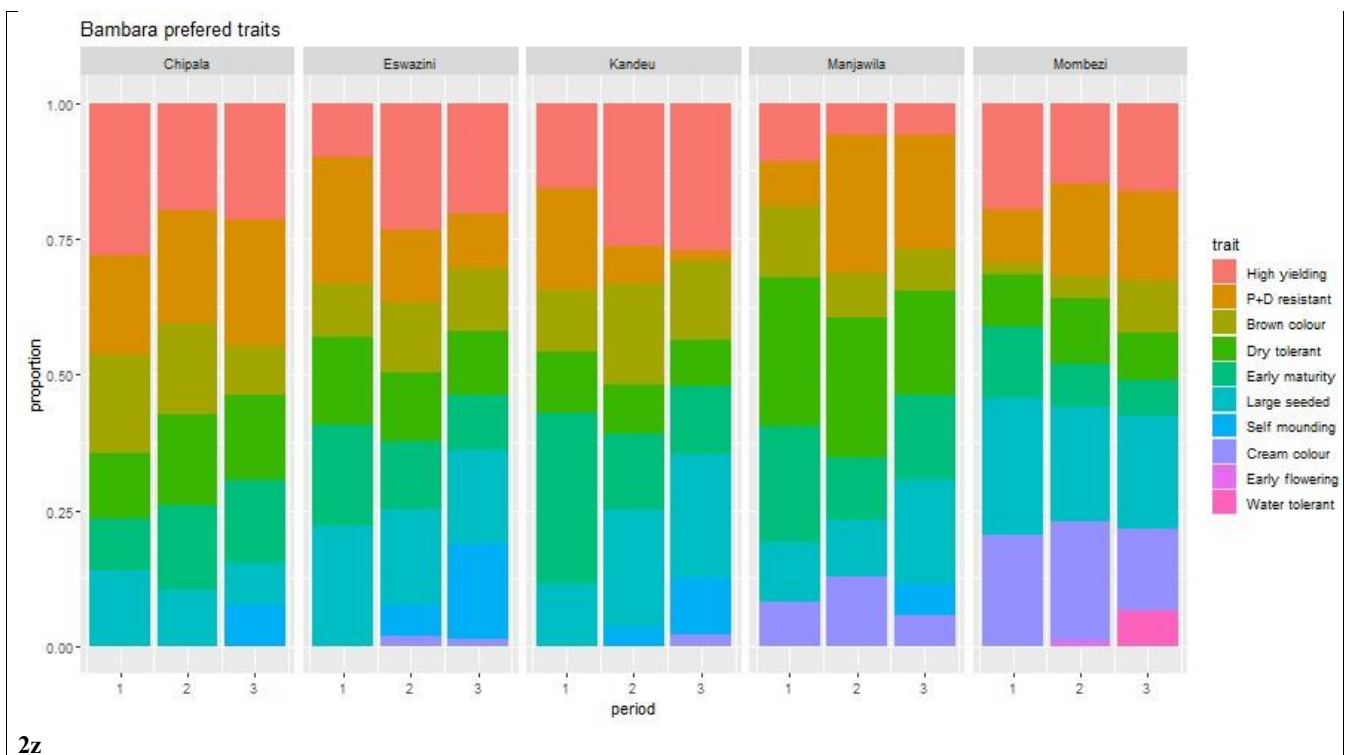
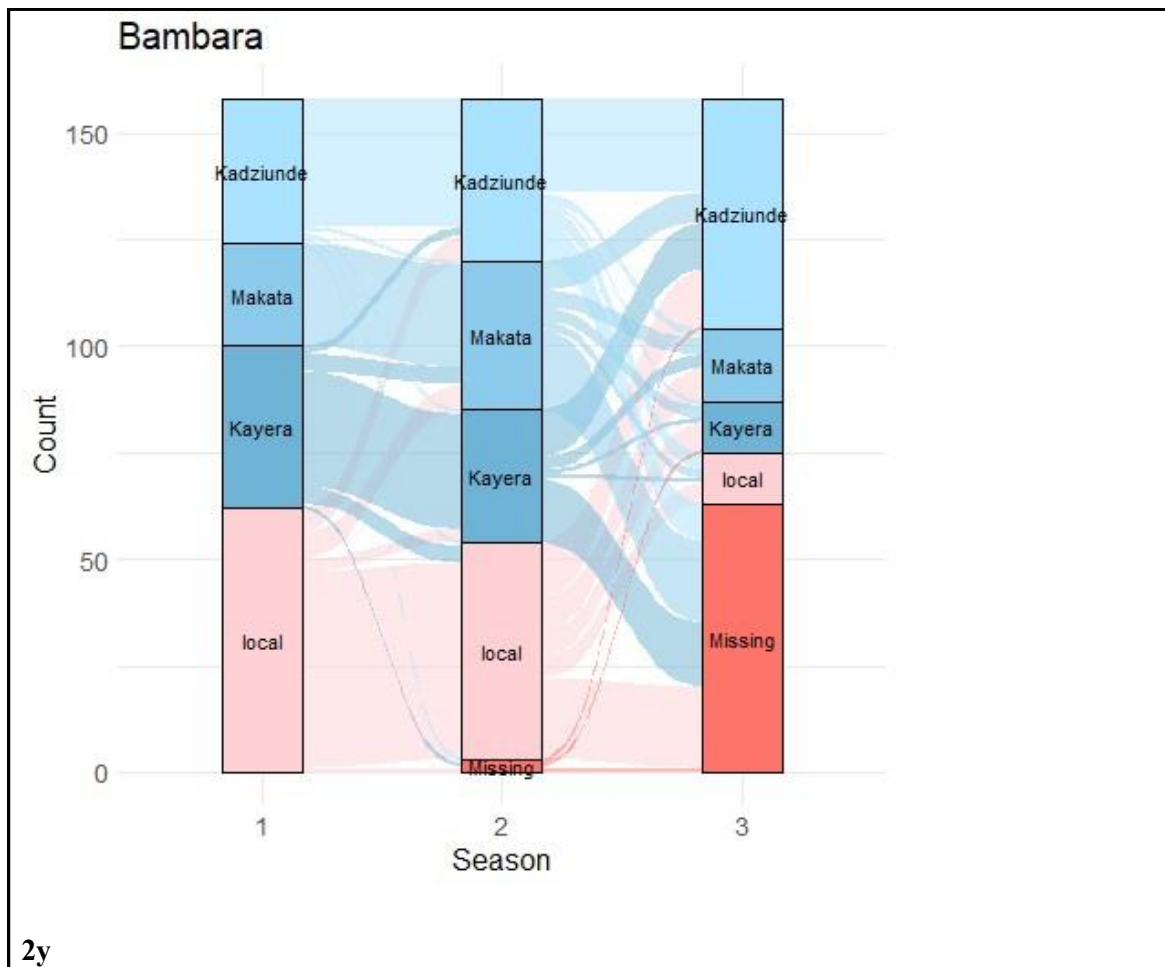


Figure 2. (x, y, z) illustrates the shifts in farmer preferences for Bambara groundnut varieties and their associated traits across three consecutive pre-planting seasons

4. Policy Recommendations

To address these challenges and unlock the potential of NUS varieties for climate-resilient agriculture, we propose the following policy actions:

3.1 Mainstream Long-Term Participatory Action Research (PAR) in National Agricultural Policy and research.

Action: The Ministry of Agriculture, in partnership with development partners and national research institutions (e.g., Lilongwe University of Agriculture and Natural Resources, Chitedze Research Station), should formally integrate long-term PAR methodologies in the national agricultural research policy and strategy.

Step	Activity	Lead Institution	Timeline	Budget Indicator
1	Mandate multi-season iterative farmer engagement in all public crop breeding programs	Ministry of Agriculture (MoA)	Year 1	Allocate specific budget line for PAR
2	Include NUS crops in national breeding programs with PAR approach	DARS, LUANAR	Year 1-2	Research budget reallocation
3	Develop national guidelines for conducting PAR in plant breeding and seed system development, drawing on proven models like the mother-baby trial design (Snapp, 2016).			
	LUANAR, DARS, MoA	Year 1-2	Technical assistance budget	
4	Pilot PAR approaches in 3 agro-ecological zones	DARS, LUANAR, Extension	Year 2-3	Pilot program budget
5	Scale successful PAR models nationally	MoA, DARS	Year 3-5	Scaling budget line

Key Performance Indicators:

- Number of breeding programs incorporating multi-season PAR
- Percentage of NUS varieties developed through PAR approaches
- Farmer adoption rates of PAR-developed varieties
- Reduction in variety abandonment rates post-release

Financing Mechanism:

- National budget should target funding to long term trials that apply PAR
- Development partner funding should also (e.g., IDRC, IFAD, World Bank, EU)
- Linking with Company as well national seed trade association of Malawi (STAM) to fund field trials with farmers

3.2. Decentralize Seed Production (contextualize) and Regulation.

Action: Reform seed policy to support the development of a decentralized seed system that recognizes and strengthens locally adapted varieties.

Table 7. Implementation roadmap to Decentralize Seed Production and Regulation

Step	Activity	Lead Institution	Timeline	Budget Indicator
1	Establish and support Local Seed Business (LSB) Hubs in key agro-ecological zones.	MoA, Seed Services Unit	Year 1-3	Capital investment budget
2	Train farmer organisations to produce, multiply, and market Quality Declared Seed of locally preferred NUS varieties (Mcguire <i>et al.</i> , 2016).			
	MoA, Extension, LUANAR	Year 1-2	Training budget	
3	Develop “Agro-Ecological Zone-Specific Seed Variety Promotion Kits”	DARS, Extension	Year 1-2	Technical development budget
4	Revise seed policy to open and strengthen Quality Declared Seed for NUS varieties (Vernooy <i>et al.</i> , 2022).			
MoA, Seed Services Unit	Year 1-2	Policy review budget		
5	Establish quality assurance systems for LSB Hubs	Seed Services Unit	Year 2-3	Quality assurance budget

Key Performance Indicators:

- Number of operational LSB Hubs established
- Volume of NUS Quality Declared Seed produced and marketed
- Percentage increase in farmer access to locally adapted NUS varieties
- Number of farmers engaged in LSB Hubs (disaggregated by gender)

Financing Mechanism:

- Public-private partnerships for seed production infrastructure
- Development partner support for LSB Hub establishment
- Farmer cooperative investment contributions

3.3 Integrate PAR Principles into the Agricultural Extension Education.

Action: Revise the curriculum and approach of Malawi’s agricultural extension services to move beyond technology transfer towards facilitation of participatory learning, adaptation and adoption.

Table 8. Implementation roadmap to Integrate PAR Principles into the Agricultural Extension Education.

Step	Activity	Lead Institution	Timeline	Budget Indicator
1	Revise extension curriculum to include PAR techniques	MoA Extension, LUANAR	Year 1-2	Curriculum development budget
2	Train extension workers in PAR techniques for continuous co-learning with farmers	Extension Training Centres	Year 2-3	Training budget
3	Establish feedback mechanisms between extension workers and researchers	Extension, DARS	Year 2-3	M&E budget
4	Develop short courses targeting field extension workers and researchers on PAR	LUANAR, Extension	Year 1-3	Short course budget

Key Performance Indicators:

- Percentage of extension workers trained in PAR techniques
- Number of PAR-based extension programs implemented
- Farmer satisfaction with extension services (disaggregated by gender)
- Feedback loop functionality between extension and research

Financing Mechanism:

- Government extension service budget reallocation
- Development partner support for curriculum revision

Table 9. Institutional Coordination Framework

Recommendation	Lead Institution	Key Partners	Coordination Mechanism
Mainstream PAR	Ministry of Agriculture	LUANAR, DARS, Development Partners	Agricultural Research Technical Working Group
Decentralize Seed production	MoA Seed Services Unit	LSB Hubs, Farmer Orgs, Private Sector	Seed Policy Implementation Committee
Integrate PAR principles in Agri-Extension Education	MoA Extension	LUANAR, DARS, Farmers	Extension Coordination Forum

Expected Impact and Link to Climate Change

Implementing these recommendations will yield significant benefits, particularly for climate change adaptation and mitigation:

4.1. Enhanced Climate Adaptation

By promoting locally adapted, drought-tolerant NUS varieties that farmers actually want and will plant, we directly enhance the resilience of farming systems to climate variability (e.g., erratic rainfall, droughts).

4.2. Improved Food and Nutrition Security

Widespread adoption of suitable NUS varieties will stabilize and diversify local food production and diets, reducing vulnerability to crop failure of staple cereals (Hunter *et al.*, 2019).

4.3. Empowerment of Local Systems

Strengthening farmer-managed seed systems empowers communities, particularly women who are often custodians of these crops, to be active agents in their own adaptation strategies (Sperling *et al.*, 2013a).

5. Implementation feasibility and Risk Mitigation

Table 10: Potential Barriers and Mitigation Strategies

Barrier	Mitigation Strategy
Limited funding for long-term PAR	Blend government budget with development partner funding; establish PAR innovation fund
Institutional resistance to change	Build coalitions; demonstrate early wins; engage champions
Limited technical capacity	Invest in training; establish South-South learning exchanges
Regulatory barriers	Engage Seed Services Unit early; develop NUS-specific regulatory pathways
Private sector disinterest	Demonstrate market potential; create incentives for NUS value chains

6. Gender and Social Inclusion

Women are central to the conservation and management of NUS yet remain systematically undervalued in formal seed systems and policy (Hunter *et al.*, 2019). Our research elevated women's voices, capturing their distinct trait preferences including drought tolerance, early maturity, and market-oriented traits, that conventional consultations overlook (Tchuwa *et al.*, 2022). Women face differentiated access to seed, land, and information, yet top-down breeding rarely accounts for this diversity (Sperling *et al.*, 2013). Gender-responsive participatory breeding improves not only adoption but also women's decision-making autonomy and household nutrition (Mkwambisi *et al.*, 2021). Despite Malawi's gender policy commitments, implementation gaps persist, making it imperative that PAR mainstreaming, seed system decentralization, and extension reform explicitly center women as leaders rather than passive beneficiaries

(Waldman *et al.*, 2016).

7. Conclusion

The complexity of agricultural systems in the face of climate change demands deeper, more meaningful, and sustained collaboration with farmers. By adopting the policies outlined in this brief, mainstreaming PAR, decentralizing seed systems, and transforming extension services, Malawi and similar countries in sub-Saharan Africa can build robust, climate-resilient seed systems that truly serve the farmers at all scales. Agricultural complexity amid climate change demands deeper, sustained collaboration with farmers. Mainstreaming PAR, decentralizing seed systems, and transforming extension services is not optional, it is essential. This approach builds robust, climate-resilient systems that serve all farmers, unlocking greater adoption, resilience, and food security across Malawi.

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