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AGRONOMIC PERFORMANCE AND LAND PRODUCTIVITY OF SORGHUM–LEGUME INTERCROPPING SYSTEMS UNDER SMALLHOLDER FARMING CONDITIONS IN MIGORI COUNTY, KENYA

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Abstract

Low agricultural productivity in the arid and semi-arid lands (ASALs) of Kenya is largely attributed to monocropping systems, sub-optimal soil and water management, inadequate pest and disease control, and limited use of adapted crop varieties. Integrating climate-resilient crops such as sorghum into diversified cropping systems can greatly enhance sustainable agricultural intensification. This study aimed to: (i) evaluate the performance of sorghum under different intercropping systems and (ii) identify suitable sorghum–legume intercrop combinations using farmer-preferred varieties. On-farm trials were conducted with 16 farmers across five villages (Godkwer, Mukuro, Nyamanga, Nyamaraga, and Waswetta II) in Migori County, Kenya. Farmers selected two improved sorghum varieties (one tall and one short) out of a pool of 8 varieties and two legume crops (beans and groundnut). The crops were grown as sole stands or in intercrop combinations in plots measuring 4 × 3.75 m arranged in RCBD replicated thrice for two seasons. Results showed significant differences ($p < 0.05$) between monocropping and intercropping systems. In all cases sorghum grain yields were higher under sole cropping than in the Mbili intercropping system across both seasons except for varieties Muk 60 and C26 which produced higher yields when intercropped with legumes. Sorghum grain yield was generally higher in 2024 than in 2025 across most villages, except in Nyamaraga where the opposite trend was observed. In contrast, legume yields were generally higher in 2025 than in 2024 across all sites. There were no significant differences in sorghum performance when intercropped with beans or groundnuts, with mean sorghum yields of 2.03 t ha^{-1} and 2.02 t ha^{-1}, respectively. Nevertheless, farmers preferred sorghum–bean intercrops due to the earlier maturity of beans, which provides an early food source during the season. The land equivalent ratio (LER) varied significantly ($p < 0.05$) depending on sorghum variety and legume crop, indicating that appropriate variety selection is critical for maximizing land productivity. Total LER values ranged from 1.33 to 2.06, demonstrating the potential advantage of intercropping in improving land use efficiency and farm productivity. Five farmer-preferred sorghum varieties with LER values between 1.25 and 2.0 were identified as suitable for enhancing income, food availability, and nutritional outcomes. Intercropping systems performed better with dwarf sorghum varieties than with tall varieties. The study demonstrates that sorghum–legume intercropping can enhance land productivity, strengthen resilience, and contribute to improved food and nutrition security in smallholder farming systems.

Keywords: *Intercropping, diversification, resilience, land equivalent ratios sorghum varieties*

Introduction

Agricultural productivity in sub-Saharan Africa remains constrained by multiple interacting biophysical and socio-economic factors, including declining soil fertility, climate variability, and limited adoption of improved agronomic practices. In western Kenya, particularly within the Lake Victoria Basin counties of Busia, Siaya, Migori, Kisumu, and Homa Bay, crop production is increasingly affected by erratic rainfall patterns, periodic drought, and declining soil fertility (Opala et al., 2010;

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Kisinyo et al., 2020; Vanlauwe et al., 2021). The region is also characterized by acidic soils with aluminum toxicity, phosphorus deficiency, and micronutrient imbalances, which collectively limit crop productivity and sustainability of smallholder farming systems (Sanchez et al., 1997; Sheahan & Barrett, 2020; Vanlauwe et al., 2021). These constraints contribute to persistent food and nutrition insecurity and high poverty levels among rural households.

Sorghum is widely recognized as a climate-resilient crop well suited to marginal environments due to its C4 photosynthetic pathway, extensive root system, and physiological capacity to tolerate drought and high temperatures (Rakshit et al., 2021). These characteristics make sorghum particularly suitable for fragile agro-ecosystems such as those found in western Kenya. However, cultivation of sorghum under monocropping systems often fails to maximize its productivity or ecological benefits. Continuous monocropping of cereals, combined with minimal application of fertilizers or organic amendments, has accelerated soil degradation and increased infestations of parasitic weeds such as *Striga hermonthica* (Midega et al., 2020; Odeny et al., 2021). As a result, yields of major cereals grown by smallholder farmers remain substantially below their potential. Sorghum (*Sorghum bicolor* L. Moench), an important staple crop in semi-arid regions, typically produces less than 1.0 t ha^{-1} under smallholder farmer management despite having much higher potential yields (FAOSTAT, 2023). The low productivity is further compounded by limited access to improved seed, poor crop management practices, and inadequate investment in agricultural research and extension services.

Agro-ecological intensification strategies such as cereal–legume intercropping offer promising opportunities to improve productivity while maintaining ecosystem sustainability. Intercropping systems enhance resource use efficiency by optimizing the capture of light, water, and nutrients while also contributing to soil fertility through biological nitrogen fixation by legumes (Kermah et al., 2020; Maitra et al., 2021). Furthermore, cereal–legume intercrops can reduce pest and weed pressures, improve soil organic matter, and increase the resilience of farming systems to climate variability (Pretty et al., 2020; Raseduzzaman & Jensen, 2020). In many parts of sub-Saharan Africa, smallholder farmers traditionally practice intercropping; however, these systems are often poorly structured with sub-optimal plant densities, unsuitable crop combinations, and limited use of improved varieties (Vanlauwe et al., 2021). In western Kenya, maize–bean intercropping dominates, yet maize often performs poorly due to moisture stress and soil infertility (Ochieng et al., 2022). Sorghum–legume systems may therefore offer a more resilient alternative, particularly where maize yields are frequently compromised by drought or *Striga* infestation (Odeny et al., 2021).

Legume integration into cereal systems has been shown to improve soil nitrogen availability, suppress parasitic weeds, and enhance overall system productivity (Kermah et al., 2020; Maitra et al., 2021). However, the selection of appropriate legume species and compatible crop varieties remains critical, particularly in areas affected by soil acidity and nutrient deficiencies. Despite the potential benefits of sorghum–legume intercropping, limited research has evaluated the performance of farmer-preferred sorghum varieties within such systems under smallholder conditions in western Kenya. Therefore, this study was conducted to evaluate the agronomic performance of sorghum under different intercropping systems and to identify suitable sorghum–legume combinations that enhance land productivity and food security among smallholder farmers in Migori County, Kenya.

Research Methodology

The study was conducted in Migori County in western Kenya within the Lake Victoria Basin. The experimental sites were located in five villages: Godkwer (1.039954° S, 34.311485° E), Mukuro (1.037180° S, 34.365310° E), Nyamanga (1.050594° S, 34.430150° E), Nyamaraga (1.126200° S, 34.369307° E), and Waswetta II (1.092502° S, 34.411717° E). The study sites fall predominantly within the Lower Midland 3 (LM3) agro-ecological zone. The region experiences a bimodal rainfall pattern with long rains occurring between March and August and short rains between October and December. Annual rainfall ranges between 900 and 1600 mm but is often erratically distributed, resulting in periodic moisture stress that limits crop productivity.

The dominant soils in the region are highly weathered Ferralsols and Acrisols characterized by low fertility, high acidity, and nutrient imbalances, particularly phosphorus deficiency and aluminum toxicity (Kisinyo et al., 2013). On-farm participatory trials were conducted during the 2024 and 2025 long rain seasons with 16 smallholder farmers distributed across the five villages. Each village had 3 farmers except Waswetta 2 which had four farmers. Farmers participated in selecting sorghum varieties and managing the trials under guidance from the research team. Two cropping systems were evaluated: Sole cropping system (monocropping), MBILI intercropping system. Farmers selected two improved sorghum varieties representing contrasting plant architecture (one tall and one short) from a pool of eight varieties previously evaluated in the region (Tall ones were T53B, T30B, N68. MUK 27 while short to medium were-MUK 60, E5, E1, , C26). The selected sorghum varieties were intercropped with two commonly grown legumes: Common bean (*Phaseolus vulgaris* L.) – GLP 2-Nyayo variety and Groundnut (*Arachis hypogaea* L.) – Red Valencia variety. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications per farm. Each experimental plot measured 4 m × 3.75 m. In the intercropping treatment, six rows of sorghum were planted alternately with six rows of legumes. Legume rows were planted in paired rows between sorghum rows at an inter-row spacing of 33 cm, while sorghum rows were spaced 75 cm apart. Within-row spacing was maintained at 25 cm for sorghum and 15 cm for legumes for the monocrop treatment, sorghum was planted at a spacing of 75 cm × 25 cm, while legumes were planted at 33 cm × 15 cm. Basal fertilizers were applied at rates of 75 kg N ha^{-1} and 30 kg P ha^{-1}, following local agronomic recommendations. Standard agronomic practices including land preparation, weeding, and pest control were implemented uniformly across all treatments. Trials were jointly managed by farmers and researchers to ensure adherence to recommended practices while maintaining realistic farmer field conditions. Data were collected at physiological maturity from six randomly selected plants within the inner rows of each plot to minimize border effects. For sorghum, the following parameters were measured: plant height (cm), panicle characteristics and grain yield (t ha^{-1}) while for legumes, number of branches, Number of pods per plant and Pod yield (t ha^{-1}) were recorded. Grain yields were adjusted to standard moisture content before analysis. The productivity advantage of intercropping systems was evaluated using the Land Equivalent Ratio (LER) based on (Menezes & Voigt, 2017).

$$LER = \frac{Y_{si}}{Y_{sm}} + \frac{Y_{li}}{Y_{lm}}$$

Where:

- Y_{si} = yield of sorghum in intercrop
- Y_{sm} = yield of sorghum in monocrop
- Y_{li} = yield of legume in intercrop
- Y_{lm} = yield of legume in monocrop

Data were analyzed by analysis of variance (ANOVA) framework using GenStat (20th Edition) statistical software. Cropping system, sorghum variety, village, and year were treated as fixed effects, while farmer fields were treated as random effects. Means were separated using the least significant difference (LSD) test at $p \leq 0.05$.

Results and Discussions

On-Farm Variation in Sorghum Grain Yield and Plant Height in selected fields in Migori County

Grain yield and plant height differed significantly ($P \leq 0.05$) among the 16 farmers' fields in both growing seasons (Table 1). In 2024, grain yield ranged from 1.63 to 2.45 t ha^{-1}, with a mean of 2.15 t ha^{-1}, while plant height ranged from 138.33 to 207.50 cm, averaging 173.84 cm. In 2025, grain yield ranged from 1.56 to 2.47 t ha^{-1}, with a mean of 2.04 t ha^{-1}, whereas plant height varied from 138.33 to 200.83 cm, with a mean of 173.51 cm. Farmer 6 recorded the highest grain yield in 2024 (2.45 t ha^{-1}), while Farmer 15 achieved the highest yield in 2025 (2.47 t ha^{-1}). The lowest grain yields were recorded in Farmer 16 (1.63 t ha^{-1}) and 3 (1.56 t ha^{-1}) during 2024 and 2025, respectively. The significant variation in grain yield and plant height was expected and reflects differences in field conditions and/or crop management practices among the farmers.

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Table 1
Mean grain yield and plant height of sorghum grown on 16 selected farmers' fields at the Migori site during the 2024 and 2025 growing seasons.

Farmer No.	Year 2024		Year 2025	
	Yield (t ha^{-1})	Height (cm)	Yield (t ha^{-1})	Height (cm)
1	2.38^{a}	181.67^{abcde}	2.40^{ab}	192.29^{ab}
2	2.17^{abc}	207.50^{a}	2.02^{def}	200.67^{a}
3	1.77^{cd}	153.00^{ef}	1.56^{g}	160.67^{c}
4	2.37^{a}	167.50^{bcdef}	2.06^{def}	160.42^{c}
5	2.35^{a}	204.67^{ab}	2.07^{de}	200.42^{a}
6	2.45^{a}	180.83^{abcde}	2.08^{cde}	184.17^{b}
7	2.37^{a}	191.67^{abcd}	2.38^{abc}	195.21^{ab}
8	2.20^{ab}	185.83^{abcde}	2.02^{def}	186.67^{ab}
9	1.92^{bcd}	148.00^{ef}	1.90^{def}	150.83^{cd}
10	2.25^{ab}	158.33^{def}	1.85^{efg}	149.17^{cd}
11	1.78^{cd}	138.33^{f}	1.73^{fg}	138.33^{d}
12	1.68^{d}	160.00^{cdef}	1.93^{def}	157.33^{c}
13	2.27^{ab}	197.50^{abc}	2.13^{bcde}	190.00^{ab}
14	2.38^{a}	168.33^{bcdef}	2.18^{abcd}	160.42^{c}
15	2.37^{a}	198.33^{abc}	2.47^{a}	200.83^{a}
16	1.63^{d}	140.00^{f}	1.91^{def}	148.75^{cd}
Root MSE	0.36	33.35	0.39	19.37
Grand mean	2.15	173.84	2.04	173.51

Means followed by the same letter(s) within a column do not differ significantly at $P \leq 0.05$ (Fisher's LSD).

Performance of Sorghum Varieties under Intercropping Systems

Fig 1 show comparison of response of sorghum varieties to intercrops combinations across 16 farmer fields in 2024 and 2025 long growing season. Across the two cropping seasons, sorghum grain yields were generally higher under sole cropping compared with the Mbili intercropping system. Varieties T53B and T30B consistently recorded the highest grain yields under monocropping during both the 2024 and 2025 seasons. In contrast, the variety Muk 60 showed the greatest variability across seasons, while E1 and E5 exhibited relatively stable performance across both cropping systems and years.

In 2025, Sorghum yield were higher in mono than in intercrops for majority of the varieties with exception of Muk 60 and C26 where intercrop with either of the legume gave higher yields (Fig 1). The highest yielding sorghum in mono was T530b (2.7 t/ha) while the lowest yielding one was Muk 60 (1.70 t/ha). Yield responses of sorghum varieties differed depending on the associated legume species. For example, T53B produced higher yields when intercropped with beans (2.50 t ha^{-1}) compared with groundnuts (2.20 t ha^{-1}). In contrast, T30B showed no significant yield difference between bean and groundnut intercrops. Similar trend followed for plant height (Fig 1). There were no significant differences in sorghum yield when intercropped with beans or groundnuts, with mean yields of 2.03 t ha^{-1} and 2.02 t ha^{-1}, respectively. Despite comparable yields, farmers preferred sorghum–bean intercrops because beans mature earlier, providing food sooner in the season. Nevertheless, our discussions with farmers also emphasized the additional long-term benefits of incorporating groundnut as an intercrop or rotation crop, including biological nitrogen fixation and reduced *Striga* infestation. In the 2025 season, most sorghum varieties produced higher yields under monocropping, with the exception of Muk 60 and C26, which performed better when intercropped with legumes. The highest grain yield under monocropping was recorded for variety T53B (2.7 t ha^{-1}), while the lowest yield was observed for Muk 60 (1.70 t ha^{-1}) (Figure 1).

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Figure 1

Response of elite sorghum varieties to intercrops combinations across 16 farmer fields in 2024 and 2025 long rain season

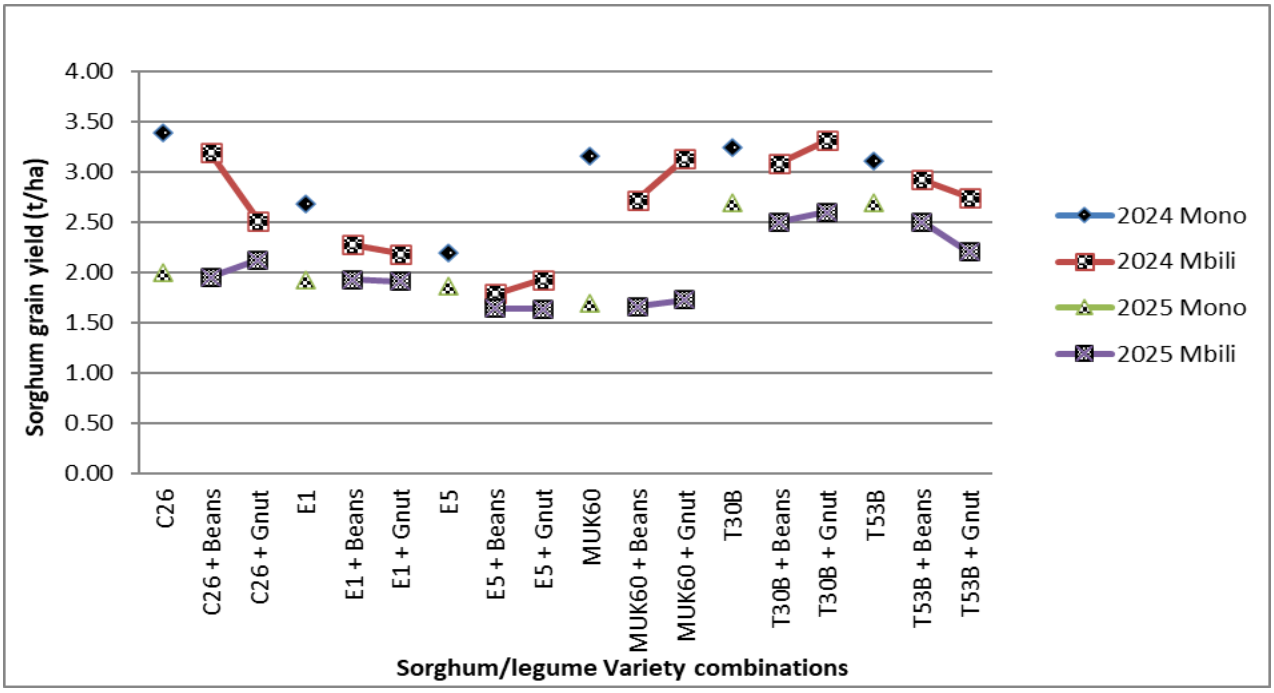


Figure 2

Demonstration of intercrops of sorghum with (a) groundnuts & (b) beans in Migori site (Owner)



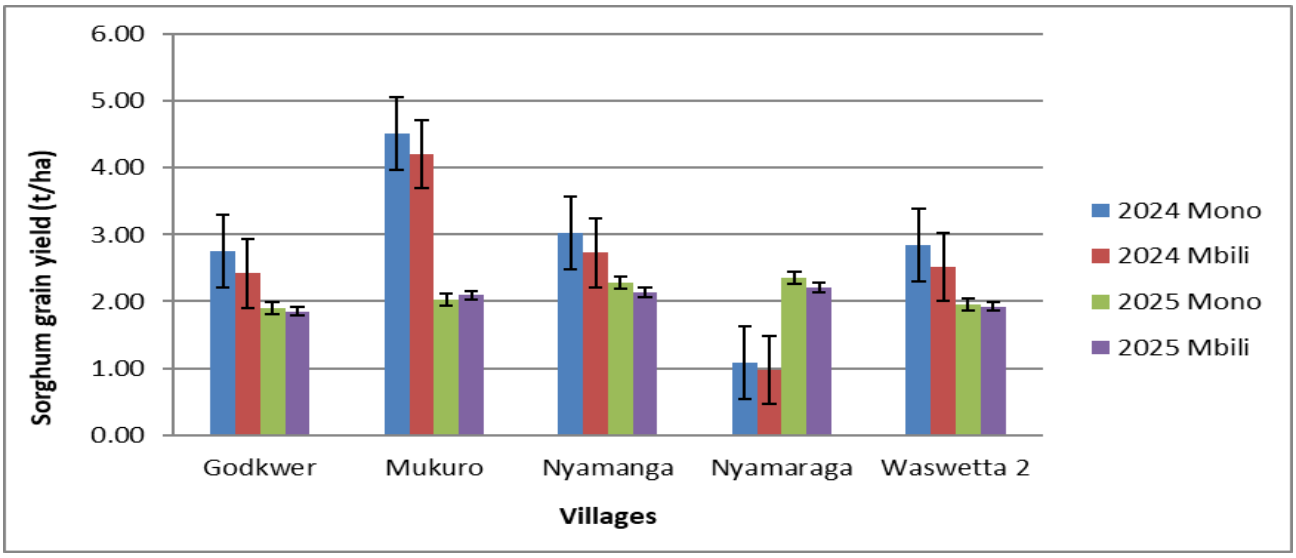
Variation in Sorghum Performance in intercrops across villages

Sorghum grain yield varied markedly among the five study villages and between seasons (Fig. 3). Grain yields were higher in 2024 than in 2025 under both sole cropping and intercropping systems in all villages except in Nyamaraga. Mukuro consistently recorded the highest yields in both years (4.2–4.5 t ha^{-1} in 2024), whereas Nyamaraga had the lowest yields in 2024 (below 1.2 t ha^{-1}). In contrast, Nyamaraga was the only site where sorghum yield improved in 2025, reaching about 2.2–2.4 t ha^{-1} under both cropping systems. Nyamanga also experienced a marked decline in yield in 2025, which was associated with early-season moisture stress that reduced crop establishment and productivity. Overall, differences between sole cropping and intercropping within individual villages were relatively small, indicating that seasonal and location effects had a greater influence on sorghum performance than the cropping system.

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Figure 3

Performance of elite sorghum varieties in sole and intercrops across 5 villages in 2024 and 2025 growing season



Performance of Bean and groundnut under sole and intercropping Systems

Legume performance differed between sole cropping and intercropping systems across sorghum varieties and seasons (Table 2). Sole-cropped beans and groundnuts consistently outyielded their respective intercrops in both years. Mean sole bean yield increased from 1.61 t ha^{-1} in 2024 to 2.50 t ha^{-1} in 2025, while sole groundnut yield increased from 1.88 to 2.75 t ha^{-1} over the same period. Intercropped bean yields ranged from 0.98 to 1.50 t ha^{-1} in 2024 and from 1.15 to 2.00 t ha^{-1} in 2025, whereas intercropped groundnut yields ranged from 0.88 to 1.56 t ha^{-1} in 2024 and from 1.41 to 2.03 t ha^{-1} in 2025. Beans generally produced higher intercrop yields when grown with the shorter sorghum varieties E1 and E5, recording the highest yields of 1.95 and 2.00 t ha^{-1}, respectively, in 2025. Similarly, groundnut intercrop yields were highest with MUK 60 (2.03 t ha^{-1}), followed by C26 (1.93 t ha^{-1}) and E5 (1.78 t ha^{-1}). Overall, legume productivity improved in 2025 across all cropping systems, with relatively higher intercrop yields achieved when legumes were grown with shorter or less competitive sorghum varieties.

Table 2

Overall bean and groundnut yields (t ha^{-1}) under sole cropping and intercropping with different sorghum varieties across five villages.

Sorghum variety	Beans 2024		Beans 2025		Groundnuts 2024		Groundnuts 2025	
	MB	IB	MB	IB	MG	IG	MG	IG
C26	1.61	1.18bc	2.50	1.68b	1.88	0.88e	2.75	1.93a
E1	1.61	1.09cd	2.50	1.95a	1.88	1.56a	2.75	1.64bc
E5	1.61	1.12c	2.50	2.00a	1.88	1.32bc	2.75	1.78b
MUK27	1.61	1.50a	2.50	1.44c	1.88	1.32bc	2.75	1.44d
MUK60	1.61	1.30b	2.50	1.80b	1.88	1.07d	2.75	2.03a
T30B	1.61	1.10cd	2.50	1.15d	1.88	1.41b	2.75	1.41d
T53B	1.61	0.98d	2.50	1.44c	1.88	1.23c	2.75	1.62c
Mean		1.18		1.64		1.26		1.69

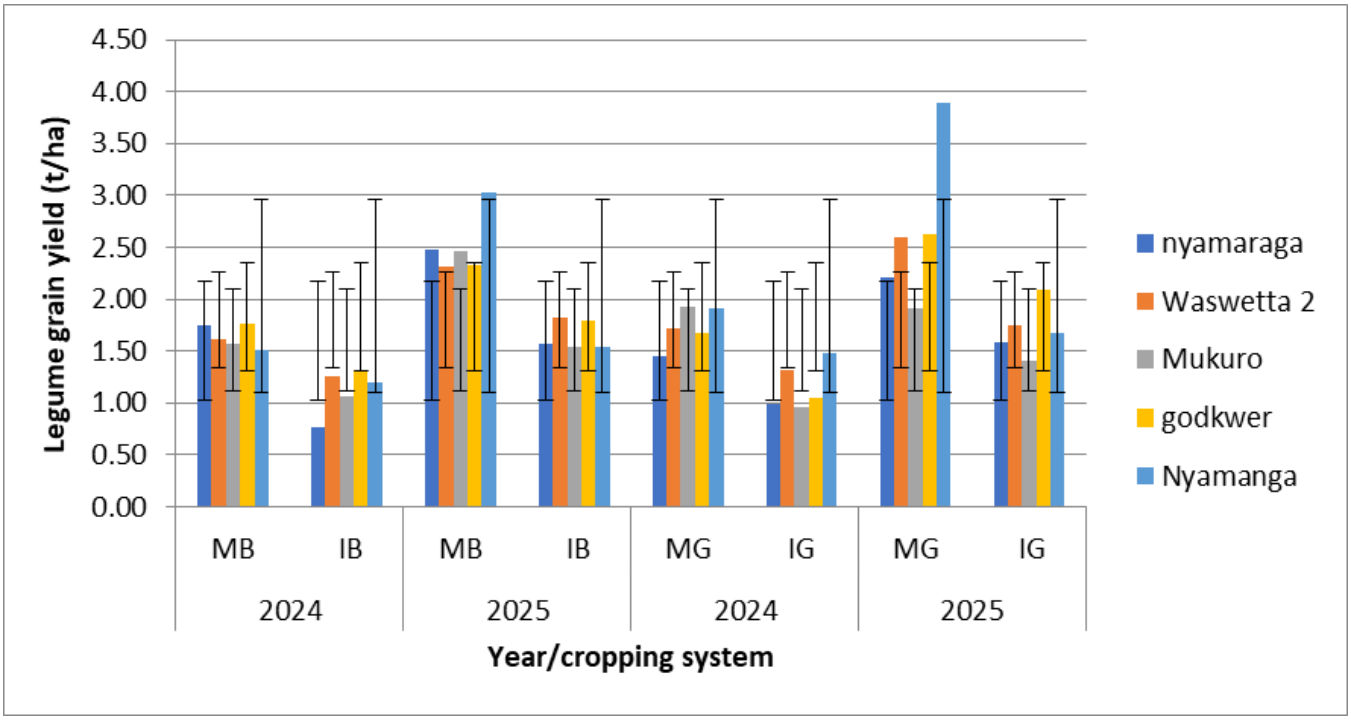
MB- beans as monocrop, IB-beans intercropped with sorghum, MG-groundnut as monocrop, IG-groundnut intercrop with sorghum

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Significant differences in legume grain yields were observed among villages in both years. In contrast to sorghum, legume yields were generally higher in 2025 than in 2024 across all study sites (Fig. 4). Nyamanga recorded the highest yields for both beans (3.03 t ha^{-1}) and groundnuts (3.89 t ha^{-1}), whereas the lowest bean yield was obtained in Waswetta II (2.31 t ha^{-1}) and the lowest groundnut yield in Mukuro (1.92 t ha^{-1}) (Fig. 4). The superior performance in Nyamanga was attributed to its well-drained sandy loam soils, which provided favorable conditions for crop establishment and growth. This was further supported by the higher germination rates observed in the village compared with the other study sites.

Figure 4

Mean yield of bean and groundnuts in sole and intercrop with sorghum across five villages in Migori



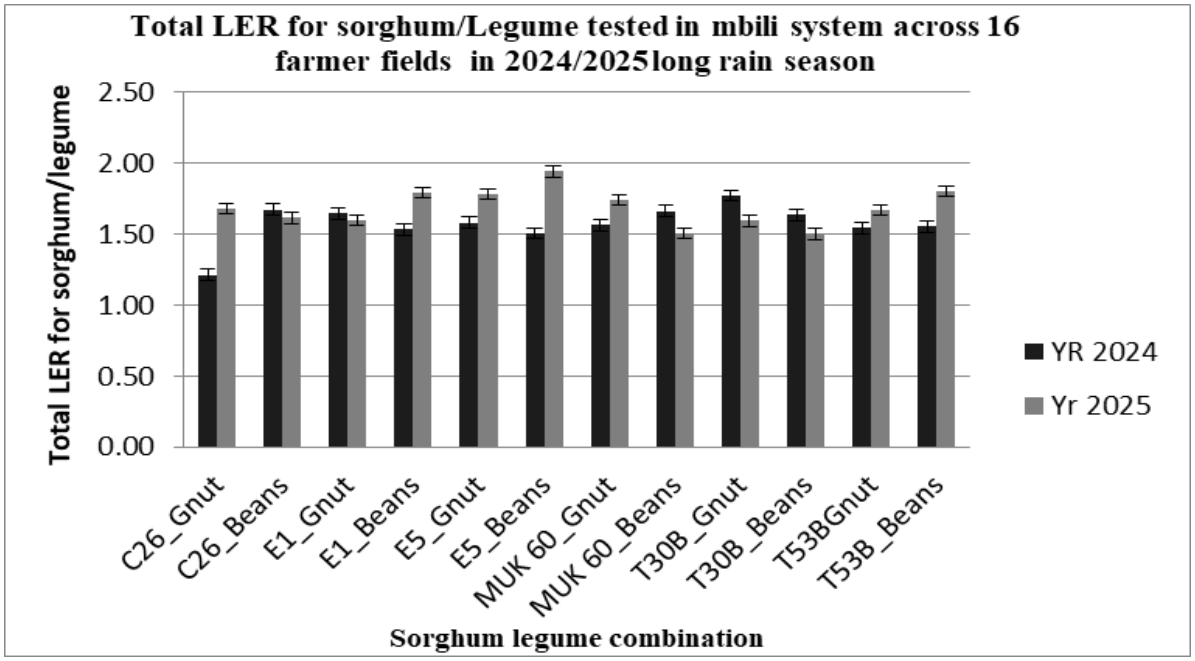
Land Equivalent Ratio

Land equivalent ratio (LER) varied significantly among sorghum–legume combinations. In both cropping seasons, total LER were generally above 1 with all the legume varieties used indicating a productivity advantage of intercropping over monocropping with the farmers in Migori. The highest LER for bean intercrops (1.94) was recorded with sorghum variety E5, while the lowest value (1.50) occurred with variety MUK 60. For groundnut intercrops, the highest LER (1.78) was also observed with variety E5 and lowest (1.60) with variety E1. Both groundnut and bean gave similar LER values (1.69 for beans and 1.67 for groundnut) (Fig 5).

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Figure 5

Total LER for sorghum/legumes tested in mbili system across 16 fields for 2 seasons



Discussions

The results of this study demonstrate that sorghum–legume intercropping systems can improve land productivity and resilience in smallholder farming systems in western Kenya. The significant variation in grain yield and plant height among farmers' fields across the two growing seasons indicates that sorghum performance was influenced by differences in field-specific environmental conditions and their interaction with the cropping system. Farmers 15, 1, and 7 recorded comparatively higher grain yields, which may be associated with differences in soil characteristics, soil nutrient availability, soil moisture retention, microclimatic conditions, previous cropping history, or other site-specific factors that were not quantified in the present study. Similar findings have been reported in recent studies, which identified environmental conditions, soil properties, and management practices as important drivers of sorghum yield variability across production environments. In particular, soil properties and rainfall variability can substantially influence sorghum yield, with low soil organic carbon and nitrogen availability contributing to reduced on-farm productivity (Muui et al., 2026; Li et al. (2025)

The significant differences in plant height further reflect variability in growing conditions among farms. Plant height is a key indicator of crop vigor and has been positively associated with biomass accumulation and yield potential under favorable environments. Other studies have likewise reported significant variation in plant height and grain yield in sorghum due to genotype × environment interactions and field management practices (Ngidi et al.,2024). These findings highlight the need for site-specific agronomic management to reduce yield variability and improve sorghum productivity among smallholder farmers.

Although monocropping produced slightly higher sorghum yields in some cases, the overall productivity advantage of intercropping was evident from the consistently high land equivalent ratios (LER) observed across treatments. LER values greater than one indicate more efficient utilization of available resources such as light, water, and nutrients compared with monocropping. This suggests that the component crops were able to exploit ecological complementarities that improved overall system productivity. Similar productivity advantages of cereal–legume intercropping have been widely reported in smallholder farming systems across sub-Saharan Africa, where diversification

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of cropping systems enhances resource use efficiency and reduces production risks (Lithourgidis et al., 2011; Mucheru-Muna et al., 2010; Kermah et al., 2020; Maitra et al., 2021). Recent meta-analyses further indicate that intercropping systems often provide greater yield stability and improved land productivity compared with sole cropping systems under variable climatic conditions (Raseduzzaman & Jensen, 2020; Smith et al., 2025).

The superior performance of certain sorghum varieties under intercropping highlights the importance of genotype selection for optimizing intercrop productivity. Shorter sorghum varieties such as E1 and E5 were particularly compatible with legumes, likely due to reduced shading effects and improved spatial complementarity between the component crops. Crop architecture, canopy structure, and phenological characteristics strongly influence the degree of competition or complementarity between intercrop components. Sorghum varieties with moderate plant height and less aggressive canopy development allow greater light penetration to the understory legume crop, thereby enhancing overall system productivity. Similar observations have been reported in other cereal–legume systems where plant architecture and growth duration influence interspecific competition and resource partitioning (Bedoussac et al., 2015; Maitra et al., 2021). Further research has shown that optimizing varietal combinations in intercrops can significantly enhance productivity through improved niche differentiation and temporal resource use (Gitari et al., 2020; Brooker et al., 2021).

The absence of significant yield differences between bean and groundnut intercrops suggests that both legumes can successfully be integrated into sorghum-based production systems in Migori County. However, farmers expressed a stronger preference for bean intercrops because of their shorter maturity period, which allows earlier access to food during the growing season. Farmer preferences play a critical role in the adoption of improved agricultural technologies, particularly in smallholder systems where resource constraints and risk management strongly influence decision-making. Participatory and farmer-centered approaches have been shown to significantly enhance adoption of improved cropping practices and technologies (Vanlauwe et al., 2021).

The observed variability in crop performance across villages underscores the strong influence of environmental heterogeneity on crop productivity in smallholder farming systems. Differences in soil fertility status, slope gradients, pest and disease pressure, and rainfall distribution were important determinants of yield variability among farms. Such spatial heterogeneity is a common characteristic of smallholder agricultural landscapes in sub-Saharan Africa and often results in large variations in crop performance even within relatively small geographical areas. These findings emphasize the need for site-specific and context-adapted agronomic recommendations when promoting improved cropping systems in heterogeneous agro-ecological environments (Tittonell et al., 2008; Vanlauwe et al., 2021). Integrated soil fertility management approaches that combine improved crop varieties, organic inputs, and appropriate cropping systems have been shown to significantly improve productivity in such heterogeneous systems (Vanlauwe et al., 2021; Giller et al., 2021). The higher legume yields observed in 2025 compared with 2024 may be attributed to improved rainfall distribution and better crop establishment during the second season. Rainfall patterns strongly influence crop establishment, growth, and yield formation in rain-fed farming systems, particularly for legumes. Favorable rainfall distribution during the 2025 season likely improved germination, vegetative growth, and pod development, resulting in higher yields. The total LER were generally above 1 with all the legume varieties used which is an indication of a productivity advantage of intercropping over monocropping with the farmers in Migori.

Conclusions

1. This study evaluated sorghum performance under different intercropping systems and identified short-to medium-height varieties such as E1, E5and C26 as better suited for sorghum–legume intercropping compared to the tall ones. Farmers preferred sorghum–bean systems over sorghum–groundnut combinations due to beans' shorter maturity period.

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2. Although sorghum yields were sometimes higher under monocropping, sorghum–legume intercrops consistently achieved land equivalent ratios >1, indicating superior land-use efficiency. Thus, sorghum–legume intercropping is a promising strategy to enhance land productivity, soil fertility, and resilience in smallholder farming systems in western Kenya.

Recommendations

1. Promote sorghum–legume intercropping particularly using the identified high-performing dwarf sorghum varieties with high land equivalent ratios (LER > 1.25).
2. Further research should evaluate the long-term agronomic, economic, and soil fertility benefits of sorghum–legume intercropping across diverse agroecological zones and seasons, including assessments of profitability, soil health, climate resilience, and gender-related adoption factors to support wider scaling of the technologies

Declaration of generative AI and AI-assisted technologies in the writing process

The author while preparing this manuscript, utilized ChatGPT- free version for checking spelling errors and grammar refinement. After using this AI tool, the author has carefully reviewed and edited the content as necessary and assumes full responsibility for the publication's content.

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Credit authorship contribution statement

The author conducted the experiments and wrote the paper

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