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ORIGINAL RESEARCH ARTICLE

Adoption of SIPs among small-scale mango growers in Kitui County, Kenya

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ABSTRACT

Sustainable Intensification Practices (SIPs) continue to be generally acknowledged as a key factor for increasing agricultural productivity while being environmentally benign. SIPs assure the safety, quality, and availability of food. However, despite the potential benefit of SIPs, their adoption among smallholder farmers in sub-Saharan Africa (SSA) – particularly mango growers – remains low. The low adoption of SIPs is generally attributed to differences in the biophysical and socioeconomic circumstances present on respective farms. Thus, this study investigates the adoption of SIPs and their determinants among mango producers in Kitui County, Kenya,Specific objective focusing on assessment of adoption of various SIPs in given counties,investigate factors determining adoption of SIPs and assessment of SIPs on production. using data collected from a cross-section survey of 438 mango farmers. The study adopted the t-tests and negative binomial regression analysis. The findings reveal that, on average, mango farmers adopted at least four (4) different SIPs. Modern crop management SIPs (5.0) having the highest mean of adoption, followed by soil management SIPs (3.0), and crop varieties and inter-crops SIPs (3.0). Water management SIPs (2.0), local crop management SIPs (2.0), and post-harvest management SIPs (0) had the least mean adoption. Comparing mango farmers who adopted SIPs versus those who did not reveals that those adopting various SIPs have significantly higher mango yields. The negative binomial regression indicates that access to market information, off-season selling, access to training, credit access, household income, distance to the tarmac, and cultivation period influences the adoption of SIPs. The results provide useful insights to direct further efforts required to encourage greater adoption of SIPs and strengthen the enabling environment for mango farmers. In addition policy makers are recommended to provide SIPs that enable farmers to produce mangoes throughout the year; Strengthen farmers SIPs capacity through training, Improve skills of extension officers and

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increase training's channel, Help farmers adopt measures that access credit. In addition, farmers to adopt the seed varieties that mature early to enable them sell their produce during off-season;

Keywords: Adoption, intensity, mango production, negative binomial regression, sustainable intensification practices.

1.0 Introduction

Sustainable Intensification Practices (SIPs) assure the safety, quality, and availability of food (Ajibade et al., 2023). The term Sustainable Intensification (SI) was first used in the 1990s in explaining the issue of food production improvement in Africa (FAO, 2010). Mueller et al. (2012) and Campbell et al. (2014) noted that intensification could include intensification of crop rotation and nutrients used in production, climate-smart agriculture including developing asset diversity, local adaptation, and diversified farming systems. Other standard definitions majorly focus on efficient flow of ecosystem services from agricultural practices (Firbank, 2009; Pretty et al., 2012; Pretty & Bharucha, 2014). Moreover Smith et al. (2017) emphasizes that the scope of SI should include social equity, human condition, and nutrition while Pretty et al. (2014) defines SI as a process or system where agricultural production is increased, with no adverse impact nor change to the land being farmed. Thus, SIPs are considered as sustainable strategies and practices that facilitate an increased land productivity by using fewer inputs while preserving the environment (Baulcombe et al., 2009; Hunt et al., 2019; Jane Dillon et al., 2016; JIAO et al., 2019;Petersen & Snapp, 2015; Pretty & Bharucha, 2014). According to these studies,such strategies include sustainable water management, crop diversification, integrated pest management (IPM), as well as inorganic and organic nutrient management.

SIPs are a crucial component in boosting agricultural productivity while preserving the environment and ensuring food safety and quality (Jane Dillon et al., 2016). This is against the backdrop of the projected global food production demand that is expected to increase by approximately 70% by 2050 due to the projected population increase of 2.3 billion people (Islam & Karim, 2019). Thus, SIPs adoption empowers to produce enough food to meet the rising global demand (Jane Dillon et al., 2016; Mueller et al., 2012). SIPs adoption improves and enhance production yield (World Bank, 2008; Pretty et al., 2012; Teklewold et al., 2013a). SIPs generally influence soil quality, biota, environmental sustainability, and crop productivity (Choudhary et al., 2018;
Bais-Moleman et al., 2019). Additionally, SIPs help conserve resources and improve soil nitrogen, enhance natural resources management, improve land productivity, reduce soil erosion, promote social equality, lessen poverty, and reduce hunger (Pretty et al., 2012; Teklewold., 2013b; Jambo et al., 2019).

In this study, several SIPs were considered, namely; soil management, water managements, crop varieties and inter-crops, local crop managements, modern crop management and post-harvest management practices. Some SIPs, like certified seeds, mango based agro forestry, mulching, lime

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application, pesticide application, drip irrigation, drip fertigation, organic mango production, optimum mango spacing, pruning, cropping patterns, integrated pest management, use of modern equipment for mango harvesting, and value addition were specifically used for mango tree's management SIPs. The study also explored various SIPs generally used by mango growers in the entire farm, this includes soil management, water management, inter-cropping, and local crop management (Pretty et al., 2018). Additionally, the Step-up project introduced new and unique SIPs which includes modern tools for mango harvesting and value addition.

Despite the potential benefit of SIPs, actual adoption among smallholder farmers in Saharan Africa is influenced by the biophysical and socioeconomic circumstances on the farm and knowledge among other factors (Kurgat et al., 2018;Teklewold et al., 2013a, Jambo et al., 2019; Wheaton et al,.2017; Mwalupaso et al., 2019). Although SIPs can enable the improvement of agricultural production, its adoption in SSA is limited. Mango production faces similar challenges that and this limits production. In addition the sector is not able to meet the growing market demand and this due to the increasing population. Environmental factors limits, accessibility of inputs and market for outputs leading to unsustainable mango production due to low returns, and increased post-harvest loss (Griesbach, 2003). Further, the adoption and utilization of SIPs in mango production are not yet fully evaluated in the context of Kitui County, Kenya.

There have been attempts to determine the significance of SIPs. Kurgat et al. (2018) assess the adoption of SIPs among vegetable producers in Kenya's rural and peri-urban areas. The results showed that adoption intensity of SIPs was lower in rural areas than peri urban areas. Teklewold et al. (2013a) evaluate factors influencing the adoption of sustainable agricultural practices (SAPs) in rural Ethiopia and found that adopting SAPs increases maize income and reduces nitrogen fertilizer use, but increases pesticide usage and labor needs, possibly to compensate for reduced tillage. While their work was generally on multiple agricultural practices, they did not consider the aspect of intensification (Pretty et al., 2014), unlike in this study where intensification was highly examined. Smith et al. (2017), through a review of the literature, identifies indicators and metrics of measuring SIPs in smallholder farming systems; these include input efficiency, water efficiency, agricultural income, crop value, food and nutrition security, biodiversity, soil quality, nutrients dynamics, and erosion (Alkire et al., 2013; Mahon et al., 2018; Smith et al., 2017). Martin-Guay et al. (2018), through a review of 126 studies, reveals that intercropping, as a type of SI system, results in increased production by an average of 38%, leading to an increased income of about 33% while utilizing 23% less land when compared to mono-cropping. Rahn et al. (2018) argues that there exists a socio-ecological trade-off in the adoption of SIPs in coffee farming in Uganda, although adoption of SI practices has a significant influence on the improvement of livelihood, environmental sustainability and production. According to Ganeshamurthy et al. (2019), agricultural intensification can be used to improve mango production, which will increase the orchard's profitability.

Thus, it is evident that although SIPs have been widely adopted in crop enterprises, such as in cereals, and vegetable production, there is still limited use in other sectors. The use of SIPs in fruit farming, specifically mango production, remains limited despite its potential (Ganeshamurthy et al., 2019). There is dearth of information on SIPs adoption intensity and its determinants among smallholder producers. To support filling the above gap, this study investigates the adoption intensity of SIPs and its determinants among mango producers in Kitui, Kenya. The study considers the following key research question: What determined the adoption of SIPs among mango producers in Kitui County? The study investigates the following specific research questions: First, which SIPs were adopted across the three different sub-counties in Kitui? Second, which factors determined the adoption of the SIPs? and last, which SIPs affected mango production?

2.0 Theoretical framework

This study is anchored on the agricultural technology adoption theory to explain farmers' decisions regarding the adoption of new technologies. Technology adoption is a multifaceted area that incorporates numerous aspects of the diffusion of innovation theory and adoption theory. Literature on technology adoption is anchored on three ideals: the economic constraints, innovation diffusion, and adopter perception ideals (Ruzzante et al., 2021). The three ideals accentuate the importance of each factor on adoption patterns and levels.

The adopter perception idealists suggest that the perceived need and characteristics of the technology are key in explaining farmer behaviour toward an innovation. Producer perception is influenced by the technology's attributes, individual aspects, and the cultural environment (Prager & Posthumus, 2010). Additionally, in this ideal, a farmer is considered a rational agent who seeks to maximize utility in ways that go beyond the financial considerations.

The prior work of Rodgers (2003), which asserts that knowledge is a crucial component in innovation adoption, sets the foundation for the innovation diffusion model. This field suggests that farmers will judge an innovation's applicability based on the knowledge they have of it. Additionally, leveraging media, farmer trainings, and/or extension agents can boost technological adoption. From early adopters to laggards, farmers are divided into various adopter types. This theory's pro-innovation bias, which assumes that all innovations are appropriate, is a weakness (Roger, 2003).

According to the economic limitations model, the observed patterns of technology adoption occur due to unequal distribution of resources. This approach contends that resources like capital are essential for an innovation's acceptance. It focuses on the significance of farmer-level economic factors in encouraging technology adoption. However, the methodology fails to account for the cultural environment and individual perspectives on innovation. The imitations model incorporates the three ideals to explain the elements affecting the adoption of new technologies. For instance, adopter perception theorists may believe that the land size may have a significant influence on how quickly innovations are adopted. This study follows similar works that incorporate variables from the three ideals: for example, Adesina & Zinnah (1993); Ntshangase et al.(2018); and Ruzzante & Labarta (2021) explain the adoption intensity among smallholder mango farmers in the study area.

3.0 Materials and methods

3.1. Study site

The study was carried out in Kitui East, Kitui Central and Mwingi West sub-counties of Kitui County in Kenya (Figure 1). Kitui County is a semi-arid region in the lower eastern part of Kenya (latitudes 0^0 10’S and $3^0$10’S and longitude $37^0$40’E and $39^0$10’E). The county receives a bimodal pattern of rainfall with an average annual precipitation of 750 mm with 40% reliability. The annual mean minimum temperature ranges from 22-28°C while, the annual mean maximum temperature ranges between 28° to 32° C (Government of Kenya, 2010). It also experiences dry spells in January and February and June to September. In Kitui County. The common soils in Kitui county are luvisols and ferralsols, which are formed when metamorphic rocks weather. The soils are well-drained, moderately deep to very dark reddish brown to dark yellowish brown and friable to firm, sand clay (Couny government of Kitui, 2018). Several areas have top soils of loamy sand to sandy loam and others with acid humic (Willy et al., 2019). The study araes was selected due to diverse agroecological areas with and rich in mango farming.

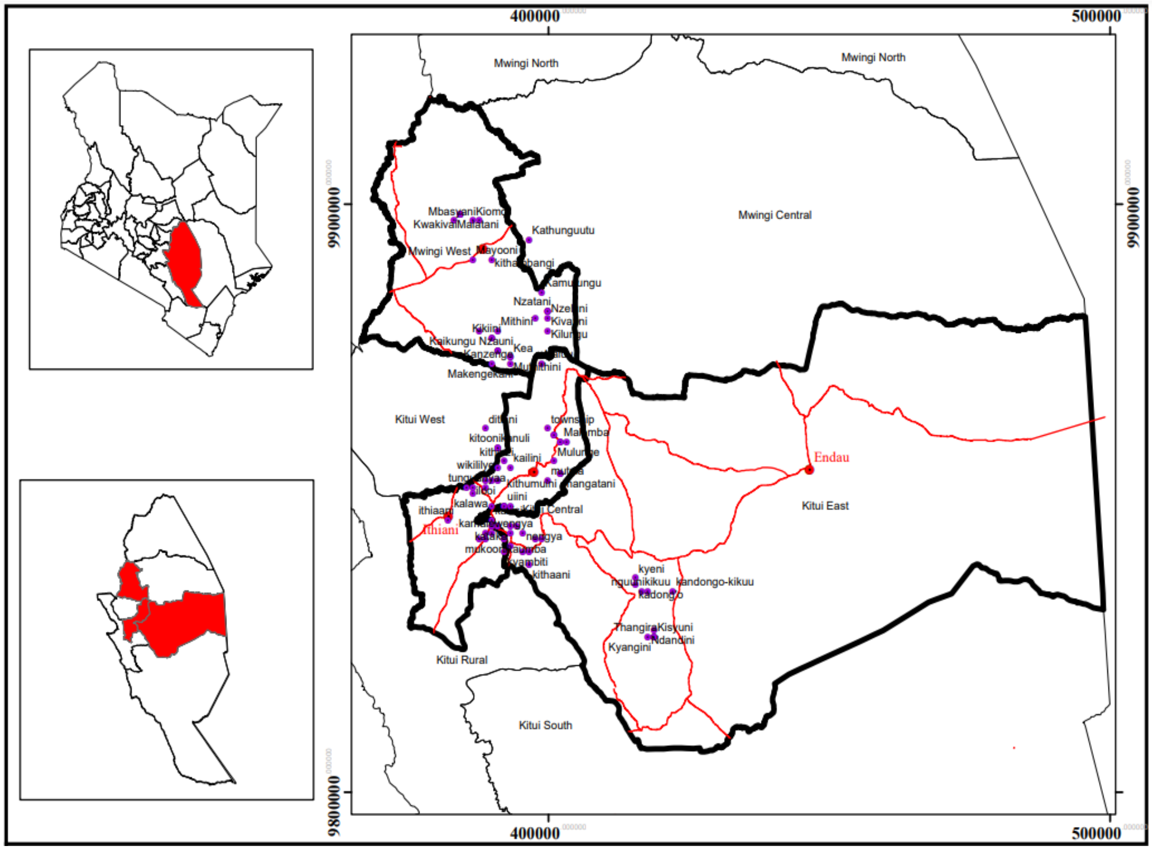

Figure.1. Map showing the study area in Kitui County

3.2. Sample and sampling procedure

Data collection employed a multi-stage sampling technique involving purposive and random sampling. At the first stage, the three sub-counties were purposely selected due to their high concentration of mango farming activities and with different agro-ecological zones. In the next step, five villages were randomly picked (those with mango farms) from each ward in the three sub-counties. Finally, households were randomly selected from each village to make a sample size of 438 respondents. A pretested questionnaire was used to collect data from the respondents. It was structured to collect information on farmers' household characteristics, SIPs, farming patterns, and institutional attributes.

3.3. Econometric analysis

A multinomial probit or logit procedure is used to describe technology adoption, with the dependent variable being a categorical variable that takes on different values depending on the technologies selected. Technology selection could be modeled using a count data model, where the dependent variable is the number of technologies chosen. The adoption intensity is better explained by count models when farmers choose to apply numerous practises.

In this study, both Poisson and negative binomial models were used to determine the intensity of SIP adoption among mango producers in Kitui County. The Poisson regression model was chosen to estimate the farmers' decisions regarding the number of sustainable intensification methods to adopt since it is a suitable model for the estimation of count data (Greene, 2008; Isgin et al., 2008). The mango producers make a series of discrete decisions that could be assessed using a Poisson distribution on an accumulation of choices. The Poisson model's density function is given as:

$$f(y/x_i) = \frac{e^{\mu_i}\ \mu^y}{y!} \quad (1)$$

Where the mean parameter, as the function of the regressors x_i and a parameter vector, β, is produced by

$$E(y/x_i) = \mu = \exp\ (x'\beta) \text{ and y= 0, 1, 2,} \quad (2)$$

Where

$$\exp(x'\beta) = \exp(\beta_0) + \exp\left(\beta_{1x_1}\right) + \exp(\beta_2 x_2) \ldots + \exp\ (\beta_n x_n) \quad (3)$$

The marginal effect of the Poisson regression model is given by

$$\beta_i = \frac{\partial \mathrm{E}[\mathrm{y}/\mathrm{x_i}]/\partial \mathrm{x_i}}{\mathrm{E}[\mathrm{y}/\mathrm{x_i}]} = \frac{\partial \mathrm{logE}[\mathrm{y}/\mathrm{x_i}]}{\partial \mathrm{x_i}} \quad (4)$$

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One feature of Poisson model is equality of the conditional mean of the dependent variable and its corresponding variance. This can be expressed as

$$V(y/x_i) = \mu(x_i, \beta) = \exp\,(x'\beta) \quad (5)$$

The assumption that the condition mean and variance are equal is typically violated, which results in over dispersion. Over dispersion occurs when the variance exceeds the mean. Unobserved heterogeneity and a large number of zero observations on the dependent variable are the main contributors to it (Gurmu & Trivedi, 1995; Cameron & Trivedi, 1998). A negative binomial model is used to resolve the challenge of over dispersion. It is expressed as follows:

$$f(y/\mu, \alpha) = \frac{\Gamma(y+\alpha^{-1})}{\Gamma(y+1)\Gamma(\alpha^{-1}+\mu)} \left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}} \left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{y} \quad (6)$$

Where

$\mu = \exp\,(x'\beta)$, y=0,1,2... and $\alpha \geq 0$ reveals the extent of over dispersion.

To establish the presence of over dispersion, a binomial regression model is estimated. The presence of over dispersion is confirmed if the alpha coefficient is significantly greater than zero and negative binomial model is adopted. In this case, alpha is significant and the binomial model is accepted. In this study we modeled the number of adopted SIPs as the dependent variable while the farmer attributes and institutional factors were the explanatory variables. Descriptive statistics were also used to estimate the mean and stand deviation of SIPs adoption among the target farmers.

4.0 Result

4.1 Mango farmers

Table 1 presents a summary of the descriptive statistics of the mango farmers. On average the mango farmers adopted 14 SIPs out of the thirty-six SIPs in the study area. Of the household heads interviewed, 80.82% were male, while 19.18% were female. The average farmer owned 1.68 acres, with the majority of farmers being older than 52.7 years (Table 1). Most farmers had attained primary education with a mean of 9 years of schooling. With respect to income, 40.63% of farmers earned less that Ksh 10,000, while 0.24% earned more than Ksh 120,000. The average distance to the nearest market and to tarmac was 6.6 and 3.51 kilometers, respectively. On average, farmers had 13.5 years of experience in mango farming. The results also indicate that 43.61% of the mango farmers had access to market information and only 11.19 % had access to credit facilities. About 13% of the farmers were found to sell mangoes during the off-season and 46.12 % of respondents had been trained on mango farming. The number of SIPs adopted by farm households ranged from one to thirty-six, with an average of 14 SIPs adopted.

Table 1: Summary statistics of descriptive characteristics of the mango farmers

Variable	Description	Statistics	
		Mean	SD
Adopted SIPs	Number of SIPs adopted	14.096	6.325
Land size	Land size in acres	1.681	1.229
Experience	Years of mango production	13.522	9.254
Distance to nearest market	Distance to the nearest market in Kilometers	6.619	0.327
Distance to tarmac	Distance of road in Kilometers	3.515	0.217
Education	Years of schooling	9.05	4.377
Age	Age of the respondents	52.744	0.647
Household size	Number of household members	5.849	2.733
		Frequency	%
Gender	Gender of household head is male	354	80.82
Selling off-season	If the respondent sells during off-season	57	13.01
Market information	If the respondent has access to market information	191	43.61
Training	If the respondent has access to training	202	46.12
Credit	If the respondent has access to credit	49	11.19
Household Income			
Below 10,000	Income is below 10,000	167	40.63
10,000-40,000	Income range is 10,000 to 40,000	213	51.82
40,000-80,000	Income range is 40,000 to 80,000	28	6.81
80,000-120,00	Income range is 80,000 to 120,000	2	.49
Above 120,000	Income is above 120,000	1	.24

Source: Field survey data, 2021

4.1.1. Farm types

Table 2 shows the different farm types in relation to the quantity of mangoes produced in kg/Ha. On average mango farmers produced 2591 Kg/Ha of mangoes. Based on the results (The number of the mango trees recorded), three different farm types were derived: small scale farmers (0-50 mango trees), medium scale farmers (51-200) mango trees, and large-scale farmers (over 201 mango trees). This shows that on average the large-scale farmers had the highest production mean of mangoes.

Table 2: Summary statistics of farm types and quantity of mangoes produced

	Mean (Kg/ha)	Standard Deviation	Frequency
Small scale	2339	574	312
Medium scale	3028	478	100
Large scale	3935	428	26
Overall	2591	703	438

Source: Field Survey Data, 2021

4.2. Adoption of SIPs by the mango farmers

4.2.1 SIPs adopted in comparison with the farm types

As shown in Table 3 the SIPs were categorised into six groups namely: soil management, crop variety and inter-crops, water management, local crop management, modern crop management and post-harvest management SIPs, respectively. There was a significant difference in the number of soil management (3.509), crop variety and inter-crops (2.36) and modern crop management (2.65) SIPs adopted across the different farm sizes.

Table 3: Summary statistics of SIPs in comparison with the farm types

SIPs	Overall mean	Small scale producers	Medium scale producers	Large scale producers	F
Soil management SIPs	3.09	3.19	2.72	2.7	3.509***
Crop varieties and inter-crops SIPs	2.17	2.21	1.83	2.6	2.36**
Water management SIPs	2.01	2.05	1.78	2.2	1.063
Local crop management SIPs	1.96	1.94	2	2.2	0.68
Modern crop management SIPs	4.79	4.91	4.18	4.65	2.65***
Post-harvest management SIPs	0.14	0.15	0.14	0	1.154

Source: Field Survey Data, 2021

Among the six groups, modern management SIPs were the most adopted with a mean of 5.0, while the post-harvest practices were least adopted with a mean of 0.0 (Figure 2).

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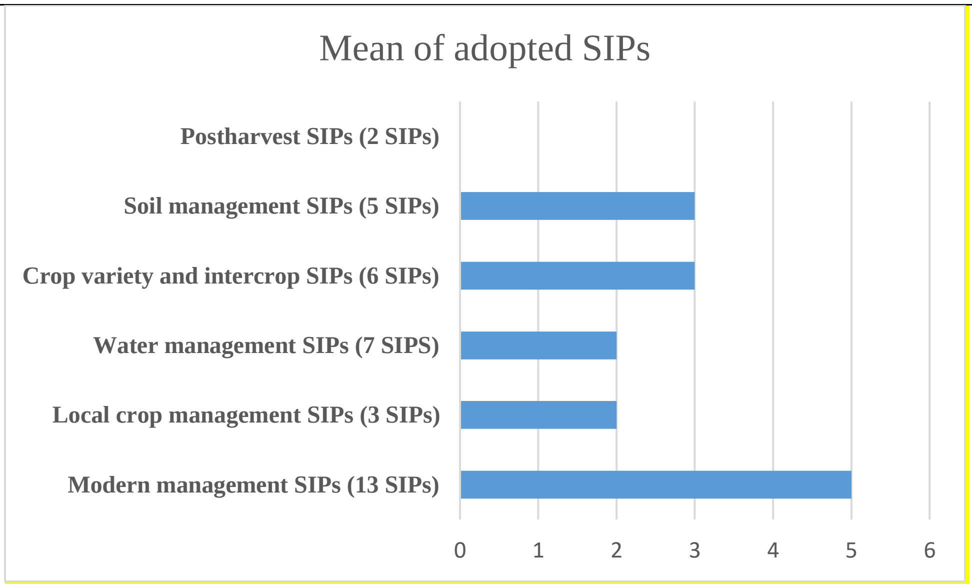

Figure 2: Mean of SIPs adopted

Source: Field survey data, 2021

4.2.2 SIPs adopted by mango farmers in the three study sites

The top six (6) SIPs adopted by the mango farmers included physical weed control (91%), fanya juu and fanya chini (terraces use) (84%), manure use, pruning (79%), soil conservation (77%), pesticide applications (76%), and mulching (74%) (Table 4).

On the other hand, drip fertigation (2%), drip irrigation (5%), water harvesting from the rocks (4%), watershed management practices (7%), use of modern equipment (5%), and value addition practices (9%) were the practices least adopted by the mango farmers. Physical weed control was highly adopted in the study region. However, its adoption was highest in Kitui Central with 97% of the respondents adopting the practice; in Kitui East 89% and in Mwingi West 78%. The majority of households adopted fanya juu and fanya chini terraces, with Kitui central leading at 93%, followed by Mwingi west at 86% and lastly Kitui East at 62%. Most respondents in Kitui East (81%) applied pesticides followed by Mwingi West at 75% and Kitui Central was last at 74%. Similarly, manure use was adopted by a large percentage of the respondents with Mwingi West leading at 89%, Kitui East with 77% and Kitui Central at 75%.

Table 4: Sustainable intensification practices adopted by mango farmers

Sustainable intensification practices	Kitui East %	Kitui Central %	Mwingi West %	Overall %
Soil Management SIPs				
Soil Conservation	68	85	71	77
Fertilizer use	24	17	44	25
Manure use	77	75	89	79
Minimum tillage use	35	23	55	34
Organic amendments use	40	38	58	43
Crop varieties and intercrops SIPs				
Mango based agroforestry	24	27	44	30
Crop variety and system improvements-new varieties	39	21	62	35
Varieties adopted to local conditions	69	27	62	45
Certified seeds	11	12	16	12
Intercropping with fodder	28	24	39	29
Water management SIPs				
Water harvesting technologies for supplemental irrigation	22	19	39	24
Agricultural water management	25	14	42	24
Water harvesting from the roofs use	24	45	55	42
Water harvesting from sand deposits near water lines use	33	18	27	24
Water harvesting rocks	1	4	7	4
Watershed management practices	3	5	18	7
Mulching	70	78	70	74
Local crop management SIPs				
Traditional lime application	36	61	41	50
Residue application	59	66	56	61
Fanya juu and fanya chini (terraces use)	62	93	86	84
Modern crop management SIPs				
Optimum mango spacing	57	64	59	61
Mowing	33	43	55	43
Pruning	62	89	74	79
Crop rotation	7	10	41	16
Cropping pattern	12	5	44	16
Integrated pest management	10	8	33	14
Physical weed control	89	97	78	91
Chemical weed control	25	29	30	29
Fertilizer application	20	15	31	20
Pesticide application	81	74	75	76
Bio-fertilizer and inorganic fertilizers	7	6	27	11
Drip irrigation	4	4	9	5
Drip Fertigation	0	1	5	2
Organic mango production	29	8	27	18
Post-harvest management SIPs				
Use of modern equipment in post-harvest	5	3	11	5
Value addition	14	3	18	9

4.3. Mango production by the farmers in the study sites

Comparing the adopters of SIPs with their non-adopter peers, the farmers who had implemented various SIPs are found to have a significantly better mango yield. Farmers who practised soil conservation realized a mean production of 2650kg/Ha while those who did not, recorded a lower mean of 2390kg/ha. Similarly, users of fertilizer (2726Kg/Ha) and manure (2634Kg/Ha) produced significantly higher quantities of mangoes compared to non-adopters, who recorded a mean of 2545Kg/Ha (Table 5). The implementation of drip irrigation and chemical weed control methods resulted in a decrease in mango production, thus contrasting with outcomes observed for other SIPs. In many instances, the primary hindrances to adopting drip irrigation systems is the significant initial investment, higher maintenance requirements compared to surface irrigation, and technical difficulties with the systems (Friedlander et al., 2013; Pandya & Dwivedi, 2016). Some farmers report that genuine chemicals for weed control are not available or they end up either over using or using the wrong herbicides. As observed, farmers additionally often prioritize fertilizer on the most profitable crop, such as for watermelon production, instead of mango production, thus representing a possible explanation for the mango production drop among adopters of fertilizer use (Islam et al., 2022).

Table 5: Farmer mango production yields among adopters and non-adopters

SIPs	Adopters		Non adopters		T-test
	N	Mean (Kg/Ha)	N	Mean (Kg/Ha)	
Organic amendments use	190	2621	248	2568	0.783
Soil Conservation	338	2650	100	2390	3.280***
Fertilizer use	110	2726	328	2545	2.345**
Manure use	346	2634	92	2545	2.498**
Minimum tillage use	147	2663	291	2554	1.542
Mango based agroforestry	131	2634	307	2572	0.850
Crop variety and system improvements-new varieties	153	2719	285	2522	2.815***
Varieties adopted local condition	199	2722	239	2481	3.617***
Certified seeds	54	2902	384	2591	3.518***
Inter-cropping with fodder	126	2652	312	2566	1.162
Inter-cropping with other tree crops	272	2626	166	2533	1.339
Water harvesting technologies for supplemental irrigation	107	2638	331	2575	0.804
Agricultural water management	103	2749	335	2542	2.631**
Water harvesting from the roofs use	183	2600	255	2584	0.236
Water harvesting from sand deposits near water lines use	104	2648	334	2573	0.953
Water harvesting rocks	18	2764	420	2583	1.070
Watershed management practices	32	2669	406	2585	0.651
Mulching	324	2943	114	2876	0.5171
Optimum mango spacing	268	2649	170	2499	2.183**
Mowing	190	2687	248	2578	2.531**
Pruning	344	2629	94	2453	2.160**
Crop rotation	72	2781	366	2553	2.528**
Physical weed control	398	2603	40	2472	1.125
Organic mango production	78	2732	360	2560	1.967*
Drip Fertigation	7	1986	386	4383	0.372
Drip irrigation	7	2668	431	2590	0.292
Integrated Nutrient Management use of bio-fertilizers and inorganic fertilizers	49	2587	351	2591	0.041
Pesticide application	333	2622	105	2492	1.656
Fertilizer application	87	2678	351	2569	1.299
Chemical weed control	125	2551	313	2607	0.755
Integrated pest management	62	2679	376	2576	1.605

Crop pattern	70	2716	368	2567	1.624
Traditional lime application	218	2631	220	2551	1.193
Crop residues application	266	2655	172	2491	2.389**
Fanya juu and fanya chini terraces use	367	2613	71	2474	1.525
Use of modern equipment in post-harvest	23	2777	415	2580	1.309
Value addition	40	2824	398	2567	2.210**

Note: ***P < 0.01, **P < 0.05, *P < 0.1 represents significance at 1%, 5% and 10% respectively
Source: Field Survey data, 2021

4.4. Determinants of intensity of SIPs adoption by mango farmers

The chance that farmers adopt drip irrigation, pruning, integrated pest management, chemical control of weeds, pesticide applications, and/or physical weed control SIPs are considerably influenced by mango sales during the off-season. One reason is that, unlike during the high season when there are plenty of mangoes for sale, higher income is generated during the off-season period due to high demand for mangoes (Table 6). The results demonstrate how the SIPs used by mango farmers in all the evaluated sub-counties were improved by the farmers' access to credit, market knowledge, and training. The majority of farmers who receive credit and training tend to increase their output as a result of the new information they receive. They also purchase new and improved mango varieties, take advantage of market incentives, conduct soil testing, upgrade irrigation systems, and look for additional credit and training. Farmers are more likely to embrace SIPs because they can receive more finance and attend more training when they are better informed about the market.

Table 6: Parameter estimates of the negative binomial regression for SIPs adoption by mango farmers in Kitui County.

Adopted SIPs	Coefficient.	Std Error	t-value	[95% conf Interval]	
Land size	.032	.017	1.85	-.002	.066
Experience	-.009	.002	-3.85***	-.014	-.005
Distance to the nearest market	-.002	.005	-0.39	-.011	.007
Distance to the tarmac	.013	.007	2.02***	0	.026
Off-season selling	.256	.061	4.20***	.137	.376
Access to training	.115	.043	2.68***	.031	.199
Credit access	.161	.066	2.43***	.031	.291
Age	0	.002	0.27	-.003	.004
Education	.036	.023	1.61	-.008	.08
Household size	-.01	.008	1.32	-.025	.005
Gender	.057	.054	1.05	-.05	.164
Household Income					
10,001-40,000	.05	.045	1.13	-.037	.137
40,001- 80,000	.174	.086	2.02***	.005	.343
120,001- 160,000	.203	.278	0.73	-.342	.749
Above 1600,000	.686	.375	1.83	-.049	1.422
Access to market information	.09	.042	2.14***	.007	.173
Constant	2.366	.148	15.95***	2.075	2.656
Alpha	2.345	.132	14.68	2.001	2.687

Mean dependent var	14.331	SD dependent var	6.285
Pseudo r-squared	0.033	Number of observations	411
Chi-square	89.457	Prob > chi2	0.000

Note: ***P < 0.01, **P < 0.05, *P < 0.1 represents significance at 1%, 5% and 10% respectively
Source: Field Survey data, 2021

5.0 Discussion

5.1 Number of SIPs adopted by mango farmers

On average the mango farmers adopted 14 SIPs out of the thirty-six SIPs in the study area. The large-scale farmers are readily able to adopt modern management SIPs due to the frequent training they attend, high income, know how on usage of genuine incentives like pesticides, fertilizer, certified seeds. SIPs have potential to enhance mango productivity in Kitui County, Kenya. Existing studies show that SIPs, like inter-cropping and crop rotation, boost farmer resilience to unpredictable climatic conditions, thus improving productivity (Ndiritu et al., 2014; Kotu et al., 2017). Similarly, soil management SIPs, water management SIPs, and modern crop management SIPs (e.g. fertilizer use, physical weed control, drip irrigation, and pruning) are expected to improve soil health, production and reduce the effects of agricultural production on the environment (Ajayi et al., 2008; Ndiritu et al., 2014). Other SIPs, like, use of improved seed varieties, show an immediate effect on crop production through improved yields (Kotu et al., 2022). The above outcomes are anticipated because, according to Kugbe et al. (2019), soil conservation, fertilizer use, and manure use are crucial for sustaining soil fertility when administered in the right quantities. Moreover, adopters of crop variety, varieties adapted to local conditions, certified seeds, agricultural water management, optimum mango spacing, mowing, pruning, crop rotation, organic mango production, crop residue application, and value addition realized significantly higher mango yields on average compared to their non-adopter counterparts. This finding is consistent with that of Vashisht et al. (2021), who found that integrating straws of rice in the soil, increases wheat yields.

5.2 Determinants of SIPs adoption

Producing mango during the off season requires adoption of practices like irrigation. Irrigating reduces the over reliance on rainfed production and enables the farmers to produce when rainfall is inadequate. Similarly, during the off-season, mango prices are typically high due to the limited supply; thus, farmer income can be increased. This finding is similar to that of Zainuri et al. (2019) who found that mango flowers could be induced through canopy management or by use of chemicals. Further, since the high market price is guaranteed during off-season, production of mangoes becomes favorable and economical (Poerwanto et al., 2008).

An increase in farmer training increases their likelihood of adopting more SIPs. These results are consistent with other findings, such as that of Kotu et al. (2018) and Ndiritu et al. (2014), who found that farmer training influences the adoption of sustainable agricultural practises.

Access to credit increases the likelihood of mango farmers adopting SIPs. Adoption of sustainable practices often requires enough funds to purchase the needed equipment and to pay for the labour and other related services. Often credit boosts funds to purchase, install, and maintain the agricultural practises, as indicated by Isign (2008) and Kotu et al (2017).

The level of household income often determines the level of capital accessible to invest in a farm. For example, some SIPs, like drip irrigation, drip fertigation, fertilizer application, water harvesting technology, chemical technology, chemical weed control, physical weed control, value addition, use of modern equipment for mango harvesting, use of certified seeds, and integrated pest management, are both capital and labour intensive, thus requiring huge funds to adopt (Diederen et al., 2013). Therefore, the availability of enough funds boosts the adoption of more practices, ultimately increasing the intensity of SIP adoptions. Additionally, family income boosts technology adoption, as the income is used to buy inputs and to cover other expenses related to technology adoption (Wouterse & Taylor, 2008).

Access to market information positively influenced the likelihood of mango farmers adopting a given number of SIPs. With market information farmers become aware of the existing technologies and potential market for their produce (Shepherd, 2011). Teklewold et al., (2013a) corroborates that access to market information is a key aspect in decision making on SIP adoption.

Farming experience implies that farmers with fewer years of mango farming experience are more likely to adopt SIPs than their more experienced counterparts. The possible explanation is that more experienced farmers are possibly more inclined to avoiding risk by not adopting new technology than their less experienced counterparts. This finding contrasts with Usman et al., (2016) ,which find a positive relationship between farming experience and technology adoption.

The distance to the tarmac increases the probability of adopting more SIPs, implying that farmers who lived far from the tarmac are less likely to adopt SIPs. In this case, the distance to the tarmac provides an important proxy for market access. Market access influences transaction costs incurred by farm households when seeking information, technologies, and support from organizations, including credit providers (Kassie et al., 2015).

6.0 Conclusion and policy implications

Mango farmers adopt on average 14 SIPs in the study area. Modern management SIPs seem promising, followed by soil management SIPs. A number of factors explain SIPs adoption intensity among mango farmers, these include experience, distance to the tarmac, household income, targeting off season, training, credit access, and access to market information. Access to market information, credit access, training, and selling during off-season have significant policy implications.

The relation between selling mango produce during off-season and SIP adoption intensity suggest that there is need for policy makers to provide SIPs that enable farmers to produce mangoes throughout the year. Using improved mango seed varieties, which can mature early, enable farmers to sell mangoes during the off-season, thus fetching high market prices. The significant role of

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training on adoption intensity is to enable the policy makers to strengthen farmers' SIP capacity by offering training programme. Further, there is need to improve the skills of the extension officers and to increase the channels of training offered to farmers, such as the use of mass media and inter-farmer interactions. Since credit access is positively associated with SIP adoption intensity, measures that help mango farmers' access credit are recommended. Similarly, since household income affects SIPs adoption, then increasing the household's capacity to increase income through, for example, diversification to other agricultural enterprises and off-income activities is recommended. Moreover, since access to market information is positively correlated with SIP adoption, there is need for policy makers to put measures in place that will help strengthen local institutions and service providers to accelerate sustained information access for mango farmers.
However, there are some limitations to this study. First, due to inter-cropping mango production with other crops, it is difficult to separate the SIPs that are specific to mango farming. Two, it is difficult to determine the influence of specific SIPs, thus further research to separate the SIPs that are specific to mango farming is recommended.

Third, the survey severely under-sampled the large-scale mango farmers, due to the fact that the majority of owners do not reside on the farm hence the mango farms were managed solely by their employees. Thus, it was not easy to obtain information on the adopted SIPs. During the survey it was found that a significant number of workers employed on these large-scale mango farms had limited or no formal education, with some having received less than 10 years of schooling. Despite the adoption of modern technology by large-scale mango farmers, the workers employed on these farms lack knowledge and are not familiar with these advancements. Thus, future interviews on SIPs should focus more on the owners of the large-scale mango farms. On the other hand, the majority of small-scale farmers, especially those living in remote areas of Kitui East and Mwingi West sub counties, do not have adequate information on modern technologies since they rely more on traditional practices due to a lack of exposure.

Fourth, part of this survey was carried out during the rainy season, which posed transportation challenges due to the poor road network and farmers being busy on their farms. Fifth, Covid-19 also affected the group discussions, individual interviews, and physical survey. Lastly, older farmers, those principally older than 60 years, experience challenges with SIP training, especially regarding fertilizer use, chemical use, drip irrigation and fertigation, use of bio fertilizer, use of modern mango harvesting tools, and on value addition.

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8.0 Declaration of competing interest

The authors confirm that they have no known financial or personal interests that could appear to influence the work reported in this paper.

9.0 Data availability

The data for this study will be made available upon request.

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